The Engineer's Guide to Level Measurement for Power and Steam Generation

2013 EDITION

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Acknowledgements

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Rosemount Process Level

Introduction

This Level Handbook is written as a user guide for level projects within the power and steam generation industry. 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.

Please remember that choosing the appropriate level device is always up to the user, and these guidelines are recommendations based upon the experience we have gathered through the years. If you are unsure about your choice, please contact your local Emerson representative. Also, if you have feedback on this handbook, both positive and negative, or feel that something is missing - then please tell us! It is an ongoing process to keep this handbook up to date.

Chapter 1 – The power & steam generation industry, gives a brief overview of the power and steam generation industry. It covers some basic knowledge, different types of power plants as well as challenges of some key level applications.

Chapter 2 - Available level technologies, shows the wide range of level technologies on the market. We describe the technologies and principles of measurement, as well as both advantages and limitations for each technology. The reason for this is simply that with the vast variety of applications, there is no technology on the market that is perfect for each and every application. Different process conditions, media to be measured and user preferences will always influence the final choice of technology.

Chapter 3 - Rosemount level products, provides an overview of the Rosemount product offering for process level applications. For more detailed information however, *please see each product's product data sheet on www.Rosemount.com*.

Chapter 4 - Level applications & technology selection, is where we come into specific level applications in the power and steam industry. This is the first step in choosing a level device for your application.

This chapter shows what technologies are suitable for each application and explains if there are any special considerations for the different technologies. The choice of technology is always the user's, but these guidelines can help in making the right decision.

Chapters 5-10 - Installation guidelines, go through the installation considerations for each level technology.

Chapter 11 - Product approvals & certifications, gives an overview of the different standards.

Chapter 12 – Focus areas, this chapter deals with different areas that can be of importance for the power and steam industry. Included here are; minimizing system errors in steam and water applications, replacing displacers with guided wave radar, safety loops, cyber security for power plants and grounding best practice.

Chapter 13 - Reference material, contains reference information such as dielectric constants for different media, steam tables, and level glossary.

Chapter 14 – Proven results, here we show examples of how customers have used level instrumentation to solve different challenges, and what the results are.

Chapter 15 – Applications overview, is a list of level applications that can be found in different types of power plants and with reference to the relevant applications in chapter 4.

The Rosemount Level Marketing Team

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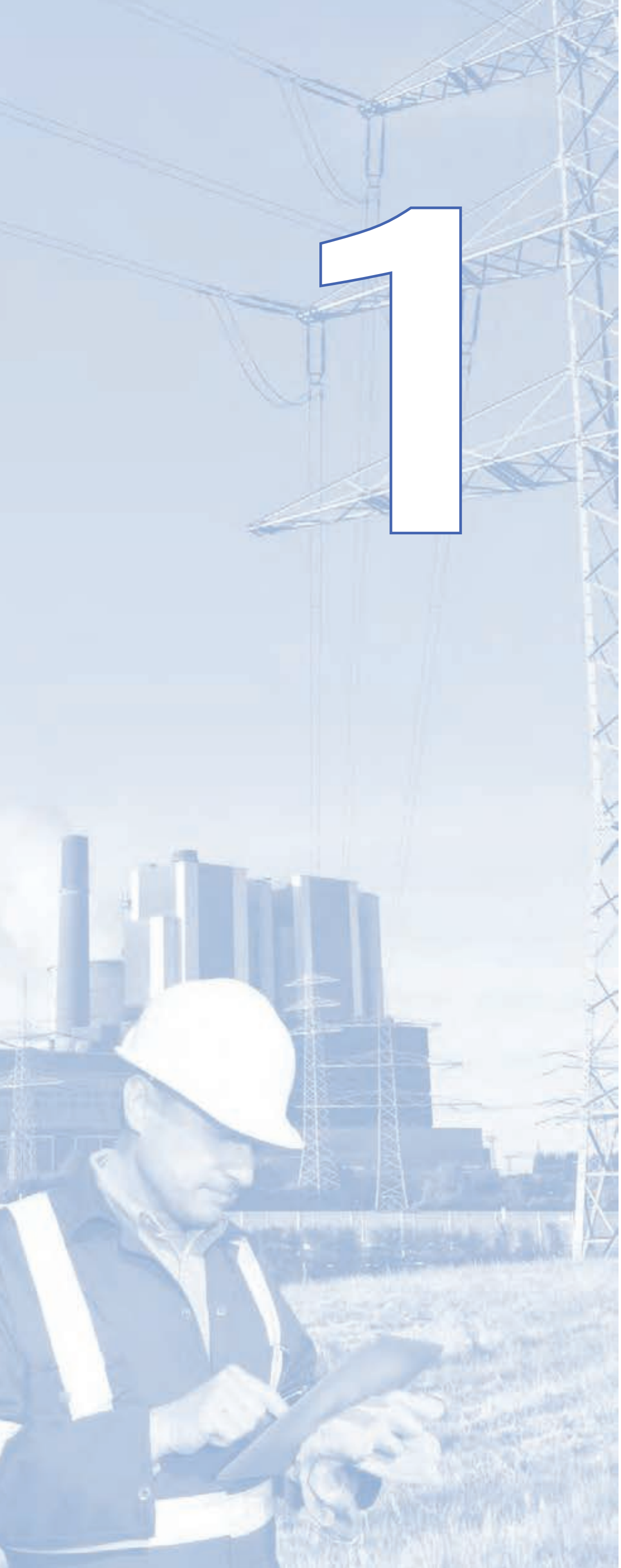

1 The power & steam generation industry

1. The power & steam generation industry

1.1 Introduction

The power generation industry is changing rapidly. Growing power demand, deregulation, and economic and environmental pressures are creating significant demand to modernize existing plants and optimize processes, as well as building new plants.

Large utility power companies are upgrading and modernizing to meet efficiency and environmental guidelines.

Small power plants are being built to serve local markets. Many process industries (e.g., chemical, pulp and paper, refining, and food and beverage) are generating their own power and using the surplus steam for other purposes such as heating office buildings or sterilizing equipment, or injecting into their processes.

Ultimately, the efficiency of a power generation system is measured by the amount of fuel burned versus the amount of electricity (measured in megawatts [MW]) produced. The balance between the energy used and the electricity generated is called the heat rate. Improvements in process control instrumentation can provide more accurate information for use in heat-rate monitoring and reduction of the plant heat rate.

1.2 Power basics

Steam power generation involves four basic stages:

1. Heat is produced
2. The heat transfers to liquid water to produce steam
3. Steam drives a turbine that turns a shaft connected to a generator
4. The generator converts mechanical energy to electricity

From a process measurement and control perspective, these stages may be thought of as two interrelated processes:

- Steam and water process
- Fuel, air, and flue gas process

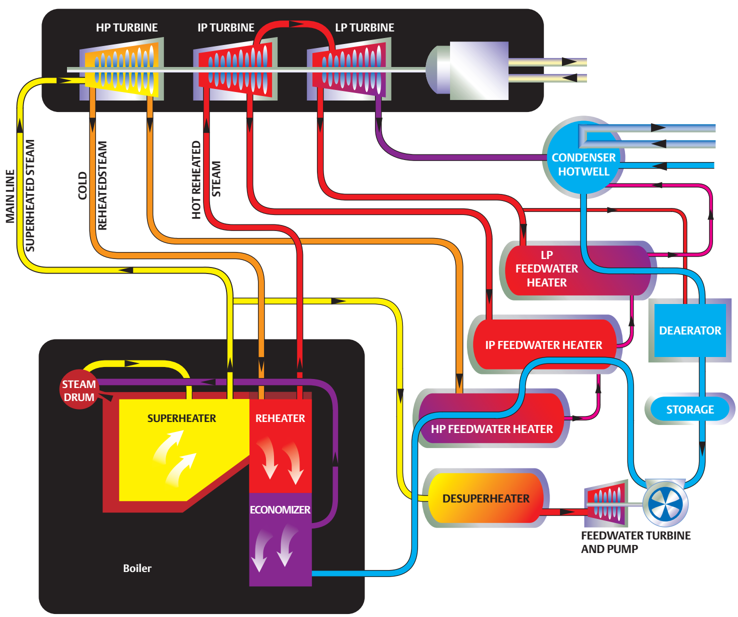

Figure 1.1.1 Illustration of the steam and water process

1.2.1 The steam and water process

The large boilers found in a power generation plants are normally water tube boilers, in which water passes through a set of tubes suspended in the boiler furnace. The heat in the furnace converts the water in the tubes in to steam by a process called evaporation.

As evaporation begins, water and steam exist together. The steam and water are separated in the boiler steam drum. The water is recirculated into the water tubes, and the steam, called saturated steam, is routed to another set of tubes that are located in the hottest part of the furnace. This set of steam tubes is called a superheater.

The finished product of the boiler is called dry superheated steam. The dry superheated steam exits the boiler through a pipe called the main steam header. In a power plant, the main steam header leads to a series of turbines.

Some of the steam is extracted from the turbines at particular stages. The extraction steam is sent to several places, including:

- To a reheater, which is another type of superheater in the boiler
- To feedwater heat exchangers used to preheat water coming to the boiler
- To a pump that pumps water to the boiler

Reheated steam has a lower pressure than steam in the main steam header. As a result, the reheated steam is routed to specially designed intermediate- or low-pressure turbines. Usually, all of the turbines are aligned and drive the same generator rotor. The steam rotates a long shaft in the generator.

Inside the generator, the shaft supports electromagnets surrounded by a coil of conductive wire. As the electromagnets rotate, current flows through the conductive wire. As more steam passes through the turbine, the torque changes from spinning due to the generator to spinning due to the steam flow. When the amount of torque due to steam is greater than the amount of torque from the generator, then electrical power is supplied to the grid.

As the steam passes the final stage of the low-pressure turbine, the steam is cooled in a condenser and is converted back into liquid water. Because the liquid water occupies less space than it did as steam, the condensation creates a vacuum. The vacuum helps provide energy to pull steam through the turbine system.

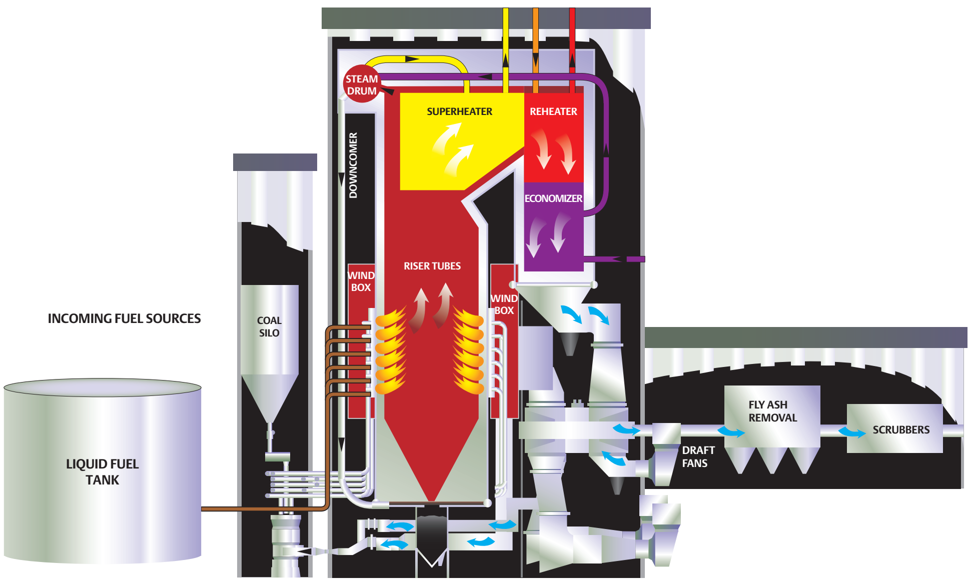

Figure 1.2.1: Illustration of the fuel, air and flue gas process

The condensed water collects in the hotwell of the condenser. The water is then pumped back into the boiler as feedwater. Because some steam and water are lost in the system, additional water, called make-up water, is added as needed.

Ultimately, the efficiency of a power generation system is measured by the amount of fuel burned versus the amount of electricity (measured in megawatts [MW]) produced. The balance between the energy used and the electricity generated is called the heat rate.

1.2.2 The fuel, air and flue gas process

Fuel is mixed with air and ignited in the combustion chamber of a boiler. The resulting flame and the hot exhaust gases are used to transfer heat to the water in the boiler tubes, turning the water to steam. The exhaust, or flue gas, is then cleaned and processed before it is released through the stack to the atmosphere.

In a nuclear fuel power plant, the steam is generated using heat released during a continuous and controlled nuclear reaction process.

1.3 Different types of power plants

Energy comes in various forms and the most convenient of all of them is electrical energy. Not only is it easy to generate, but it can also be generated through a number of different ways with the help of different types of power plants. In this section, the most common types of power plants are described.

1.3.1 Thermal power plants

These power plants generate electrical energy from thermal energy, or heat. Since heat is generated by burning fossil fuels like coal, petroleum, or natural gas, these power plants are also referred to as fossil fuel power plants. The heat generated by burning the fossil fuels turns rotating machinery that changes the thermal energy into mechanical energy. This rotating machinery can be a steam turbine, a gas turbine or a combination of the two. The rotating turbine is attached to a generator that converts the mechanical energy of the rotating turbine into electrical energy.

<u>Basic principle of a steam turbine</u>

The thermal cycle behind a steam turbine is called “the Rankine cycle”.

- According to this cycle, water is heated inside the boiler to produce superheated steam
- The steam expands inside the turbine to rotate the burned in a gas turbine, 20% of the heat is wasted in exhaust from stacks of heat recovery boilers

Only 28% of the heat energy is lost during the condensation process and with 6% of estimated auxiliary power consumption, overall electrical output is around 55%.

<u>Combined cycle</u>

Combined cycle power generation uses two cycles to produce electricity:

- The Brayton cycle
- The Rankine cycle

In the Brayton cycle, a fuel-fired turbine drives an electric generator. Natural gas turbines are the most common choice for power generation. Gas turbines work on the same principle as jet engines. Successive fans compress air and push it into a combustion chamber, where the air is mixed with fuel from fuel injectors. The air-fuel mix is ignited, and the resulting explosion of hot gas jets out the back of the chamber. The jet stream turns turbine blades that are specially designed to be driven by hot exhaust gases, and the turbine blades turn a generator rotor.

In the Rankine cycle, the hot exhaust gas from the turbine is captured in a heat-recovery steam generator (HRSG, pronounced her'-sig). The steam from the HRSG turns a steam turbine, which also drives an electrical generator.

The HRSG is designed to capture heat from the exhaust of a gas turbine. As exhaust gases leave the turbine, they pass a flue. If the flue is closed, the gases are routed out a chimney stack to the atmosphere. If the flue is open, the gases pass into the HRSG and act as the burner in the boiler. The flue is used to control the burner level in the same way that the combustion control system operates in a conventional boiler. Supplemental burners may be used in a HRSG to augment or replace the heat from the gas turbine exhaust.

The feedwater, steam separation, and superheating functions of a HRSG are essentially the same as those of a conventional boiler. The flue gas system of a HRSG is somewhat different than that of a conventional boiler. Because the flue gas is turbine exhaust, the HRSG has no need for the fly ash removal and flue gas treatment used in conventional, coal-fired facilities.

As with conventional boiler systems, the steam produced by a HRSG is used to turn a steam turbine. Extraction steam is used to run other parts of the system and may be reheated in the HRSG and sent to a low-pressure turbine just as in a conventional boiler/turbine system.

In some combined cycle systems, the first and second cycles drive the same electrical generator. More commonly, the first and second cycles (i.e., the gas turbine and the steam turbine) drive separate generators.

Cogeneration

Cogeneration is the use of steam to generate electricity and to run steam-driven applications. In plants that use a topping cycle, the cogeneration system produces electricity and subsequently applies the steam to a secondary application. In plants that use a bottoming cycle, the steam is used to run steam-driven applications first and the steam is subsequently used to generate electricity.

The firing systems used in industrial boilers for cogeneration vary widely, two kinds are described below:

- Stoker firing—a stoker firing system spreads fuel over a moving grate, where the fuel is burned. A feeder controls the rate at which fuel is released onto the grate, and a spreader distributes the fuel evenly. Heated air, called underfire air, passes up through apertures (small holes) in the grate. Above-grate air, called overfire air, stirs up the gases rising from the grate. The overfire air also ensures that combustibles rising from the grate are burned before they exit the stoker as flue gas
- Fluidized-bed firing—a fluidized-bed firing system blows air through a bed of powdered lime and fuel. Because the lime and fuel mixture is suspended in an air cushion, it behaves like a fluid. The powdered lime is heated by pilot burners and flows around the combustion chamber. Fuel is blown into the hot fluidized lime through a nozzle and ignited. The lime absorbs some of the undesirable byproducts of the combustion. Fluidized bed firing is often used with poor quality fuels (e.g., waste for incineration)

In a cogeneration system, a portion of steam from a boiler is used to generate electricity. The remaining steam may be used in a variety of steam-driven applications. The types of steam-driven applications include:

- Process steam—many plants have specific in-plant uses for steam or the heat carried by steam
- District heating—the system can supply heat to the plant and nearby buildings
- Custody transfer—some plants have no need for steam or produce more steam then they can use. These plants can sell the steam to a nearby buyer who has steam-driven applications (e.g., process steam or district heating)

So, thermal efficiency of combined cycle power plants is much higher than the conventional steam power plants and gas turbine plants.

1.3.2 Nuclear power plants

A nuclear power plant is similar to a fossil fuel power plant in that it creates steam to generate electricity. The key difference is the heat source. Nuclear power plants utilize self-propogating nuclear fission within a reactor to generate the heat and turn water into steam.

The heat released from the fission process is absorbed by a coolant (most typically water) in a closed-loop which circulates out of and back into the containment area. The coolant is either converted directly to steam, 1000 psig nom. (boiling water reactor, BWR) or a heat exchanger is utilized within the containment volume to transfer the heat from the high pressure liquid coolant (2250 psig nom.) to produce steam in an independent feedwater loop (pressurized water reactors, PWR). There are variations of these designs two of which are 1) CANDU reactors, which originated in Canada and utilize heavy water as the coolant and 2) gas cooled reactors in the UK which utilize CO2 as the coolant. Technology in reactor systems continues to evolve.

The rest of the process cycle is similar to any conventional steam power plant; steam rotates the steam turbine generator and produces power.

The majority of equipment used inside the reactor containment has to be nuclear qualified; therefore special pressure transmitters manufactured by Rosemount Nuclear Instruments, Inc. (RNII) are supplied.

Outside the reactor containment, standard commercial grade transmitters and instruments are widely accepted and, in most applications, do not need to be nuclear qualified.

1.3.3 Hydro power plants

These plants use the kinetic energy of flowing water to produce electrical energy. Hydro power plants use water from rivers or large reservoirs. Water flows through a dam and rotates a turbine. A combination of head pressure and flowrate determines the amount of electricity that can be produced.

Despite their low operation cost and cleanliness, the major drawback of hydro power plants is that they are highly dependent on the consistency of the water supply in the area where they are built. For this reason, large reservoirs are built to ensure adequate supply.

1.3.4 Non-conventional energy power plants

Other steam thermal power plants include geothermal, solar thermal, and bio-mass or landfill gas powered plants. All plants share some common attributes including the use of steam to drive a turbine and produce electric power.

Solar energy is one of the most abundant natural resources that are capable of providing more power than the current demand requires. Most of the solar power plants are concentrating solar power plants, in which the rays of the sun are concentrated into a single beam using lenses and mirrors. The beam is then used to heat a working fluid that is used to generate steam. Besides the concentrating solar power plants, multi-megawatt photovoltaic plants have also been built in recent times. In these plants, sun rays are concentrated on photovoltaic surfaces which convert the sun's energy into electrical energy using the photoelectric effect.

1.3.5 Industrial steam generation & HVAC (Heating, Ventilation & Air Conditioning) plants

These are boiler facilities within a plant that may be producing steam for uses other than electricity generation. The steam may be used to supply heat or steam input for a process. Refineries use the steam to heat oil in different units, such as the FCC (fluid catalytic cracker); paper mills use steam to breakdown stock; food plants may use the steam for cooking or sterilization; and chemical plants may use the steam for heating a process.

Subsequently, these plants may or may not get much steam back in the form of condensate. This would vary with the end use of the steam. There are also low pressure heating boilers that simply supply steam for heating and most of the condensate is returned.

For details on suitable technologies and best practice on power applications see chapter 4.

1.4 Challenges of key level applications

1.4.1 Drum level control

The steam drum contains a turbulent mixture of water with many entrained steam bubbles, with steam above. Maintaining a constant liquid water level in the steam drum requires a complex control system to account for pressure changes in the steam drum that accompany changes in steam demand.

The demand for steam varies inversely with pressure changes inside the steam drum, causing two phenomena called shrink and swell. Shrink and swell make controlling steam drum level very difficult.

As steam demand decreases, drum pressure increases. The increased pressure compresses the entrained steam bubbles, and drum level appears to shrink, even though drum level is actually increasing. Conversely, as steam demand increases, drum pressure decreases and the gas bubbles expand, causing drum level to appear to swell. To account for shrink and swell, power plant engineers employ a control system with three or more measurement points. The control system is called a three-element control system, and the three measurement points are:

- P—steam flow, derived from a pressure measurement taken at the first stage of the high-pressure turbine (The steam flow represents the demand for steam)
- F—rate at which feedwater is flowing to the steam drum (The rate is measured directly)
- L—water level in the steam drum (Water level is measured directly)

In the control system, steam demand (P) serves as the setpoint for the feedwater flow (F).

An increase in steam demand signals the feedwater controller to increase feedwater flow to the steam drum. The drum level measurement (L) is used to trim, or fine tune, the feedwater flow rate.

Although power plants employ many variations of the three-element drum level control system, each control system uses the same three measurement points to control the water level in the steam drum.

Inaccurate drum level control can cause damage to the steam drum, the boiler tubes, and even the turbine. If the level is too low, there is a risk of damage to the steam drum and the tubes, as well as a risk of the boiler exploding. If the level is too high, there is a risk that water will be carried over into the turbine causing catastrophic damage to the turbine.

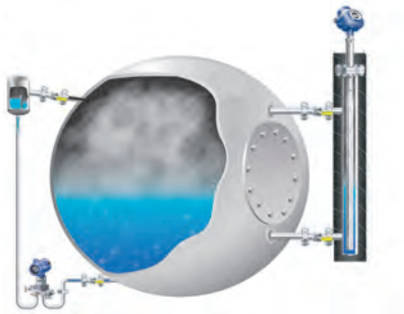

Figure 1.4.1: Boiler drum level control with differential pressure and guided wave radar

1.4.2 Oil and hydrogen cooling control

A generator rotor turns at speeds of up to 3,600 rpm. Heat from friction builds wherever fast moving parts make contact with the structure of the generator. Because immense electrical currents are generated in the field coil and because the coil has some inherent electrical resistance, heat also develops in the coil.

To keep generator temperatures within operating limits, oil is used to lubricate and cool moving parts and hydrogen is used in the generator shell to cool the coils. Hydrogen produces less atmospheric resistance than air and also conducts heat efficiently. Generator oil and hydrogen are both continually circulated and cooled. Hydrogen and oil cooling is accomplished in heat exchangers, through which cool water, called service water, is passed. The circulating water may come from a nearby river or lake or from a cooling tower system. The oil and hydrogen circulating water generally comes from the same source as the water used for cooling in the condenser.

1.4.3 Feedwater heater levels

There are numerous feedwater heaters in a steam power generation system. Feedwater heaters are divided into low, intermediate and high pressure categories. The pressure category refers to the pressure of the condensate or feedwater in the heater. All feedwater heaters operate in the same way. Heat is provided by steam and condensate which is bled from the turbine casing. The extraction steam is passed over heat exchange tubes. Feedwater (or condensate if the water has not yet been deaerated) flows through the tubes and is warmed by the extraction steam.

The steam entering the heater transfers heat to the feedwater. The saturation point of steam (i.e., the temperature at which steam condenses) increases as pressure increases. Because the steam in the feedwater heater is under pressure, condensation of the extraction steam occurs as the temperature of extraction steam drops. The extraction steam condensate collects in the bottom of the feedwater heater and is eventually pumped to the condenser hotwell to rejoin the feedwater system.

A critical measurement in a feedwater heater system is the level measurement of the extraction steam condensate . If the condensate level falls below the drain, the drain will be unsealed and steam will pass through the heater without transferring the maximum amount of heat to the feedwater. This may be referred to as “blow-through”. If the condensate level rises onto the feedwater tubes, heat transfer from the steam will be decreased. A level measurement is used to trigger the opening and closing of the drain valve. When extraction-steam condensate is drained from a feedwater heater, it is not routed directly to the condenser hotwell (except in the case of the initial, low-pressure feedwater heater). Extraction steam condensate drains to the previous feedwater heater. For example, when extraction steam condensate from the fifth feedwater heater reaches the high level setpoint, the drain valve is opened and extraction steam condensate is drawn into the fourth feedwater heater.

Note that under normal operating conditions, the feedwater heaters use extraction steam to operate. However, under conditions of turbine trip (i.e., the turbine is shut down unexpectedly for safety or maintenance reasons), the supply of extraction steam will be interrupted. Because the boiler feedwater supply cannot be interrupted, steam to heat the feedwater (and, in some cases, to run feedwater pumps) during a turbine trip is supplied from the main steam header. However, the steam from the main steam header is superheated. Feedwater heaters and pumps are designed to use cooler steam. Therefore, the steam is passed through a desuperheater. A desuperheater is a system in which cool feedwater is sprayed through superheated steam to cool it.

Overall plant efficiency can be improved if feedwater heaters are monitored and controlled to operate at peak efficiency (e.g. a 5 MW gain in a 500 MW plant) at all times. By connecting level control through a control system rather than through local level controls, operators can adjust the feedwater heater extraction steam condensate level setpoint, to match changes in load conditions faster and optimize efficiency.

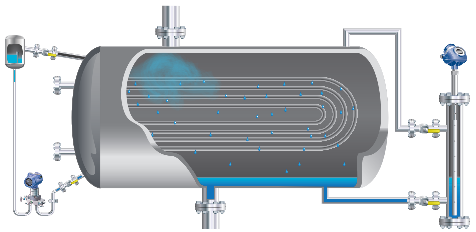

Figure 1.4.2: Feedwater heater level with guided wave radar and differential pressure

1.4.4 Turbine water induction prevention (TWIP)

The fast rotating equipment of the turbine is dependent upon clean dry steam. Water ingress into a steam turbine can occur from a number of sources and may have catastrophic consequences. Even a small amount of water can cause enormous damage to the turbine blades, the cylinders and the housing. Steam will naturally start to condense as soon as it sees a drop in temperature or pressure. At various points along the steam's path, small collection points or drip legs are included for the condensate to pool for return to the boiler system.

Water can reach the turbine from various feedwater sources and under a number of operating conditions.

<u>For example:</u>

- High water level in either HP, IP or LP feedwater heater, usually caused by tube leaks or the failure of the drainage arrangement
- High water level in the deaerator: if there is a mismatch between the inflow and outflow the vessel can flood. In each of these cases the water may flow, via the bled steam lines and against the steam flow, towards the turbine
- Undrained bled steam lines. Wet steam can deposit water on the pipe work walls, and condensation can occur at bends in the pipe work and at valves. Condensation is also a problem during start up when the steam lines are being warmed
- A unit trip or sudden load reduction, resulting in a pressure reversal. During a trip the HP turbine pressure decays rapidly and the lower pressure areas fall to condenser vacuum almost immediately. In contrast, the pressures in the feed system change relatively slowly. Large pressure differentials are created which will tend to stimulate flow towards the turbine from the feed system
- Reverse steam flow in the bled steam lines can potentially carry water from heaters or undrained low points to the turbine with consequential damage. Water ingress is not only a problem when the turbine is at operating speed; water flowing onto hot cylinders can cause severe chilling with distortion or cracking of the cylinders

1.4.5 Deaerator control

The deaerator removes entrained air from the condensate. Condensate flows into the deaerator, mixes with extraction steam, and flows over a set of metal trays. The condensate agitates as it flows over the metal trays; this churning action releases the entrained air contained in the condensate. The air vents out of the top of the deaerator while the condensate flows into a storage tank.

The level of the condensate is measured in the storage tank. The deaerator's efficiency is destroyed if the condensate level rises into the shell. The tank must also hold a sufficient amount of condensate to supply the feedwater heaters.

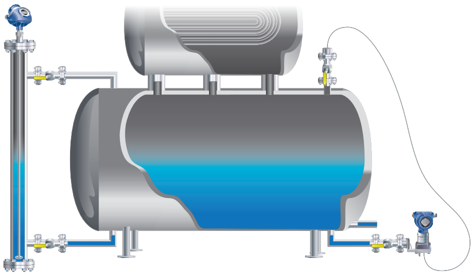

Figure 1.4.3: Deaerator level with guided wave radar and differential pressure

1.4.6 Condenser and make-up water control

Strong vacuum pressures build up in a condenser because large amounts of steam are being condensed into water. The liquid occupies less space than the equivalent amount of steam. A typical condenser is very large to accommodate the space needed for the steam. At the bottom of the condenser is the hotwell where condensate collects. The condensate is returned to the feedwater system.

Because the hotwell is the starting point for all boiler feedwater, the hotwell level is carefully controlled. Since the pressure conditions can change from vacuum to positive pressures, level measurements can be challenging. The density of the water as condensation occurs can change significantly.

If the hotwell level falls to the low setpoint, make-up water is added to the hotwell from the make-up water storage tanks. Make-up water is water that has been demineralized, purified, and treated in a water treatment system for use in the boiler. If the hotwell level reaches the high setpoint, condensate from the hotwell is pumped to the make-up water storage tank. Condensate from the hotwell that is pumped to the make-up water storage tank is called reject. Typically, reject flow, make-up water flow, and make-up water storage tank levels are measured.

1.4.7 Circulating water and cooling tower control

To cool steam in the condenser and to cool oil and hydrogen in the generator cooling system, large amounts of cool water must be circulated through heat exchangers in these systems. The water used for this purpose is called circulating water. In many cases, circulating water, pumped directly from a river or lake, is used for cooling and then returned to its source. In other cases, circulating water is pumped from a well or other source. In some instances, a cooling tower is used to cool the water so that it can be reused in the circulating water system. A 160 MW power plant commonly uses 88,000 gallons (333,000 liters) of circulating water per minute in the condenser.

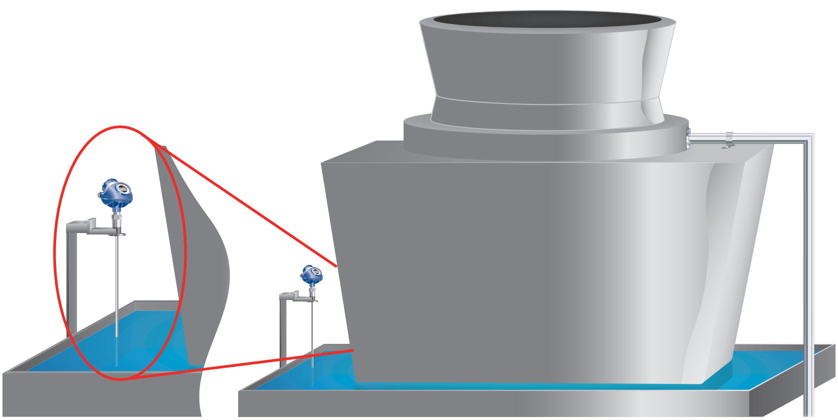

Figure 1.4.4: Cooling tower basin level with guided wave radar; overview and close-up

In a cooling tower, warm circulating water from the plant is pumped to the top of the tower and dropped down through a series of baffles to the bottom, releasing heat as it falls. Many cooling towers are equipped with fans at the top to blow warm water vapor out of the tower more quickly and thus speed cooling. The cooled water collects at the bottom of the tower. The level of this cooled water is monitored. If the level falls to the low setpoint, water is pumped into the tower bottom from a river, lake, or circulating-water storage pond nearby.

Measuring level in a cooling tower could be challenging due to the high amount of vapors and condensation as the water trickles through the tower. Plus, the water can be contaminated with debris such as leaves or algae, and occasional foam.

For details on suitable technologies and best practice on key level applications see chapter 4.

Available technologies

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2. Available technologies

There are many level technologies on the market, all with advantages and limitations. No single technology is good for all applications, and 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.

Each technology has physical limits such as pressure and temperature capabilities. The material here includes general guidelines. *For specific details, see chapter 3 on Rosemount level products.*

2.1 Guided wave radar
- continuous level measurement

2.1.1 Basic principle

Guided wave radar (GWR) is also called time domain reflectometry (TDR) or micro-impulse radar (MIR). In a guided wave radar installation, the GWR 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 GWR 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 GWR 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 (GWR) 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. GWR 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. GWR 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 their 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 GWRs 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.

Because it is non-contacting, the gauge's susceptibility to corrosion is limited and it is an ideal choice for viscous, sticky, and abrasive fluids. Non-contacting radar can frequently be used in vessels with agitators. High frequency devices 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 width is inversely proportional to antenna size. The beam width 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

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 (DK) 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 DK; fuel oil, lube oil and some solids, such as lime, have a low DK.

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 top of the tank or above the liquid surface in a sump/wet well 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

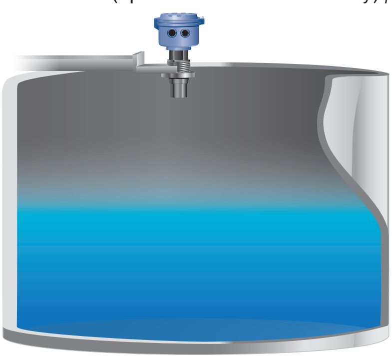


Figure 2.3.1 Illustration showing an ultrasonic transmitter

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 easy to install on empty tanks or on tanks containing liquid. Set-up is simple and those devices with on-board programming capability can be configured in minutes.

As there is no contact with the media and no moving parts, the devices are virtually maintenance free. Wetted materials are usually an inert fluoropolymer, and resistant to corrosion from condensing vapors.

Because the device is non-contacting, the level measurement is unaffected by changes in the liquid density, dielectric, or viscosity, and performs well on aqueous liquids and many chemicals. Changes in process temperature will change the speed of the ultrasonic pulse through the space above the liquid, but built-in temperature compensation automatically corrects this. Changes in process pressure do not affect the measurement.

2.3.3 Limitations

Ultrasonic transmitters rely on the pulse being unaffected during its flight time. Liquids which form heavy vapors, steam or vapor layers should be avoided (use a Radar transmitter in these instances). As the pulse needs air to travel through, vacuum applications are not possible.

Materials of construction generally limit the process temperature to around 158 °F (70 °C) and pressure to 43 psig (3 bar).

The condition of the liquid surface is also important. Some turbulence can be tolerated but foaming will often damp out the return echo.

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

Ultrasonic transmitters can be used on silos containing dry products such as pellets, grains or powders, but these are more difficult to commission. Factors such as surface angle of repose, dusting and long ranges must be taken into account. A guided wave radar transmitter is better suited to dry product applications.

2.4 Ultrasonic sludge blanket monitoring and control
- continuous level measurement

2.4.1 Basic principle

<u>Suspended solids monitoring</u>

The percentage of suspended solids within a slurry can be calculated by measuring how much an ultrasonic signal is attenuated as it travels through the fluid.

An ultrasonic transmitter/ receiver pair is submerged in a tank or mounted within a pipe section. An ultrasonic signal is transmitted between the transmitter and receiver crystals and is scattered by suspended solids particles that are present in the slurry. The amount of signal received by the receiver crystal is inversely proportional to the percentage of suspended solids within the slurry.

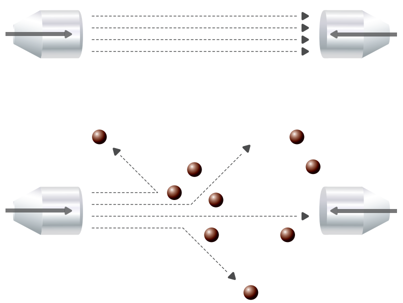


Figure 2.4.1 Illustration showing the principle of suspended solids monitoring

2.4.2 Advantages

Ultrasonic systems are easy to install and those fitted with an on-board calibration function can be configured quickly.

Since the technology is submersible, measurements are unaffected by turbulence, heavy vapors and foaming.

The technology is very robust, based on non-optical principles and incorporates no moving parts, therefore systems are virtually maintenance free.

2.4.3 Limitations

Systems are typically designed to operate in applications where the percentage of suspended solids is within the range of 0.5-15%. If the supernatant contains a very high percentage of suspended solids, the ultrasonic signal may be attenuated completely.

The ultrasonic signal will also be attenuated by the presence of entrained air or gas within the supernatant. If entrained air or gas is present, measurement accuracy may be affected.

An additional limitation is that the system has to be submerged.

2.5 Pressure transmitters
- continuous level measurement

2.5.1 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. In closed vessel level applications, a DP transmitter must be used to compensate for the vessel being pressureized or under a vacum.

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, also known as hydrostatic pressure, is the pressure exerted by the column of liquid. Head pressure is directly proportional to the specific gravity (S.G.) of the fluid and the height of the fluid column.

- 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 H2O=0.43 psig).

Closed tank level measurement

In closed vessel level applications, a DP transmitter must be used for compensation in vessels that are pressurized or under a vacuum. 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.

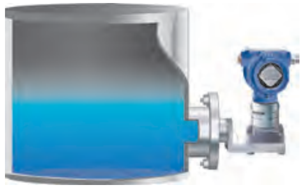


Figure 2.5.1 Illustration showing a pressure transmitter

The 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 gage or absolute transmitters can be used to calculate DP in an Electronic Remote Sensor configuration.

- Level = Differential Pressure / Specific Gravity

2.5.2 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.

2.5.3 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 technology can further eliminate 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.

2.6 Capacitance
- continuous and point level measurement

2.6.1 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 inches

D = Distance between the plates in inches

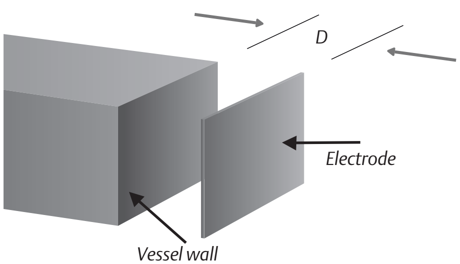


Figure 2.6.1 Capacitance principle

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.

2.6.2 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.

2.6.3 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 non metallic 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.

2.7 Displacer transmitters
- continuous measurement

2.7.1 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 (Archimede’s 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.

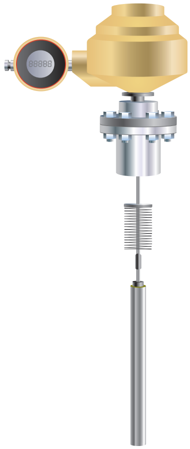


Figure 2.7.1 Illustration showing a spring displacer

2.7.2 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.

2.7.2 Limitations

The accuracy of the level measurement is dependant upon correct calibration of the instrument at operating conditions. If these conditions would 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.

2.8 Nuclear

- continuous and point level measurement

2.8.1 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.

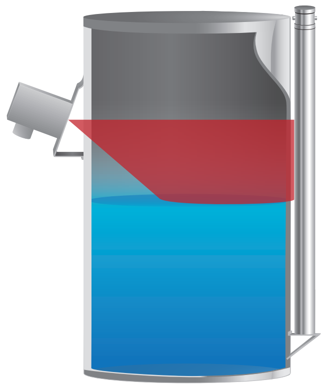


Figure 2.8.1 Illustration showing a nuclear device

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.

2.8.2 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.

2.8.3 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.

2.9 Laser
- continuous level measurement

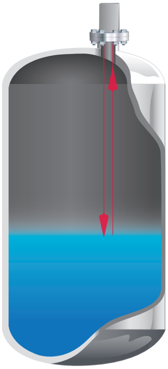


Figure 2.9.1 Illustration showing the laser principle

2.9.1 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.

2.9.2 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.

2.9.3 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. The beam is thin and can easily be interfered.

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 chamber contains a magnetic float that moves up and down with the level and triggers the visual indicators in the column. The float can also trigger a magnetostrictive sensor, which is a sensor that responds when they are exposed to a magnetic field.

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

The magnetic float contained in the chamber is designed to sit at the total level and/or the interface between two adjacent fluids based on their specific gravity. To get both the surface level and the interface level, two floats designed for different specific gravities are installed. The indicators typically comprise a housing containing a column of flippers or rollers. The flippers or rollers 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 flipper or roller. This will indicate the position of the float contained in the chamber. As the level within the chamber rises and falls, the float rises and falls, and the level is communicated to and displayed by the MLI's indicators. The magnetic lines of flux also stimulate other magnetostrictive sensors or switches, such as reed switches, attached to the column.

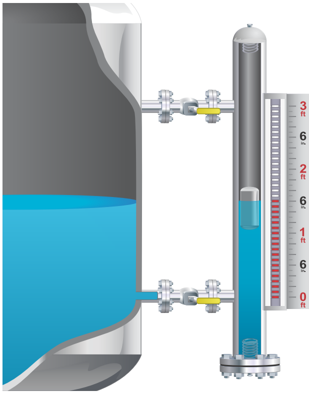


Figure 2.10.1 Illustration showing a magnetic level indicator

2.10.2 Advantages

MLIs are typically used to provide operating personnel with a visual indication of the level 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. MLIs typically remain in service for decades.

2.10.3 Limitations

MLIs 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. In certain circumstances, boiler code requires that the plant operator can observe the process media directly. In these cases an MLI 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 MLIs 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 Magnetostrictive
- continuous level measurement

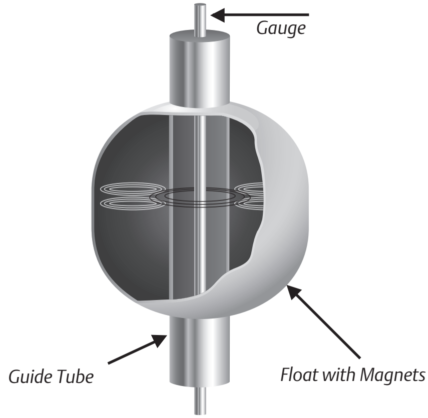


Figure 2.11.1 Illustration showing the magnetostrictive magnetic fields

2.11.1 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, a torsional "twist" is initiated. This then creates a sonic wave, which is detected and timed.

The magnetostrictive level device may also be externally mounted to an MLI for non-invasive level control. In this case, the sensor is attached to the exterior of the MLI, and senses the magnetic field generated by the float inside of the MLI.

2.11.2 Advantages

The magnetostrictive devices are precise (<1/32" or 1 mm) and in addition to level, interface and numerous temperatures can also be measured on the same assembly.

2.11.3 Limitations

The magnetostrictive gauge measures the position of the float, which means that any change in density can cause a measuring error. The magnetostrictive technology is intrusive and can therefore clog or stick, and it is also corrosion sensitive. Long lengths, typically > 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.

2.12 Servo
- continuous level measurement

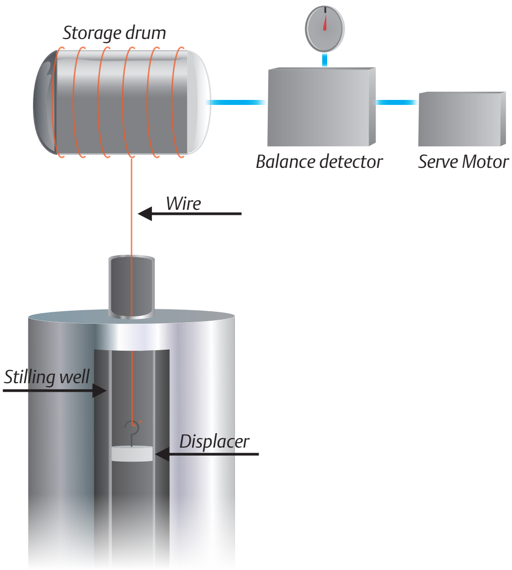


Figure 2.12.1 Illustration showing the servo powered level gauge

2.12.1 Basic principle

The servo powered level gauge uses a bi-directional motor attached to a displacer and cable. A displacer float is attached to the wire which is stored on a measuring drum. The servo motor is controlled by an electronic weighing balance which continuously senses the buoyancy of the partly immersed displacer. In an equilibrium condition, the apparent weight of the displacer balances against the force of the balancing springs when partly immersed in the fluid. A level rise or fall causes a variation in buoyancy. The detector controls an integration circuit in the bi-directional motor which turns the measuring drum, thus raising or lowering the displacer until the balance position is restored.

Servo tank gauges are normally mounted on the top of the tank on a stilling well. To maximize accuracy, the displacer must be mounted in a stilling well to prevent horizontal movement of the displacer. If not contained in a stilling well, it can be subject to mounting errors.

Servo level gauges may also be used for interface measurements. In this case, the displacer is sized for the heavier material and sinks through the upper layer.

Factors affecting the system accuracy are: expansion of cable due to temperature changes, mounting location, tank bulging due to liquid head stress resulting in a reference point movement, changes in density of the product, and cable and drum tolerance.

2.12.2 Advantages

The servo powered level gauge provides a direct level measurement with good instrument level accuracy (± 0.5 mm).

Some servo gauges can be remotely activated to hoist or lower the level sensing displacer for an overall repeatability and performance check or calibration.

By lowering the displacer it is also possible to measure density and/or detect a water interface below the product surface in the bottom of the tank.

In the externally mounted configuration, the sensor is attached to the exterior of the MLI, allowing it to be installed or serviced without removing the indicator from service.

2.12.3 Limitations

To maximize accuracy, the displacer must be mounted in a stilling well to prevent horizontal movement of the displacer.

The gauge has many moving parts that are susceptible to mechanical wear and sensitive to dirt and product buildup.

Density change of the measured product may affect the immersion of the sensing element in the equilibrium condition.

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 requirement to maintain accuracy. The real product level measurement is not available during these density and water interface measurements.

2.13 Vibrating fork switches
- point level detection

2.13.1 Basic principle

A tuning fork switch comprises a two prong fork which is driven to oscillation at its natural frequency, usually by a piezo-crystal assembly. The switch is mounted on the side or top of a tank using a flange or threaded process connection such that the forks protrude into the tank.

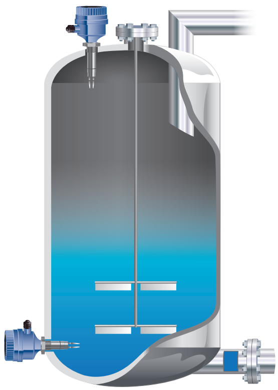


Figure 2.13.1 Illustration showing vibrating fork switches mounted on top and on the side of the tank

When in air, the forks vibrate at their natural frequency which is monitored by a detector circuit. When liquid 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 to operate an alarm, pump or valve. The frequency of operation of the switch is chosen to avoid interference from normal plant vibration which may cause false switching.

The design is glandless, and material of construction is usually stainless steel, allowing use in high pressure and temperature applications, with options of coated wetside or exotic materials for corrosive applications.

2.13.2 Advantages

The vibrating fork switches are virtually unaffected by flow, bubbles, turbulence, foam, vibration, solids content, coating, properties of the liquid, and product variations. There is also no need for calibration and it requires minimum installation procedures. No moving parts or crevices means virtually no maintenance.

2.13.3 Limitations

Vibrating fork switches are not suitable for very viscous media. Build up between the forks, causing bridging of the forks, will cause false switching.

2.14 Float & 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.

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.

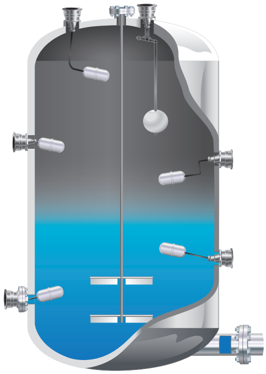


Figure 2.14.1 Illustration showing different mounting positions of float switches

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.

2.15 Conductivity water & steam interface monitoring
- continuous point level detection

2.15.1 Basic principle

By measuring electrical resistance of the fluid within a column or steam line, it is possible to detect the presence of either water (typical value between 2Ω-100KΩ) or steam (typical value >10MΩ).

To measure water level within a steam drum or boiler, a vertical array of electrodes may be installed within a water column attached to the boiler, above and below the normal water level. The resistance at each electrode is measured, a step change in resistivity between two adjacent electrodes identifies the water level.

The different resistive properties of steam and water may also be exploited in turbine water induction prevention systems (TWIP). By installing electrodes in to the steam lines and measuring the resistance, the unwanted presence of water can be detected allowing the appropriate safety measures to be taken.

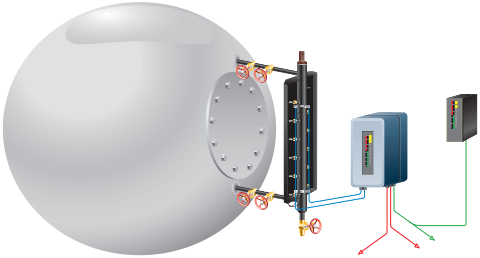


Figure 2.15.1 Illustration showing an conductivity water/steam detection system on a boiler drum

2.15.2 Advantages

Detecting the presence of either steam or water through a resistivity measurement is a proven technique. The difference between water and steam resistivities is substantial, making measurements simple and reliable.

Using an electronic method to indicate water level or differentiate between the presence of steam or water offers a very high level of system self checking and integrity compared to mechanical methods since there are no moving parts. This also greatly reduces the requirement for routine maintenance.

2.15.3 Limitations

The reliability of the system is dependant upon the quality of the water in the system. Whilst this is usually very clean, the presence of dirty water can foul the electrodes. In more sophisticated systems, however, this will not cause a fault or trip.

Operating temperature is limited by the material of construction to 1040 °F (500 °C).

2.16 Technology overview for continuous level

Process Conditions	Guided wave radar	Non-contacting radar	Ultrasonic	Pressure	Capacitance	Displacer	Nuclear	Laser	MLI	Magnetostrictive	Servo (in stilling well)
Aeration	Good	Moderate	Moderate	Moderate	Good	Good	Moderate	Moderate	Good	Moderate	Moderate
Agitation	Poor	Good	Poor	Good	Moderate	Good	Good	Moderate	Good	Moderate	Moderate
Ambient temperature changes	Good	Good	Moderate	Moderate	Good	Moderate	Good	Good	Good	Good	Good
Corrosion	Moderate	Good	Good	Moderate	Good	Moderate	Good	Good	Moderate	Moderate	Moderate
Density changes	Good *	Good	Good	Moderate	Good	Moderate	Moderate	Good	Moderate	Moderate	Poor
Dielectric changes	Good	Good	Good	Good	Poor	Good	Good	Good	Good	Good	Good
Dust	Good	Moderate	Poor	Good	Good	Poor	Good	Poor	Poor	Good	Poor
Emulsion	Moderate **	Good	Good	Good	Good	Good	Good	Good	Moderate **	Moderate **	Moderate **
Foam	Good	Moderate	Poor	Good	Moderate	Good	Good	Poor	Good	Good	Moderate
High process temperature limits	Good	Moderate	Poor	Good	Good	Good	Good	Good	Good	Poor	Moderate
High vessel pressure limits	Good	Moderate	Poor	Good	Good	Good	Good	Good	Moderate	Poor	Moderate
Internal obstructions	Moderate	Moderate	Moderate	Good	Moderate	Good	Moderate	Moderate	Good	Good	Good
Low process temperatures (< 0°F, <-40)	Good	Good	Good	Good	Good	Moderate	Good	Good	Moderate	Good	Good
Low vessel pressures (vacuum)	Good	Good	Poor	Moderate	Good	Good	Good	Good	Good	Good	Good
Noise (EMI, motors)	Good	Good	Moderate	Good	Good	Good	Good	Moderate	Good	Good	Good
Product coating	Moderate	Good	Moderate	Moderate	Poor	Poor	Moderate	Moderate	Poor	Poor	Poor
Slurries	Moderate	Good	Moderate	Moderate	Moderate	Poor	Good	Good	Moderate	Moderate	Poor
Solids	Good	Good	Moderate	Poor	Moderate	Poor	Good	Good	Poor	Poor	Poor
Vapors	Good	Good	Moderate	Good	Moderate	Good	Good	Moderate	Good	Good	Good
Viscous, sticky product	Moderate	Good	Good	Moderate	Moderate	Poor	Good	Good	Poor	Poor	Poor

Table 2.16.1: Rating of each technology based on its capability of handling each challenge.

Good: *This condition has little or no impact on performance of this technology.*

Moderate: *This technology can handle this condition, but performance could be affected or special installation is needed.*

Poor: *This technology does not handle this condition well, or does not apply.*

* *A changing dielectric value will impact interface measurement accuracy.*
** *Overall level OK, interface level moderate.*

2.17 Technology overview for point level detection

Process Conditions	Capacitance	Nuclear	Vibrating fork	Float switch
Aeration	Good	Moderate	Good	Good
Agitation	Moderate	Good	Good	Good
Ambient temperature changes	Good	Good	Good	Good
Corrosion	Good	Good	Moderate	Moderate
Density changes	Good	Moderate	Good	Moderate
Dielectric changes	Poor	Good	Good	Good
Dust	Good	Good	Good	Good
Emulsion	Good	Good	Good	Good
Foam	Moderate	Good	Moderate	Good
High process temp limits	Good	Good	Good	Good
High vessel pressure limits	Good	Good	Good	Good
Internal Obstructions	Moderate	Moderate	Good	Good
Low process temp limits	Good	Good	Good	Good
Low vessel pressure limits	Good	Good	Good	Good
Noise (EMI, motors)	Good	Good	Moderate	Good
Product coating	Poor	Moderate	Moderate	Moderate
Slurries	Good	Good	Moderate	Moderate
Solids	Moderate	Good	Poor	Poor
Vapors	Moderate	Moderate	Good	Good
Viscous/ sticky product	Moderate	Good	Moderate	Moderate

Table 2.17.1: Rating of each technology based on its capability of handling each challenge.

- *Good: This condition has little or no impact on performance of this technology.*
- *Moderate: This technology can handle this condition, but performance could be affected or special installation is needed.*
- *Poor: This technology does not handle this condition well.*

Rosemount level products

Topic Page

3. Rosemount level 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 its product data sheet on Rosemount.com*

3.1 Guided wave radar

There are three series of Rosemount guided wave radars; the 5300 series, the 3300 series and the 3308 series. For guidance in choosing the correct model for your application, *please see the table 3.1.1 on the next page .*

Benefits of Rosemount guided wave radar:

- 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
- Few installation rules
- 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 Smart Wireless THUM Adapter

3.1.1 5300 Series superior performance guided wave radar

- 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
- Safety system suitable (SIL2)
- ASME B31.1 available for selected flanges
- Boiler standards EN 12952-9 and EN 12953-11 compliant

3.1.2 3300 Series versatile and easy to use guided wave radar

- Handles most liquid storage and monitoring applications
- First 2-wire level and interface transmitter with field proven reliability
- 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.

Figure 3.1.1: Rosemount 3300 (Left) & Rosemount 5300 (Right)

Specification and selection guide for guided wave radar[1]

		3300	3308	5300
Certification	Explosion proof or intrinsically safe	●	●	●
	Overfill protection (DIBt / WHG)	●	○	●
	Safety system suitable	○	○	●
	Marine approvals	○	○	●
	EN 12952-9 and EN12953-11 compliant	○	○	●
Output	4-20 mA with HART	●	○	●
	FOUNDATION fieldbus	○	○	●
	MODBUS	●	○	●
	WirelessHART	●[2]	●	●[2]
Configuration	Customized PC setup and support software	●	○	●
	AMS™ Suite / Field communicator (e.g. 375/475)	●	●	●
	Delta V	○	○	●
	DTM compliant [3]	●	○	●
	Enhanced EDDL/DTM capabilities	○	●	●
Diagnostics	Standard diagnostic capabilities	●	●	●
	Enhanced diagnostic capabilities	○	●	●
Probe materials	Stainless steel or PTFE covered	●	●	●
	Duplex 2205, Alloy C-276, Alloy 400	○	○	●
Max/min temp/pressure	-40 to 302 °F (-40 to 150 °C)/-14 (-1) to 580 psig (40 bar)	●	●	●
	-320 to 752 °F (-196 to 400 °C)/-14 (-1) to 5000 psig (345 bar)	○	○	●
Performance	Maximum measuring range	75ft/23m	33ft/10m	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	±0.25in/6mm	±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]	●

KEY: Available ● Not available ○

1 *For more information please refer to the product data sheet (PDS) and GWR application and selection guide*
2 *With the 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. Consult factory in case of non-metallic tanks or open air applications*

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

3.1.3 3308 series wireless guided wave radar

- 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

- 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 measurements

Figure 3.1.2: Rosemount 3308

3.2 Non-contacting radar

- Top mounted, non-contacting, direct level measurement
- Wide temperature and pressure ranges
- 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 Smart Wireless THUM™ Adapter for wireless solution
- High flexibility with interchangeable transmitter heads and antennas
- No moving parts and no contact with the liquid
- Easy setup of the advanced transmitter software through the Rosemount Radar Master configuration tool
- Wide selection of antennas and materials
- There are two series of Rosemount non-contacting radars; the 5400 series and the 5600 series.

For guidance in choosing the correct model for your application, please see the table 3.2.1 on the next page.

Figure 3.2.1: Rosemount 5400 (Left) & Rosemount 5600 (Right)

3.2.1 5400 series 2-wire superior performance

- Maximum mounting and application flexibility is ensured with a wide range of antennas and two models with different microwave frequencies, 5401 (6 GHz) and 5402 (26 GHz)
- Liquid level measurement
- Dual Port Technology enables a stronger signal than other 2-wire radar transmitters, providing better measurement reliability
- Condensation resistant antenna is much less susceptible to coating, increasing reliability and reducing maintenance
- Faster and simpler commissioning with the easy to use Measure-and-Learn™ functionality in the transmitter
- Circular polarization reduces echoes from obstacles and tank walls
- Can measure through non-metallic tanks
- Advanced transmitter software can be easily configured using the user-friendly software "Rosemount Radar Master"
- Easy integration into new or existing plants with a choice of FOUNDATION ™ fieldbus with extensive support for PlantWeb™ alerts, Modbus or 4-20 mA with superimposed HART™
- Safety system suitable (SIL2)

3.2.2 5600 series 4-wire for niche applications

- Handles a wide range of process conditions due to high sensitivity and unique signal processing features
- Wide temperature range
- Liquid and solid level measurement
- High repeatability ensuring an extremely reliable and accurate level transmitter even in the toughest conditions
- Ultra-wide power supply
- Modbus and analog 4-20 mA superimposed with HART

Specification and selection guide for non-contacting radar[1]

		5400	5600
Certification	Explosion proof or intrinsically safe	Available	Available
	Overfill protection (DIBt / WHG)	Available	Available
	Safety system suitable	Available	Not available
	Marine approvals	Available	Not available
Output	Separate wiring for power and communication (e.g. 4-wire)	Not available	Available
	4-20 mA with HART	Available	Available
	FOUNDATION fieldbus	Available	Not available
	MODBUS	Available	Available
	WirelessHART with the THUM Adapter	Available	Available
Configuration	Customized PC setup and support software	Available	Available
	AMS Suite / Field communicator (e.g. 375/475)	Available	Available
	Delta V	Available	Available
	Enhanced EDDL capabilities	Available	Not available
	DTM compliant [2]	Available	Not available
Diagnostics	Standard diagnostic capabilities	Available	Available
	Enhanced diagnostic capabilities	Available	Not available
Antenna materials	Stainless steel, Alloy C-276, Alloy 400 or PTFE covered	Available	Available
	Titanium or Tantalum	Not available	Available
Max/min/ temp/pressure	-40 to 302 °F (-40 to 150 °C) / -14 (-1) to 232 psig (16 bar)	Available	Available
	-40 to 752 °F (-40 to 400 °C) / -14 (-1) to 798 psig (55 bar)	Not available	Available
Performance	Maximum measuring range	115ft/35m	164ft/50m
	Minimum dielectric constant	1.9[3]	1.9[3]
	Reference accuracy	0.12in/3mm	0.2in/5mm
Application considerations	Heavy vapors or bubbling/boiling surfaces	5401	Available
	Valves, taller nozzles, small openings and internal structures	5402	Not available
	High turbulence and rapid level changes	Available	Available
	Solids, granules, powders	Not available	Available

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

KEY: Available ● Not available ○

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

2 *For configuration in Fieldmate, FieldCare, and PactWare*

3 *If installed in vessel. Min DK 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 Ultrasonic level transmitter & controller

3.3.1 3100 series ultrasonic level transmitters

- Can be configured for liquid level, volume and open channel flow calculations, with a 4–20 mA / HART output
- Easy to install and set up using on-board programming, push buttons or built-in display
- Self-learning functionality to ignore internal structures
- Minimal maintenance - no moving parts and resistant to corrosion
- Accuracy unaffected by changes in density, dielectric and viscosity
- Built-in temperature compensation corrects for changes in vapor temperature
- May be combined with the Rosemount Smart Wireless THUM™ Adapter for wireless solution
- Integral relays for alarm or control duties
- Flexibility of models to fit different markets, such as industrial/ effluent treatment markets or exposed sites such as reservoirs, rivers or remote works

There are five models in the Rosemount ultrasonic level transmitter range and for guidance in choosing the correct model for your application, please see the table 3.3.1 on the next page.

Figure 3.3.1: Rosemount 3100 (Left) & Rosemount 3107 (Right)

3.3.2 Level controllers

- Provides intrinsically safe power to the transmitter, or any other 4-20mA / HART transmitter
- Program wizards to assist configuration and set-up for level, pump control and open channel flow applications
- Pre-configured tank volume calculations for different tank shapes, and flow curves for most common weirs and flumes
- LCD display, 4-20mA output, 5 x SPDT relay contacts, totalizer output for flow applications
- HART digital communication with transmitter
- Datalogging up to 7000 events
- May be combined with Rosemount Smart Wireless THUM™ Adapter for wireless solution

Figure 3.3.2: Rosemount 3490 controller

Specification and selection guide for ultrasonic level transmitters[1]

		3101	3102	3105	3107	3108
Application	Level	●	●	●	●	●
	Level (occasional submersion)	○	○	○	●	●
	Distance	○	●	●	●	●
	Tank volumes	○	●	●	●	●
	Open channel flow - flumes/weirs	○	●	●	●	●
	Strapping table 10 points	○	●	●	●	●
Range	1 to 11 ft. (0.3 to 3.3 m)	●	●	●	●	●
	1 to 26 ft. (0.3 to 8 m)	●	●	●	●	○
	1 to 36 ft. (0.3 to 11 m)	○	●	●	●	○
	1 to 40 ft. (0.3 to 12 m)	○	○	○	●	○
Certification	Intrinsically safe/hazardous area	○	○	●	●	●
Output	Relay 2 x SPDT	○	●	○	○	○
	4-20 mA	●	●	●	●	●
	HART	○	●	●	●	●
	WirelessHART with the THUM Adapter	○	●	●	●	●
Housing	Die cast aluminium	●	●	●	○	○
	Glass filled nylon (plastic)	●	●	●	○	○
	UPVC (plastic)	○	○	○	●	●
Wetted material	PVDF (plastic)	●	●	●	○	○
	UPVC (plastic)	○	○	○	●	●
IP rating	IP66/67 Type 4X	●	●	●	○	○
	IP68 Type 6P (33 ft (10 m))	○	○	○	●	●
Ambient temperature	-4 to 158 °F (-20 to 70 °C)	●	●	●	○	○
	-40 to 158 °F (-40 to 70 °C)	○	●	●	○	○
	-40 to 140 °F (-40 to 60 °C)	○	●	●	●	●
Process pressure	-3.6 to 44 psi (-0.25 to 3.0 bar)	●	●	●	●	●
Reference accuracy	±0.5% of range or ±0.2 in. (5 mm) [2]	●	●	●	●	●
	±0.25% of range or ±0.1 in. (2.5 mm) [2]	○	●	●	●	●

Table 3.3.1: Specification and selection guide for Rosemount ultrasonic transmitters

KEY: Available ● Not available ○

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

[2] *Whichever is the greater*

3.4 Differential pressure & hydrostatic level

3.4.1 DP 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 (WirelessHART) protocols

There are a number of Rosemount pressure transmitter models. For guidance in choosing the correct model for your application, please see the table 3.4.1 on the next page.

Figure 3.4.1: Rosemount 3051S direct mount (Left) & Rosemount 3051S ERS™ system (Right)

Electronic Remote Sensors (ERS)

- A digital pressure solution for tall vessels
- Eliminate excess impulse piping and capillary
- Provides additional process insight with MultiVariable capabilities

1199 seal systems

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

3.4.2 9700 Submersible hydrostatic level transmitter

- Submersible or external level transmitters for use in vented and open tanks
- Rugged stainless steel or aluminum bronze construction
- Tough flush mounted ceramic sensor for long life
- Simple, low cost installation
- Analog 4-20 mA communications

Figure 3.4.2: Rosemount 9700

Specification and selection guide for pressure[1]

		3051S ERS	3051S	3051	2051	Hydro-static
Transmitter protocols	4-20 mA	●	●	●	●	●
	HART	●	●	●	●	○
	FOUNDATION fieldbus	●	●	●	●	○
	WirelessHART	○	●	●	○	○
	WirelessHART 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	○	●	●*	○	○
Process temp.	-4 to +194 °F (-20 to +90 °C)	●	●	●	●	●
	-103 to 600 °F (-75 to +316 °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 aluminium bronze and ceramic capacitive sensor	○	○	○	○	●

Table 3.4.1: Specification and selection guide for pressure transmitters

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

* *Enhanced units only*

KEY: Available ● *Not available* ○

3.5 Magnetic level indicators and magnetostrictive level transmitters

In May 2012, Emerson acquired ISE Magtech. This means that Emerson will be providing solutions with magnetic level indicators and magnetostrictive level transmitters in the future, but for now *please refer to Magtech at: www.isemagtech.com for detailed product information.*

ISE Magtech's magnetic level indicator coupled with the Rosemount guided wave radar creates a complete liquid measurement solution by combining a local visual indication of level with a robust transmitter to support plant operators' needs for visual and automated system monitoring.

Figure 3.5.1: Magtech MLI together with a Rosemount 5300 fitted to a chamber

3.6 Conductivity water & steam interface monitoring

3.6.1 2468 Hydrastep electronic gauging system

- High reliability steam/ water electronic gauging system
- The ideal "fit and forget" solution to overcome the problems associated with unreliable, maintenance intensive gauge glasses
- Designed for totally reliable operation, Hydrastep is both fail-safe and fault tolerant
- Rugged electrodes fitted to a water column
- Red (steam) and green (water) indicators - which can be sited anywhere in the plant - display the water level
- An independent report by Factory Mutual Research concluded that the probability of Hydrastep missing a trip condition is less than 1 in 300 million and that nuisance trips will be less than 1 in 10 million.

3.6.2 2462 Hydratect water / steam detection system

- Water detection /turbine water induction prevention (TWIP)
- Dual redundancy design. No single fault will cause system failure.
- Built in diagnostics/ self-validating circuitry inform user of fault condition
- No maintenance costs and makes routine testing unnecessary
- Hydratect technology is recognized by insurance companies and reduces insurance premiums
- May be combined with the Rosemount 702 wireless discrete transmitter

Figure 3.6.1: Hydratect (left) & Hydrastep (right)

Specification and selection guide for conductivity steam/water interface monitoring[1]

		Hydrastep	Hydratect
Application	Steam drum level gauging	●	○
	Water / condensate level detection alarm	○	●
Water column	Carbon steel low pressure to 1740 psi (120 bar)	●	○
	Carbon steel high pressure to 3045 psi (210 bar)	●	○
	Stainless steel supercritical to 4350 psi (300 bar)	●	○
	Carbon steel manifold (optional)	○	●
Electrodes	Min 8 to max 32 per water column	●	○
	2 per manifold or for local installation	○	●
Control unit	Stainless steel IP65 / Type NEMA4	●	●
	Power supply AC or DC to order	●	●
	Dual redundancy power supply option	●	○
	Electrode output / trip validation	●	●
Output	High visibility local LED indication	●	●
	High visibility remote LED indication	●	○
	4-20 mA	●	○
	Relays	●	●

Table 3.6.1: Specification and selection guide for conductivity steam/water interface monitoring

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

KEY: Available ● *Not available* ○

3.7 Sludge blanket monitoring & control

3.7.1 MSM - Suspended solids density monitoring and control

- Continuous sludge discharge monitor for up to 15% suspended solid
- Rugged 316 stainless steel sensors for in-tank or pipe section mounting
- Bright backlit LCD local display

MSM448 - Pipe section sensors

- Epoxy coated carbon steel with 316 stainless steel transducers
- The pipe is coated to minimize grease and debris build up, and typically monitors suspended solids during a tank de-sludge cycle

MSM433 - Suspended tank mount sensor

- Available in a range of sizes depending on the range of density to be measured
- The sensors are of welded 316 stainless steel construction with an IP68 submersible rating for the cable entry
- The sludge density is measured between the sensor fork gap

Figure 3.7.1: MSM400 controller (left), MSM433 sensors (middle) & MSM448 pipe sensor (right)

Specification and selection guide for ultrasonic suspended solids[1]

		MCU200/433	MSM400/433	MSM400/448
Application	Interface - point level	●	●	○
	Blanket level	○	○	○
	Sludge density - in tank	○	●	○
	Sludge density - tank discharge	○	○	●
	Automatic de-sludge control	○	●	●
Certification	Intrinsically safe/hazardous area	○	●	●
Supply	24 Vdc	●	●	●
	110 / 230 V, 50 / 60 Hz	●	●	●
Output	Control / alarm relay SPDT	●	●	●
	Fault indication	●	○	○
	Dedicated fault relay SPDT	○	●	●
	4-20 mA	○	●	●
	HART	○	●	●
Sensor wetted material	UPVC/ceramic	○	○	○
	316 Stainless steel	●	●	●
Sensor IP rating	Type 6P (IP68) submersible	●	●	●
Process temperature	-40 to 122 °F (-40 to 50 °C)	●	●	●
	-40 to 150 °F (-40 to 65 °C)	○	○	●
	-40 to 158 °F (-40 to 70 °C)	○	○	●
Process pressure	Atmospheric	●	●	●
	145 psi (10 bar)	●	●	●
	1520 psi (105 bar)	●	●	○

Table 3.7.1: Specification and selection guide for sludge blanket monitoring and control system

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

KEY: Available ● Not available ○

3.8 Point level detection

3.8.1 Vibrating fork level switches

- Level detection and control for the process industries
- Short fork design for minimal tank intrusion or pipe mounting
- Compact and lightweight design for side or top mounting
- Rapid wet to dry time for highly responsive switching
- Drip-off fork design

There are different models of Rosemount vibrating forks. For guidance in choosing the correct model for your application, please see the table 3.8.1 on the next page.

2120 - Standard model

- Choice of switch outputs includes intrinsically safe and relay
- DIBt/WHG overfill protection certification
- Flanged, threaded and extended length options

Figure 3.8.1: Rosemount 2120 - standard model (left) & Rosemount 2130 - enhanced model (right)

2130 - Enhanced model

- Extended operating temperature range
- Built-in diagnostics continuously check electro output, diagnostics, and PlantWeb Alerts – wirelessly
- Ideal for critical alarm duties
- Low density capability
- Safety system certified to IEC 61508

2160 - Wireless model

- Communicates switch output, diagnosticsand alerts – wirelessly
- Robust self-organizing technology
- Exceptional >99% data reliability and network stability
- SmartPower™ - Long life power module
- Fork sensor requires low power, battery life approx. 10 years at 60 second update
- Instrument health diagnostics of the fork and sensor (detects external damage to the forks, internal damage to the sensor, excessive corrosion and over-temperature)
- WirelessHART 7
- Configurable to as fast as one second update

Specification and selection guide for vibrating forks[1]

		2110	2120	2130	2160
Certification	Explosion proof certification	○	●	●	○
	Intrinsically safe	○	●	●	●
	Safe area / ordinary location	●	●	●	●
	Overfill protection (DIBt/WHG)	○	●	●	●
	Safety system certified to IEC 61508	○	○	●	○
Output	8/16 mA	○	●	●	○
	Direct load switching	●	●	●	○
	PNP solid state	●	●	●	○
	DPDT [3] relay output	○	●	●	○
	NAMUR	○	●	●	○
	WirelessHART	○	● [2]	● [2]	●
Diagnostics	Basic self-check	●	●	●	●
	Advanced health/self-check diagnostics	○	○	●	●
Housing	Glass filled nylon (plastic)	○	●	○	○
	Metal (Aluminum/Stainless steel)	●	●	●	●
Wetted material	316L Stainless steel	●	●	●	●
	ECTFE/PFA copolymer, coated 316L SST	○	●	●	○
	Corrosion resistant nickel alloy C-276	○	●	●	●
Process temperature	-40 to 302 °F (-40 to +150 °C)	●	●	●	●
	-94 to 500 °F (-70 to +260 °C)	○	○	●	●
Process pressure	1450 psig at 122 °F (100 barg at 50 °C)	●	●	●	●
Connections	Threaded	●	●	●	●
	Hygienic	●	●	●	●
	Flanged	○	●	●	●
Extended lengths available		○	●	●	●

Table 3.8.1: Specification and selection guide for vibrating fork switches

KEY: Available ● Not available ○

[1] *For more information please refer to the product data sheet (PDS).*
[2] *When used in conjunction with Rosemount 702 Wireless discrete transmitter*
[3] *DPDT: Double pole double throw switching*

3.8.2 Electro-mechanical float and displacer switches

- Robust and reliable switching in most liquids
- Glandless 3 magnet switching system
- Operates in extremes of pressure and temperature
- Wide range of flanges, floats and switching outputs available
- Vertical and horizontal mount switches for in-tank or external chamber mounting
- A floating roof tank alarm switch model is available for use on floating roof tanks to signal if the roof rises too high
- Wide range of materials of construction available
- Comprehensive standard range or custom design chambers to suit existing process connections
- Float switches can be wirelessly enabled using the Rosemount 702 discrete input transmitter

For guidance in choosing the correct model, horizontal or vertical, for your application, please see the table 3.8.2 on the next page.

Figure 3.8.2: Horizontal switch (left), Vertical switch (middle) & Floating roof tank switch (right)

Specification and selection guide for electromechanical switches[1]

		Horiz	Vert
Certification	Explosion proof	●	●
	Intrinsically safe circuit suitability	●	●
	General purpose	●	●
	Safety system suitable	●	○
Output/switch type	General purpose	●	●
	Low powered circuits	●	●
	High power circuits	●	●
	Hermetically sealed	●	●
	Pneumatic	●	○
	WirelessHART	●[4]	●[4]
Housing	Aluminum	●	●
	Aluminum bronze	●	○
	Gunmetal	●	○
	Cast iron	○	●
	Drawn steel	○	●
	Stainless steel	●	●
Wetted parts	Stainless steel	●	●
	Exotic materials	●	●
Process temperature	Maximum 752 °F (400 °C)[2]	●	●
	Minimum -148 °F (-100 °C)[2]	●	●
Process pressure	Maximum 1479 psig at 68 °F (102 barg at 20 °C)	●	●
	Maximum 2900 psig at 68 °F (200 barg at 20 °C)	●	○[3]
Mounting	Threaded	●	●
	Flanged	●	●
	Chamber	●	●

Table 3.8.2: Specification and selection guide for float switches

KEY: Available ● Not available ○

1 *For more information please refer to the product data sheet (PDS)*
2 *Dependent on option and material selected - refer to product data sheet.*
3 *Special option only*
4 *When used in conjunction with Rosemount 702 wireless discrete transmitter*

3.9 Wireless level measurement, detection & control

3.9.1 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.

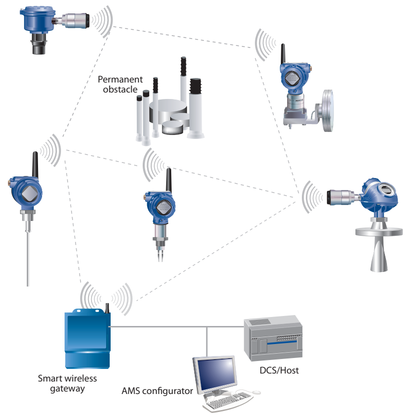


Figure 3.9.1: Schematic view of a wireless, self-organizing network with process level devices

3.9.2 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.

3.9.3 Rosemount smart wireless THUM™ adapter

The 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 was previously 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

Figure 3.9.2: The THUM Adapter together with the 5400 non-contacting radar

The THUM adapter can be used with the following Rosemount level products:

- 5300 and 3300 series guided wave radars
- 5400 and 5600 series non-contacting radars
- 3100 series ultrasonic transmitters
- 3051 series DP level transmitters

3.9.4 Rosemount 3051S and 3051 wireless pressure transmitters

Industry leading capabilities extended to IEC 62591 (WirelessHART).

- 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

Figure 3.9.3: Rosemount 3051S wireless differential pressure transmitter

3.9.5 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
- WirelessHART 7
- Configurable to as fast as one second update

Figure 3.9.4: Rosemount 2160 wireless vibrating fork switch

3.9.6 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.

- Suitable to use with float switches and Hydratect water / steam detection system
- Simple and effective, retrofit to existing switches on plant

Figure 3.9.5: Rosemount 702 wireless discrete transmitter with a float switch

3.9.7 Rosemount 3308 wireless guided wave radar

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 3308 combines fast and simple commissioning with robust measurement data.

- Dirty 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

Figure 3.9.6: Rosemount 3308 wireless guided wave radar transmitter

3.10 9901 - chambers for external mounting of process level instrumentation

3.10.1 Introduction

The Rosemount 9901 is a self-contained chamber for externally mounting the Rosemount range of process level instruments to a vessel. *See figure 3.10.1.*

Figure 3.10.1: Painted CS 9901 chamber with a 5300 GWR and SST 9901 chamber

Externally mounting an instrument in a chamber means that it can be isolated for routine maintenance while keeping the plant operational. It is also useful for in-tank restrictions that do not allow mounting of the instrument in the vessel and to minimize level changes in vessels with turbulent liquids.

This approach offers many advantages when solving application challenges:

In-tank constraints:

- agitator
- heat exchanger
- internal structures

Isolation of instrument:

- live maintenance
- safety
- hazardous liquids
- high pressure
- high temperature

Turbulent vessel conditions:

- chamber acts as a stilling well

Having one supplier for both chambers and instrumentation can ensure that products are correctly sized and the solution is optimized for that specific application.

3.10.2 Chamber

The chamber, also known as a cage or bridle, is connected to the main process vessel such that the liquid level in the chamber is the same as that in the process vessel.

There are two process connections on the body of the chamber which allow mounting to the vessel.

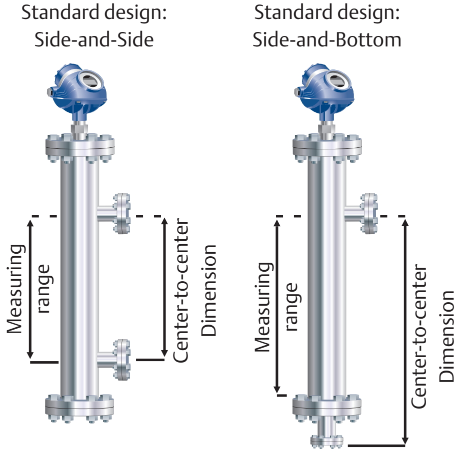


Figure 3.10.2: Showing the most common configurations

The instrument is mounted on top of the chamber through the flanged or threaded instrument connection. A threaded version is available for the vertical float level switch.

Standard materials are carbon steel and stainless steel, with other materials available upon request.

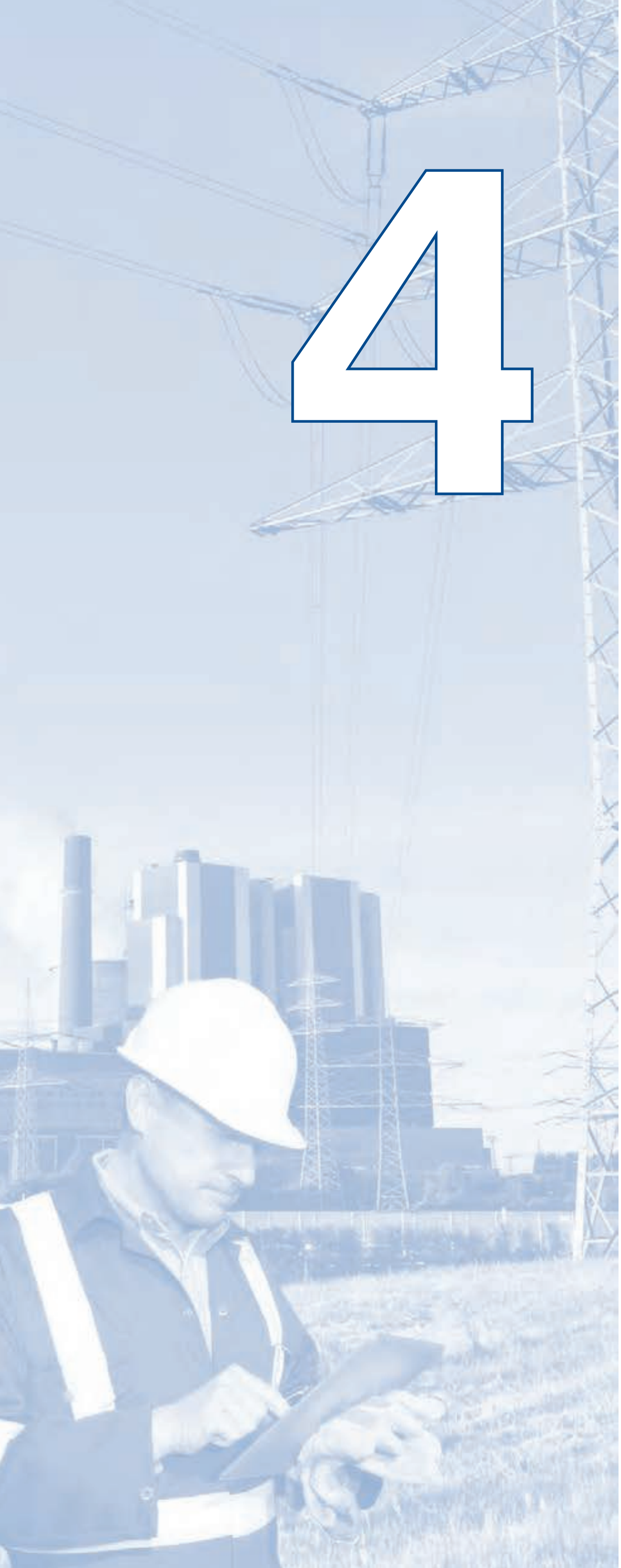
3.10.3 Chamber design

Rosemount 9901 chambers are designed to the ASME B31.3 standard (B31.1 available), and are pressure equipment directive (PED) compliant.

Weld neck flanges and full penetration welds in accordance with EN ISO 15614-1:2004 and ASME boiler and pressure vessel code section IX are used through out. All welders are qualified to EN 287-1:2004 and ASME boiler and pressure vessel code section IX.

All construction materials are fully traceable in accordance with the EN 10204 type 3.1 certificate.

Every 9901 is hydro-tested as standard. A full range of non destructive testing (NDT) is also available.



4

Level applications & technology selection

For content, see next page.

4. Level applications & technology selection

This chapter goes through a lot of the level applications found in different types of power plants. For each application, we give a brief description of the primary function as well as the characteristics and challenges.

Then we list the technologies that can be used to measure level in each application. This list is to provide the reader with information about which ones they can choose from. There will always be user preference when it comes to making the choice, but we want to make sure to give all the options. This is the first step in choosing a level device for your application.

Under best practice, we explain if there are any special considerations for the different technologies. This can be which model to choose, different options in the model code, how to best install it and so on.

Best practice does not tell you what technology to choose, but gives information on what to keep in mind for the different choices.

Boiler system

4.1 Boiler drum level control

4.1.1 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. If the level is higher than the set-point, wet steam may be carried over to turbine which damages the turbine blades. In either case, the system will trip if hi or low level set points are reached.

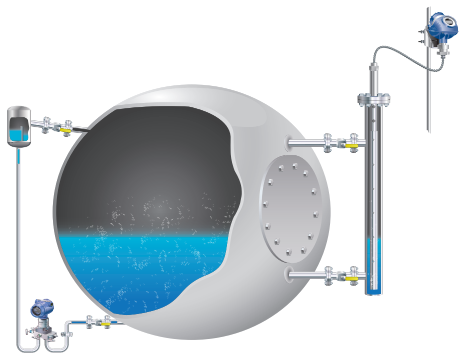


Figure 4.1.1: Boiler drum level control with differential pressure and guided wave radar

4.1.2 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

4.1.3 Suitable technologies

Technology	Installation guidelines in chapter:
Guided wave radar	5
Differential pressure	7
Float switch	9
Hydrastep	10

4.1.4 Best practice

Redundant measurements are required for safety. Guided wave radar and differential pressure can both be used, in conjunction with hydrastep, to create a triple layered safety solution. Hydrastep can be used for low level trip protection while GWR or DP are used for continuous level. Float switches can be used for high and low level alarms.

Guided wave radar

- Use Rosemount 5300 Series GWR with high temperature, high pressure seal (Model code: H) specially designed Dynamic Vapor Compensation (DVC) probe with a reference reflector for dynamic compensation (Model code: 3V, 4V), *for details on dynamic vapor compensation see section 5.18*
- The GWR is recommended to be mounted in a 3, or 4 - in. (75 or 100 mm) diameter bypass chamber with flanges appropriately sized for the pressure and temperature of the application
- Materials used for the chamber should meet boiler code requirements and the chamber should be isolated directly from the boiler by valves
- Chambers and the piping to the chambers should be insulted to maintain the temperature between the vessel and the chamber
- Use remote electronics housing connection to keep electronics at suitable ambient temperature. *See Rosemount 5300 Product Data Sheet for details*
- In applications above 2610 psi (180 bar) use DP transmitter
- Include SIL option (QS with HART, 4-20 output (option H)) if SIS installation

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
- For SIL suitable prior use installations use the QS option code with either the 3051S or 3051 transmitters. For SIL 2 certified installations use the QT option with the 3051S or 3051 Enhanced transmitters

4.2 Boiler drum level indication

4.2.1 Primary function of application

Visual indication of drum level is an important safety check. Having an independent indication from the continuous level adds extra protection against low water level.

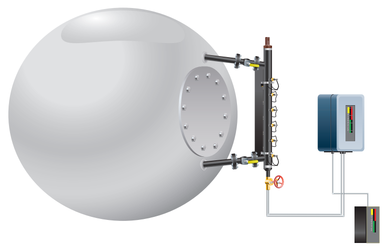


Figure 4.2.1: A Hydrastep system on a boiler drum

4.2.2 Application characteristics and challenges

- High pressure and temperature
- There are limited options for getting a visual signal to a remote location

4.2.3 Suitable technologies

Technology	Installation guidelines in chapter:
Hydrastep	10

4.2.4 Best practice

- Use Hydrastep in conjunction with the existing level measurement and control system
- Hydrastep offers protection for low level trips

- Chambers and the piping to the chambers should be insulted to maintain the temperature between the vessel and the chamber.

4.3 High pressure (HP) feedwater heater

4.3.1 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.

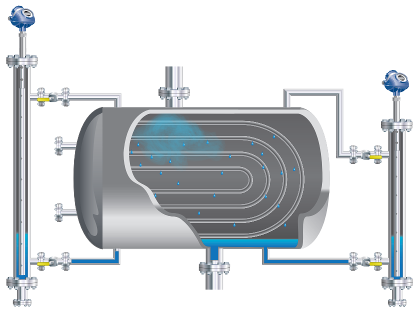


Figure 4.3.1: Feedwater heater level with long and short range installation of external chamber

4.3.2 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

4.3.3 Suitable technologies

Technology	Installation guidelines in chapter:
Guided wave radar	5
Differential pressure	7
Vibrating fork switch	9
Float switch	9
Hydrastep	10

4.3.4 Best practice

Redundant measurements are required for safety. One unit is used for level measurement control while the other is a back-up measurement and may be used for alarm purposes.

Guided wave radar

- Use Rosemount 5300 Series GWR with high temperature, high pressure seal (Model code: H) specially designed Dynamic Vapor Compensation (DVC) probe with a reference reflector for dynamic compensation (Model code: 3V, 4V), *for details on dynamic vapor compensation see section 5.18*
- The GWR is recommended to be mounted in a 3, or 4 - in. (75 or 100 mm) diameter bypass chamber with flanges appropriately sized for the pressure and temperature of the application
- Short range installation is recommended, *see figure 4.3.1*
- Materials used for the chamber should meet boiler code requirements and the chamber should be isolated directly from the HP heater by valves
- Chambers and the piping to the chambers should be insulted to maintain the temperature between the vessel and the chamber
- Use remote electronics housing connection to keep electronics at suitable ambient temperature. *See Rosemount 5300 product data sheet for details*
- Include SIL option (QS with HART, 4-20 output (option H)) if SIS installation

Differential pressure

- Use a wet leg system if temp is over 600°F (316°C), Tuned system with high temperature fill fluid for heaters less than 600°F (316°C)
- For SIL suitable prior use installations use the QS option code with either the 3051S or 3051 transmitters. For SIL 2 certified installations use the QT option with the 3051S or 3051 Enhanced transmitters

Switches

- 2130 or 2160 is recommended as these switches can be used for temperatures up to 500°F (260°C) . Since they have no moving parts, maintenance is minimized and reliability is increased

- Float switches can be used for higher temperature applications

4.4 Low pressure (LP) feedwater heater

4.4.1 Primary function of application

Feedwater heaters are staged to gradually increase pressure and temperature of the water prior to the boiler by transferring heat from steam into the feedwater. Control of feedwater heater level can impact overall plant efficiency. Redundant measurements are required for safety.

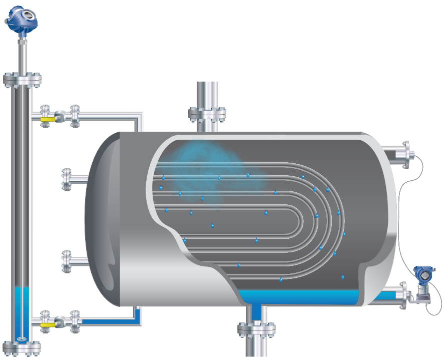


Figure 4.4.1: Low pressure feedwater heater with guided wave radar and tuned system DP level

4.4.2 Application characteristics and challenges

- The first low pressure heater in the series may be under vacuum, but may need to meet design requirements for high pressure conditions

4.4.3 Suitable technologies

Technology	Installation guidelines in chapter:
Guided wave radar	5
Differential pressure	7
Vibrating fork switch	9
Float switch	9
Hydrastep	10

4.4.4 Best practice

Redundant measurements are required for safety.

Guided wave radar

- Use 5300 with standard process seal (option S) single rigid probe (option 4A) with centering disk
- Include SIL option (QS with HART, 4-20 output (option H)) if SIS installation
- The GWR is recommended to be mounted in a 3, or 4 - in. (75 or 100 mm) inner diameter bypass chamber with flanges appropriately sized for the pressure and temperature of the application
- Chambers and the piping to the chambers should be insulted to maintain the temperature between the vessel and the chamber

Differential pressure

- Use a tuned system
- For SIL suitable prior use installations use the QS option code with either the 3051S or 3051 transmitters. For SIL 2 certified installations use the QT option with the 3051S or 3051 Enhanced transmitters

4.5 Steam separators (once through systems)

4.5.1 Primary function of application

A steam separator is used to knock out the water in the generated steam to produce a consistent and high quality steam. Measurement of the steam separator condensate level is used to control the water level in the steam separator. If water level is too high, mechanisms used to knock and keep the water out of the steam may be defeated resulting in lower quality steam. If water level is too low, the system is running at low efficiency and the concentration of the water may increase causing scaling and other issues.

4.5.2 Application characteristics and challenges

- High pressure and temperature equipment required
- Density and dielectric of steam increase as pressure and temperature increase
- Density and dielectric of liquid decrease as pressure and temperature increase

- 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

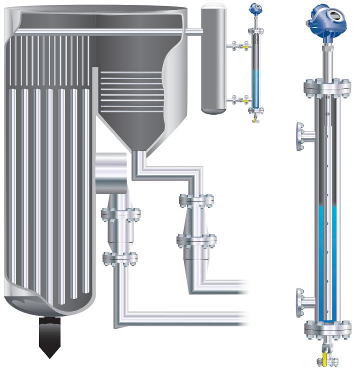


Figure 4.5.1: Steam separator with guided wave radar

4.5.3 Suitable technologies

Technology	Installation guidelines in chapter:
Guided wave radar	5
Differential pressure	7
Float switch	9
Hydrastep	10

4.5.4 Best practice

Guided wave radar

- Use Rosemount 5300 Series GWR with high temperature, high pressure seal (Model code: H) specially designed Dynamic Vapor Compensation (DVC) probe with a reference reflector for dynamic compensation (Model code: 3V, 4V), *for details on dynamic vapor compensation see section 5.18*
- The GWR is recommended to be mounted in a 3, or 4 - in. (75 or 100 mm) diameter bypass chamber with flanges appropriately sized for the pressure and temperature of the application
- Materials used for the chamber should meet boiler code requirements and the chamber should be isolated with valves
- Use remote electronics housing connection to keep electronics at suitable ambient temperature. *See Rosemount 5300 Product Data Sheet for details*

Differential pressure

- Use a wet leg system

4.6 Boiler blowdown tanks

4.6.1 Primary function of application

This tank receives blowdown water from the boiler and may serve as drain when the steam generator is drained for maintenance. Too much blowdown from the boiler wastes both energy and chemicals used to treat the boiler water. Level measurement is needed to provide a safe boiler blowdown system.

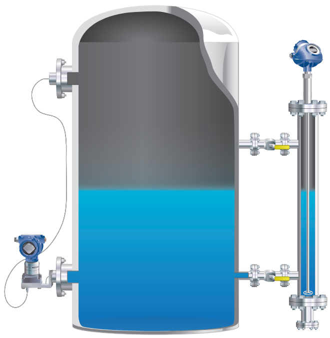


Figure 4.6.1: Boiler blowdown tank with tuned system DP level and guided wave radar

4.6.2 Application characteristics and challenges

- Reduction in pressure causes flashing of steam and density changes. Water may contain sludge/particulates

4.6.3 Suitable technologies

Technology	Installation guidelines in chapter:
Guided wave radar	5
Differential pressure	7
Vibrating fork switch	9
Float switch	9

4.6.4 Best practice

Guided wave radar

- Use 5300 guided wave radar with high temperature, high pressure seal (option H) with single lead probe (option 4A)
- The use of a single rigid probe eliminates issues with buildup of magnetite or other deposits
- A centering disk will keep the probe centered in the chamber (option S3 or S4)
- The GWR is recommended to be mounted in a 3, or 4 - in. (75 or 100 mm) diameter bypass chamber with flanges appropriately sized for the pressure and temperature of the application

Differential pressure

- Use a tuned system with high temperature fill fluid

Switches

- Float switch
- 2130 vibrating fork switch (high temp)

4.7 Flash / surge tanks

4.7.1 Primary function of application

Collection point for condensate drain lines.

4.7.2 Application characteristics and challenges

- Reduction in pressure causes flashing of steam and density changes
- Magnetite buildup may occur

4.7.3 Suitable technologies

Technology	Installation guidelines in chapter:
Guided wave radar	5
Differential pressure	7
Vibrating fork switch	9
Hydratect	10

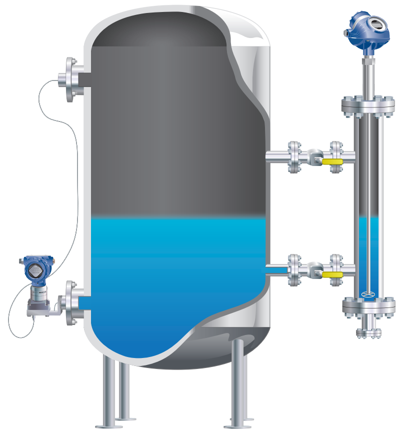


Figure 4.7.1: Flash tank level with tuned system DP level and guided wave radar

4.7.4 Best practice

Hydratect detection systems are commonly used in smaller condensate pots. For larger flash surge tanks, GWR or DP with turned systems can be used for continuous level measurements.

Guided wave radar

- Use 5300 guided wave radar with high temperature, high pressure seal (option H) with single lead probe (option 4A)
- The use of a single rigid probe eliminates issues with buildup of magnetite or other deposits
- A centering disc will keep the probe centered in the chamber (option S3 or S4)
- The GWR is recommended to be mounted in a 3 or 4 - in. (75 or 100 mm) diameter bypass chamber with flanges appropriately sized for the pressure and temperature of the application

Differential pressure

- Use a tuned system with high temperature fill fluid

Switches

- Float switch
- Use a 2130 vibrating fork switch

4.8 Condenser hotwell

4.8.1 Primary function of application

As the steam passes the final stages of the turbine, the steam is cooled in a condenser and converted back into liquid water. The condensed water collects in the hotwell of the condenser. The water is then pumped back into the boiler as feedwater. Low levels would trigger makeup water to enter system from storage. A high level would divert excess water to condensate storage. By regulating condensate level control, steam extraction from turbine can be optimized to match changes in load conditions faster. Accurate condenser level control ensures continuous feedwater to boiler.

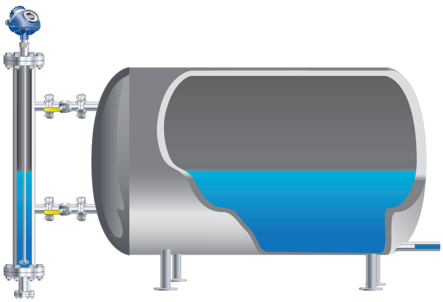


Figure 4.8.1: Condenser hotwell with guided wave radar

4.8.2 Application characteristics and challenges

- Vacuum is created during condensation process
- Drop in pressure can result in both vibration and large density changes of the liquid

4.8.3 Suitable technologies

Technology	Installation guidelines in chapter:
Guided wave radar	5
Vibrating fork switch	9
Float switch	9

4.8.4 Best practice

Redundant measurements are required for safety.

<u>Guided wave radar</u>

- Use 5300 with standard process seal (option S) single rigid probe (option 4A) with centering disc
- The GWR is recommended to be mounted in a 3, or 4 - in. (75 or 100 mm) inner diameter bypass chamber with flanges appropriately sized for the pressure and temperature of the application

<u>Switches</u>

- Vibrating fork switches offer low maintenance options for high and low alarm points

4.9 Condensate storage

4.9.1 Primary function of application

Holds and stores excess condensate from the hotwell. Water from here becomes make-up water before any fresh water is added as it does not require additional water treatment. This saves on chemical costs.

4.9.2 Application characteristics and challenges

- Clean water
- Stable conditions

4.9.3 Suitable technologies

Technology	Installation guidelines in chapter:
Guided wave radar	5
Non-contacting radar	6
Differential pressure	7
Vibrating fork switch	9
Float switch	9

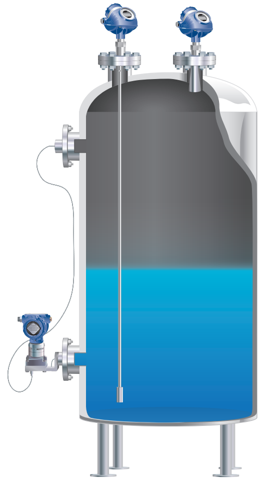


Figure 4.9.1: Condensate level with non-contacting, guided wave radar or tuned system DP level

4.9.4 Best practice

<u>Non-contacting or guided wave radar</u>

- Use 5400 non-contacting radar with a standard cone antenna (option 2S, 3S or 4S) or a 5300 guided wave radar with flexible single probe with weight (option 5A)
- Both types of devices can be mounted on a flanged nozzle following nozzle guidelines in *section 5.6 for GWR and 6.4 for non-contacting radar*

<u>Differential pressure</u>

- Tuned system with direct mount on bottom connection

4.10. Deaerator

4.10.1 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.

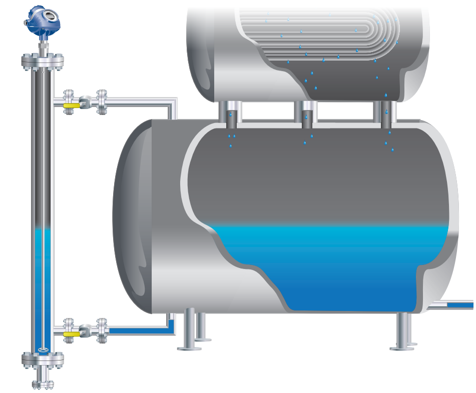


Figure 4.10.1: Deaerator level with guided wave radar

4.10.2 Application characteristics and challenges

- Fluctuating temperatures and pressure
- Operating pressure is low and may go under vacuum
- Flashing of steam is common
- Density changes of water can occur

4.10.3 Suitable technologies

Technology	Installation guidelines in chapter:
Guided wave radar	5
Vibrating fork switch	9
Float switch	9
Hydrastep	10

4.10.4 Best practice

Guided wave radar

- Use 5300 with standard process seal (option S) single rigid probe (option 4A) with centering disk
- Include SIL option (QS with HART, 4-20 output (option H)) if SIS installation
- The GWR is recommended to be mounted in a 3, or 4 - in. (75 or 100 mm) inner diameter bypass chamber with flanges appropriately sized for the pressure and temperature of the application

Differential pressure

- Use a tuned system
- For SIL suitable prior use installations use the QS option code with either the 3051S or 3051 transmitters. For SIL 2 certified installations use the QT option with the 3051S or 3051 enhanced transmitters

Turbines

4.11 Gland steam condenser

4.11.1 Primary function of application

The gland steam condenser collects steam from the sealed turbine shaft. Once captured, the steam is condensed and returned with the other condensate.

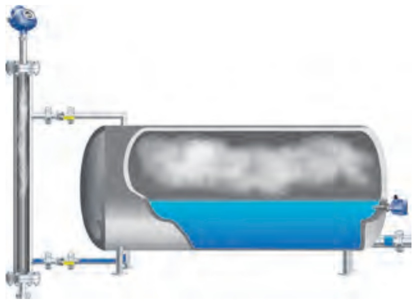


Figure 4.11.1: Gland steam condenser level with guided wave radar and vibrating fork switch

4.11.2 Application characteristics and challenges

- Steam vapors
- Density changes
- Pressure drops from turbine conditions to low pressure will create water condensation

4.11.3 Suitable technologies

Technology	Installation guidelines in chapter:
Guided wave radar	5
Vibrating fork switch	9
Float switch	9

4.11.4 Best practice

Guided wave radar

- Use 5300 with high temperature, high pressure seal (option H) with single rigid probe (option 4A) with centering disc (option Sx)
- Mount in 3 or 4" bypass chamber and insulate

4.12 Lubrication oil tanks

4.12.1 Primary function of application

Rotating equipment such as turbines must be kept well lubricated to avoid damage due to friction. Heat is generated in the turbines and oil is used to help cool it. An adequate supply must be available at all times for turbines and generator bearings. On larger vessels, continous monitoring of supply is important. Tanks are monitored to prevent overfill as well as leakage.

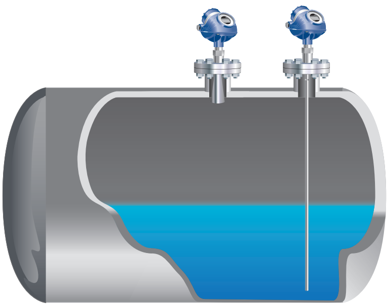


Figure 4.12.1: Lubrication oil level with non-contacting or guided wave radar

4.12.2 Application characteristics and challenges

- Size of tanks vary widely which may impact technology choice
- Low dielectric constant, but clean fluid
- Switches are integral for backup

4.12.3 Suitable technologies

Technology	Installation guidelines in chapter:
Guided wave radar	5
Non-contacting radar	6
Differential pressure	7
Hydrostatic	7
Ultrasonic	8
Vibrating fork switch	9

4.12.4 Best practice

Guided wave and non-contacting radar

- Use either 5300 guided wave radar with single rigid (option 4A) or flexible probe (option 5A) or 5402 non-contacting radar with standard cone antenna (option 2S, 3S, or 4S)
- Tank sizes may vary, use 5400 non-contacting radar on larger tanks over 10 ft. (3 m) (user preference)
- Direct mounting into vessel following nozzle guidelines in *section 5.6 for GWR and 6.4 for non-contacting radar*
- Alternative:
  - o A 5300 guided wave radar with coaxial probe (option 3B) may be used if mounting area is restricted due to nearby obstacles or long narrow nozzles
  - o Coaxial probes should only be used with clean fluids

Hydrostatic

- Possible to use hydrostatic if vessel is at ambient conditions

4.13 Hydraulic oil tanks

4.13.1 Primary function of application

Maintains adequate oil level for hydraulic actuators for critical turbine control and safety valves.

Figure 4.13.1: Hydraulic oil tanks with guided wave radar, non-contacting radar and vibrating fork switch.

4.13.2 Application characteristics and challenges

- Hydraulic oil is clean, low dielectric fluid
- Vessels tend to be small

4.13.3 Suitable technologies

Technology	Installation guidelines in chapter:
Guided wave radar	5
Non-contacting radar	6
Differential pressure	7
Ultrasonic	8
Vibrating fork switch	9

4.13.4 Best practice

<u>Guided wave and non-contacting radar</u>

- Use either 5300 guided wave radar with single rigid (option 4A) or flexible probe (option 5A) or 5402 non-contacting radar with standard cone antenna (option 2S, 3S, or 4S)
- Tank sizes may vary, use 5400 non-contacting radar on larger tanks over 10 ft. (3 m) (user preference)
- Direct mounting into vessel following nozzle guidelines in *section 5.6 for GWR and 6.4 for non-contacting radar*
- Alternative:
  - o A 5300 guided wave radar with coaxial probe (option 3B) may be used if mounting area is restricted due to nearby obstacles or long narrow nozzles
  - o Coaxial probes should only be used with clean fluids

<u>Differential pressure</u>

- Use a tuned system

4.14 Steam bleed / extraction lines / condensate drip legs (TWIP)

4.14.1 Primary function of application

Steam will start to condense as soon as it leaves the boiler. Condensate pots and traps are strategically located along the steam lines to collect any condensate and return it to the condenser. This prevents condensed water from hitting the fast moving turbines.

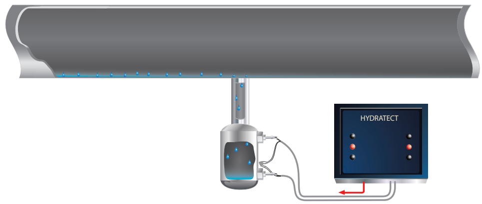


Figure 4.14.1: Condensate drip legs with Hydratect

4.14.2 Application characteristics and challenges

- Small and limited space for instruments
- Equipment must handle the high temperature and pressure

4.14.3 Suitable technologies

Technology	Installation guidelines in chapter:
Vibrating fork switch	9
Float switch	9
Hydratect	10

4.14.4 Best practice

- Condensate drip lines will slowly fill with water and must be emptied. A Hydratect system will detect the presence of this water under high temperature and pressure conditions
- Vibrating forks could be used where temperatures are less than 500 °F (260 °C)

Water supply and pretreatment

4.15 Demineralization system / chemical storage

4.15.1 Primary function of application

The function of the demineralization plant is to treat the raw river or sea water and make it suitable for steam generation. The process requires a series of filtration and chemical treatments to deliver clean high quality feedwater for the boilers. Water treatment and waste water disposal system requires a precise and accurate chemical process to deliver the desired compositions. The raw water and chemical handling require special materials for longer service life. Acid and alkali chemicals are toxic and any spillage causes operational and safety hazards.

Figure 4.15.1: Chemical storage level with non-contacting and ultrasonic

4.15.2 Application characteristics and challenges

- Chemical storage vessels may contain corrosive materials
- Chemical storage may include: sodium hypochlorite, brine, antifoam, caustic, acid, hydrazine, and phosphate solutions
- Vessels are usually vented or at minimal pressure conditions

4.15.3 Suitable technologies

Technology	Installation guidelines in chapter:
Guided wave radar	5
Non-contacting radar	6
Differential pressure	7
Ultrasonic	8
Vibrating fork switch	9
Float switch	9

4.15.4 Best practice

- Consider material compatibility
    - o PTFE or exotic material solutions are available
- Top-down connections:
    - o 5400 non-contacting radar
    - o 3300/3308/5300 guided wave radar
        - – If tanks are non-metal, use 5300
    - o 3100 Ultrasonic transmitter
- Level switches for overfill prevention or pump protection

4.16 Intake water screens

4.16.1 Primary function of application

Raw water is taken from water reservoir or river. Water intake requires removal of biological impurities and debris. Intake water passes through screens or filter to remove debris. Measurements are taken on both sides of screen to monitor clogging of screens.

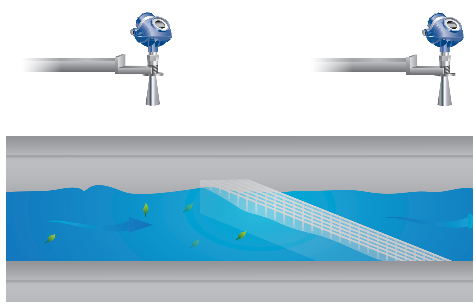


Figure 4.16.1: Non-contacting radar mounted over water flow with intake water screens.

4.16.2 Application characteristics and challenges

- Depending on the access for mounting, this may be a long range application
- Raw water application which may be turbulent
- Upstream side may have floating debris
- Top-down measurement

4.16.3 Suitable technologies

Technology	Installation guidelines in chapter:
Non-contacting radar	6
Hydrostatic	7
Ultrasonic	8

4.16.4 Best practice

Non-contacting radar

- Use 5401 with standard cone antenna, 6" or 8" (option 6S or 8S)
- Direct flange connection or bracket mounting (option BR)

Ultrasonic

- An ultrasonic transmitter such as the 3102 or 3105 can be used for shorter range applications (< 30 ft (9 m)) and where ambient conditions are mild

Controller

- The 3490 controller can be used with either the radar or ultrasonic transmitter to calculate the level differential and trigger an alarm

4.17 Rock salt

4.17.1 Primary function of application

Salt is used in the demineralization process.

Figure 4.17.1: Rock salt level with non-contcting or guided wave radar

4.17.2 Application characteristics and challenges

- May be heavy
- Dusty

4.17.3 Suitable technologies

Technology	Installation guidelines in chapter:
Guided wave radar	5
Non-contacting radar	6

4.17.4 Best practice

Guided wave and non-contacting radar

- Use 5300 guided wave radar with thicker flexible probe (option 6A) for vessels less than 50 ft (15 m)
    - o Direct mount with free hanging probe
- Use 5600 for non-contacting, with parabolic (option 45S) or 8" cone antenna (option 28S)

4.18 Brine tank

4.18.1 Primary function of application

Purpose of the application is to supply highly concentrated brine solution for the demineralization system. The salt must level must monitored to determine when fresh salt is needed.

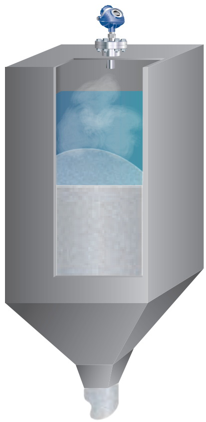


Figure 4.18.1: Brine tank with non-contacting or ultrasonic

4.18.2 Application characteristics and challenges

- Water over pile of salt
- Corrosive

4.18.3 Suitable technologies

Technology	Installation guidelines in chapter:
Non-contacting radar	6
Ultrasonic	8

4.18.4 Best practice

- Non-contacting radar or ultrasonic to measure water level

4.19 Boric acid, heavy water & make-up water

4.19.1 Primary function of application

Boric acid

Boric acid is used in the safety injection system to treat water going into reactor.

Heavy water

Nuclear plants require special heavy water as coolant which requires open storage in sumps.

Make up water

Demineralized water is stored in the tanks which supplies make-up water in condensate system. Treated, clean make-up water must be available at all times. System shutdown can occur if no make-up water is available.

Figure 4.19.1: Water and boric acid storage with a non-contacting radar

4.19.2 Application characteristics and challenges

- Clean water
- Water: high dielectric material; stable density

4.19.3 Suitable technologies

Technology	Installation guidelines in chapter:
Guided wave radar	5
Non-contacting radar	6
Differential pressure	7
Hydrostatic	7
Ultrasonic	8
Vibrating fork switch	9
Float switch	9

4.19.4 Best practice

- For top mount connections 2", 3", or 4", use Rosemount 5402 non-contacting radar with standard cone antenna (option xS)
- Or use 5401 with standard cone antenna, 6" or 8" (option 6S or 8S)
- Consider an ultrasonic transmitter Rosemount 3102 or 3105 if the nozzle is more than 3" diameter
- Direct mount
- Mount according to nozzle guidelines in *section 6.4 for non-contacting radar or section 8.1.2 for ultrasonic*
- For sided mounted connections use tuned system DP level

Cooling system

4.20 Closed cooling water tanks

4.20.1 Primary function of application

Generator oil and hydrogen are continually circulated and cooled via heat exchanger with cooling water. A supply of water must be kept on hand. Hydrogen cooling and oil cooling systems must be controlled closely and accurately to ensure that the turbine/generator set are operated continuously and efficiently. Without oil and hydrogen cooling, turbine bearings may cease and generator stator winding could be overheated causing permanent damage.

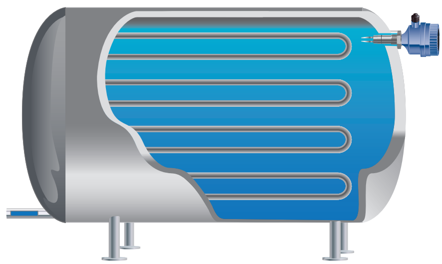


Figure 4.20.1: Closed cooling water tanks with vibrating fork switch to ensure adequate water level

4.20.2 Application characteristics and challenges

- Clean fluid
- Small vessels, limited access
- The access point may be limited which will impact technology choice

4.20.3 Suitable technologies

Technology	Installation guidelines in chapter:
Vibrating fork switch	9
Float switch	9

4.20.4 Best practice

- Vibrating fork switches can be used to detect when level drops below the desired fill level
- Use compact vibrating fork switches to fit into small connections

4.21 Cooling tower basin

4.21.1 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 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.

4.21.2 Application characteristics and challenges

- Water which can become foamy due to chemical additions for build-up of algae, leaves or similar debris
- Usually a top-down measurement

4.21.3 Suitable technologies

Technology	Installation guidelines in chapter:
Guided wave radar	5
Hydrostatic	7
Vibrating fork switch	9
Float switch	9

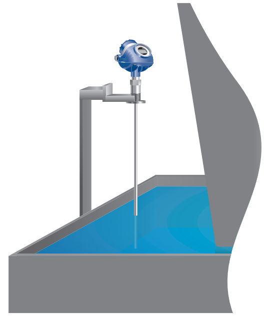


Figure 4.21.2: A guided wave radar transmitter installed with a foam dam on a cooling tower

4.21.4 Best practice

Guided wave radar

- Use GWR with single rigid probe (option 4A)
- Bracket mounting (option BR with a 1 1/5" NPT process connection (option RA))
- If unit is to be mounted so that it will be rained on, consider the use of a remote mount housing connection
- Alternative:
    - o For foamy applications, use a foam dam around the device, or a large diameter metallic stilling well

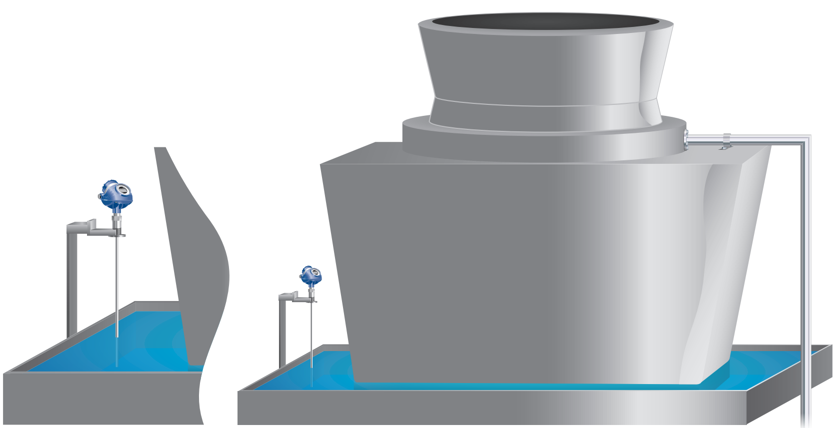


Figure 4.21.1: Cooling tower basin level with guided wave radar; overview and close-up

4.22 Refrigerants

4.22.1 Primary function of application

Freon, glycol and other refrigerants are used in the chillers to help cool the condenser.

Figure 4.22.1: Measuring level on refrigerants with guided wave radar

4.22.2 Application characteristics and challenges

- Cold conditions
- Some refrigerants (such as freon) may be turbulent as it goes through phase changes due to pressure changes

4.22.3 Suitable technologies

Technology	Installation guidelines in chapter:
Guided wave radar	5
Differential pressure	7

4.22.4 Best practice

Guided wave radar

- Use 5300 with coaxial probe (option 3B) if mounted inside vessel
- Use single probe (option 4A or 4B) if mounted in chamber
- Insulate chamber, up to about 4 inches (100 mm) above flange
- If the process temperature will be less than -76°F (-60°C), then the use of a 5300 with a cryogenic process seal (option C) is recommended. This unit includes special welds that can withstand temperatures as low as -321°F (-196°C)

Fuel supply

4.23 Fuel oil storage

4.23.1 Primary function of application

Low density oil or bunker fuel is used as secondary fuel source in boilers and heat-recovery steam generator (HRSG). The function of the fuel oil handling system is to unload, safely store, and deliver the fuel oil to boiler burners at adequate pressure for start-up and peak load firing needs. Storage of fuel oil must be monitored for inventory/supply.

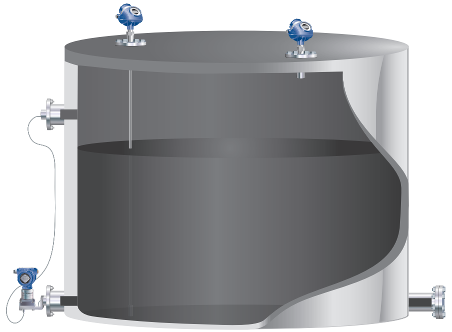


Figure 4.23.1: Fuel oil level with guided wave radar, non-contacting radar, or tuned system DP.

4.23.2 Application characteristics and challenges

- Fuel oil is clean, but density may vary with new supply

4.23.3 Suitable technologies

Technology	Installation guidelines in chapter:
Guided wave radar	5
Non-contacting radar	6
Differential pressure	7
Vibrating fork switch	9
Float switch	9

4.23.4 Best practice

Non-contacting radar

- Use non-contacting radar installed directly into the tank according to nozzle guidelines in section 6.4
- Use 5402 with a 4" cone antenna (option 4S) for tanks up to 66 ft (20 m). For vessels larger than 66 ft (20 m) use the 5600 with a 6" or 8" cone anten na
- For non-contacting radar, use standard cone antenna, following antenna guidelines in *section 6.1*

Guided wave radar

- For GWR, single flexible probe (option 5A) may be used for vessels up to 115 ft (35 m). Follow nozzle guidelines on in *section 5.6*
- Use the 5301 GWR, with standard seal (option S) and a flexible probe (option 5A) directly mounted at top

Differential pressure

- Use a tuned system

4.24 Natural gas separators

4.24.1 Primary function of application

Removal of condensed (liquid) gas in the natural gas separators is necessary to increase gas turbine life.

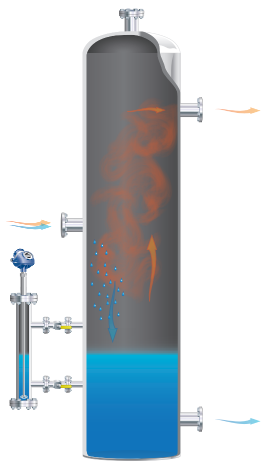


Figure 4.24.1: Natural gas separator with guided wave radar in an external chamber

4.24.2 Application characteristics and challenges

- Clean gas and fluid
- Pressurized
- Vessel is normally empty or has very low levels of condensed liquid under good operating condtions
- Low dielectric hydrocarbons

4.24.3 Suitable technologies

Technology	Installation guidelines in chapter:
Guided wave radar	5

4.24.4 Best practice

Guided wave radar

- Use 5300 with single rigid probe (option 4A or 4B) with centering disc. Either PTFE or SST centering discs (option Px or Sx) could be used
- Mount in chamber following guidelines *in section 5.11*
- Insulate
- Use the high pressure seal (option P) if vessel pressure exceeds 580 psi (40 bar)

4.25 Coal crusher hopper

4.25.1 Primary function of application

Coal conveying should be handled accurately so that it does not cause any overfill and spillage. Any overfill is unsafe and causes fire hazards in the area and may cause a plant outage.

4.25.2 Application characteristics and challenges

- Continuous feed of solid coal to coal crusher with very big coal rocks, narrow measuring range
- Can be dusty, but often sprayed with water to minimize static charge
- This is considered a hazardous area due to risk of explosions

Figure 4.25.1: Coal crusher hopper with non-contacting or guided wave radar

4.25.3 Suitable technologies

Technology	Installation guidelines in chapter:
Guided wave radar	5
Non-contacting radar	6

4.25.4 Best practice

Non-contacting radar

- Use 5600 non-contacting radar with parabolic antenna (option 45S)
- For coal applications, no PTFE bag should be used
- Start-up service is strongly recommended when using the 5600 in solids applications. Contact your local Emerson representative for details

4.26 Coal mill supply silo (bunker)

4.26.1 Primary function of application

Coal from coal handling is filled in coal silos which maintains feed to coal mills. Coal consumption in boiler is maintained by these bunkers. A continuous supply of coal is maintained to the burners.

Figure 4.26.1: Coal bunker level with non-contacting radar

4.26.2 Application characteristics and challenges

- Can be dusty, but often sprayed with water to minimize static charge

4.26.3 Suitable technologies

Technology	Installation guidelines in chapter:
Guided wave radar	5
Non-contacting radar	6

4.26.4 Best practice

Non-contacting and guided wave radar

- Use 5600 non-contacting radar with parabolic antenna (option 45S)
- For coal applications, no PTFE bag should be used

- Start-up service is strongly recommended when using the 5600 in solids applications. Contact your local Emerson representative for details
- Alternative:
  - o Use 5300 guided wave radar with thicker flexible probe (option 6A)

4.27 Coal stack pile & other fuel sources (bark, garbage)

4.27.1 Primary function of application

- After being crushed, coal is stacked in open stack pile. The stacker should limit the pile height through continuous level measurement. This is raw material storage; plant must have adequate supply at all times. Coal stack piles are also monitored for any self-ignited fires
- Monitor fuel inventory to assure adequate supply

Figure 4.27.1: A non-contacting radar transmitter installed over a coal stack pile

4.27.2 Application characteristics and challenges

- Can be dusty, but often sprayed with water to minimize static charge
- Heavy material that can have multiple reflections

4.27.3 Suitable technologies

Technology	Installation guidelines in chapter:
Non-contacting radar	6

4.27.4 Best practice

Non-contacting radar

- Use 5600 non-contacting radar with parabolic antenna (option 45S)
- For coal applications, no PTFE bag should be used
- Start-up service is strongly recommended when using the 5600 in solids applications. Contact your local Emerson representative for details

Fuel combustion/cleanup

4.28 Ammonia, anhydrous

4.28.1 Primary function of application

Used for neutralization of flue gases. Flue gas in coal contains NOx which needs to be removed by adding ammonia in a honey comb-like structure.

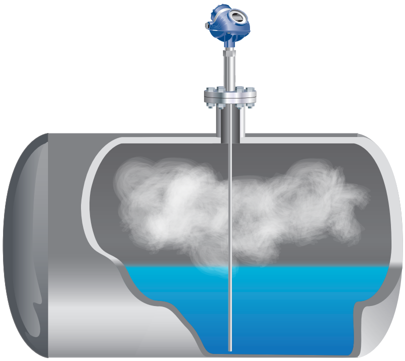


Figure 4.28.1: Ammonia level with guided wave radar

4.28.2 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

4.28.3 Suitable technologies

Technology	Installation guidelines in chapter:
Guided wave radar	5
Vibrating fork switch	9
Float switch	9

4.28.4 Best practice

Guided wave radar

- Use 5301 with single rigid (option 4A) or flexible probe (option 5A) or coaxial probe (option 3B) depending on size of vessel
- Mount directly in tank
- In anhydrous ammonia applications, it is recommended that the high pressure tank seal, (option P) should be used, as no o-rings are present
- Heavy vapors attenuate the radar signal and can affect the measuring range
- *For further information, see section 5.17*
- Alternative:
  - o If an isolation valve is required, then DP is suitable, but subject to errors due to density changes

4.29 Ammonia, aqueous

4.29.1 Primary function of application

Used for neutralization of flue gases. Flue gas in coal contains NOx which needs to be removed by adding ammonia in a honey comb-like structure.

Figure 4.29.1: Ammonia (aqueous) level with non-contacting radar

4.29.2 Application characteristics and challenges

- Aqueous ammonia is stabilized by the presence of water so density changes are not as common as with anhydrous ammonia
- Light vapors are present

4.29.3 Suitable technologies

Technology	Installation guidelines in chapter:
Guided wave radar	5
Non-contacting radar	6
Differential pressure	7
Vibrating fork switch	9
Float switch	9

4.29.4 Best practice

Guided wave and non-contacting radar

- Use 5301 with single rigid (option 4A) or flexible probe (option 5A) or coaxial probe (option 3B) depending on size of vessel
- Or use a 5401 with standard cone antenna
- Mount directly in tank
- *For further information, see section 5.17*
- Alternative:
  - o If an isolation valve is required, then DP is suitable or the 5402 with a process seal antenna may be used

4.30 Ash slurry, lime slurry or liquid gypsum

4.30.1 Primary function of application

- The fly ash is mixed with raw water and pumped as a slurry to retaining pond
- Limestone is mixed with raw water to make lime slurry which is sprayed as fine droplets into the exhaust gas in a spray tower
- Liquid gypsum (calcium sulfate) is a byproduct of neutralization of SO'x with lime to remove sulfur in flue gas

4.30.2 Application characteristics and challenges

- Dusty
- Turbulent

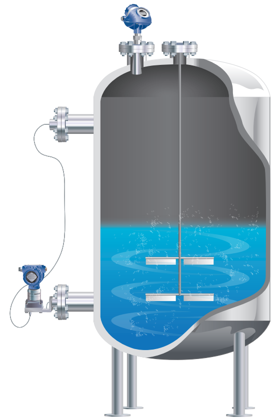


Figure 4.30.1: Ash and lime slurry with non-contacting rador or tuned system DP level with extended seals.

4.30.3 Suitable technologies

Technology	Installation guidelines in chapter:
Non-contacting radar	6
Differential pressure	7
Vibrating fork switch	9

4.30.4 Best practice

Non-contacting radar

- Use 5400, direct mount with standard cone antenna (option xS)
- The 5400 should be mounted where it is not directly over the agitator blades
- The 5400 can be mounted close to the wall of the vessel

Differential pressure

- Use a tuned system with extended (EFW) seals to reduce coating in recessed areas. The face of the diaphragm seals should be flush with the tank wall

4.31 Sulfur solution tanks

4.31.1 Primary function of application

Collection vessel for sulfur solution from scrubbers after treatment with gypsum.

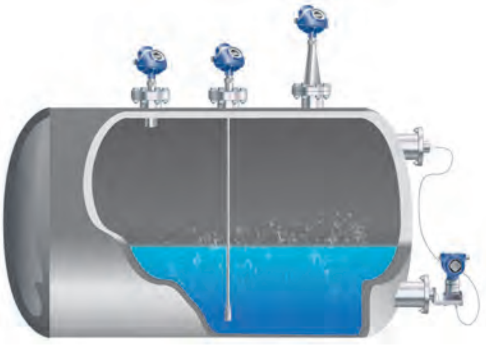


Figure 4.31.1: Sulfur solution tank level with non-contacting radar, guided wave radar and tuned system DP level

4.31.2 Application characteristics and challenges

- The sulfur solution can be corrosive

4.31.3 Suitable technologies

Technology	Installation guidelines in chapter:
Guided wave radar	5
Non-contacting radar	6
Differential pressure	7

4.31.4 Best practice

Non-contacting radar

- Use 5400, direct mount with standard cone antenna (option xS)
- Or use 5402 with process seal antenna

4.32 Scrubbers

4.32.1 Primary function of application

Flue gas is cleaned by flowing through scubbers. Liquid levels must be maintained.

Figure 4.32.1: Scrubber level with guided wave radar in an external chamber

4.32.2 Application characteristics and challenges

- Fluid becomes corrosive
- May contain particulates

4.32.3 Suitable technologies

Technology	Installation guidelines in chapter:
Guided wave radar	5
Differential pressure	7

4.32.4 Best practice

Guided wave radar

- Use 5300 with single rigid probe (option 4A or 4B) with centering disk. Either PTFE or SST centering discs (option Px or Sx) could be used
- Mount in chamber following guidelines in *section 5.11*
- Insulate

4.33 Ash hopper - bottom ash or fly ash

4.33.1 Primary function of application

Ash hopper

Hoppers receive ash from the fly ash precipitators. Ash handling in the plant is a dusty process requiring very accurate handling. Any overfill and spillage can cause dust clouds in the plant and create operational hazards.

Bottom ash

Unburnt carbons from firebox settled at the bottom of boiler. It is quenched in water and disposed.

Fly ash

The dry fly ash is collected from bottom of electrostatic precipitator or baghouse hoppers and is stored in fly ash silo. The level of fly ash is monitored for inventory and disposal.

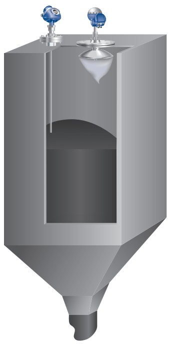


Figure 4.33.1: Ash hopper or fly ash with guided wave radar or non-contacting

Figure 4.33.2: Bottom ash with guided wave radar or non-contacting

4.33.2 Application characteristics and challenges

- Dusty solids
- Access for instrumentation may be limited
- Can be heavy and sticky
- Vapor space may be steamy

4.33.3 Suitable technologies

Technology	Installation guidelines in chapter:
Guided wave radar	5
Non-contacting radar	6

4.33.4 Best practice

Guided wave and non-contacting radar

- 5303 guided wave radar with single lead flexible probe (option 6A), free hanging, direct mount. Consult factory for assistance on pull force calculations if vessel height is over 50 ft (15 m)
- Alternative:
    - 5600 non-contacting radar – parabolic antenna (option 45S) for tanks higher than 20 ft (6 m) or 8" cone antenna (option 28S) for tanks less than 20 ft (6 m). Use PTFE bag on parabolic antenna to minimize dust
    - On 8" cone antenna, use flushing connection with an air purge to minimize dust buildup (option 98S). *See section 6.13 for further information*
    - Install according to guidelines in *section 6.13*
    - Start-up service is strongly recommended when using the 5600 in solids applications. Contact local Emerson representative for details

4.34 Lime silo

4.34.1 Primary function of application

Lime supply is needed for flue gas desulfurization. Sulfur in flue gas is removed by spraying lime slurry, and Limestone is used for creating lime slurry.

See figure 4.33.1: Ash hopper or fly ash with guided wave radar or non-contacting for illustration

4.34.2 Application characteristics and challenges

- Dusty solids measurement
- Lime can be very dense so taller vessels may require non-contacting radar

4.34.3 Suitable technologies

Technology	Installation guidelines in chapter:
Guided wave radar	5
Non-contacting radar	6

4.34.4 Best practice

<u>Guided wave and non-contacting radar</u>

- 5303 guided wave radar with single lead flexible probe (option 6A), free hanging, direct mount. Consult factory for assistance on pull force calculations if vessel height is over 50 ft (15 m)
- Alternative:
  - 5600 non-contacting radar – parabolic antenna (option 45S) for tanks higher than 20 ft (6 m) or 8” cone antenna (option 28S) for tanks less than 20 ft (6 m). Use PTFE bag on parabolic antenna to minimize dust
  - On 8” cone antenna, use flushing connection with an air purge to minimize dust buildup (option 98S). *See section 6.13 for further information*
  - Install according to guidelines in *section 6.13*
  - Start-up service is strongly recommended when using the 5600 in solids applications. Contact local Emerson representative for details

4.35 Powder activated carbon (PAC), combustion salt, bone meal, dried sludge

4.35.1 Primary function of application

- PAC attracts mercury to the fly ash to enhance its removal in baghouse or electrostatic precipitator
- By-product of combustion of non-coal fuel sources such as waste incineration
- Bone meal or dried sludge additives supplement solid fuels to enhance burning

Figure 4.35.1: Powder level with guided wave radar

4.35.2 Application characteristics and challenges

- Very light weight
- Solid
- Dusty material

4.35.3 Suitable technologies

Technology	Installation guidelines in chapter:
Guided wave radar	5

4.35.4 Best practice

<u>Guided wave radar</u>

- Use 5303 with flexible single lead probe (option 6A)
- Direct mounting, following nozzle guidelines in *section 5.6*

- In most cases, the probe can be free-hanging. An exception would be in cases where the fill and empty cycles causes significant probe movement. If that case, the probe should be anchored near the bottom where it can be kept away from obstacles
- Use probe-end projection function, *see section 5.16.2*
- *See section 5.16 for considerations for solid applications*

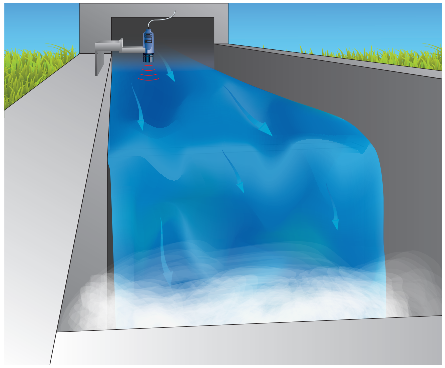
Effluent

4.36 Effluent flow

4.36.1 Primary function of application

Water discharge from power plants requires removal of impurities and datalogging to comply environmental regulations. Open channel flow is computed from the height of the liquid in a flow structure upstream of an obstruction.

Figure 4.36.1: Ultrasonic transmitter mounted above an open channel flow



4.36.2 Application characteristics and challenges

- Rapidly moving water
- Top down measurement

4.36.3 Suitable technologies

Technology	Installation guidelines in chapter:
Guided wave radar	5
Non-contacting radar	6
Ultrasonic	8

4.36.4 Best practice

Ultrasonic

- Ultrasonic with a 3490 controller
- This combination offers a number of equations for open channel flow configurations

4.37 Open atmosphere sumps

4.37.1 Primary function of application

Treated waste water or rain collection water is stored in open atmosphere sumps.

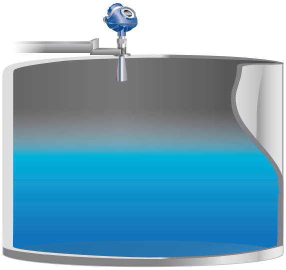


Figure 4.37.1: Open sump level with non-contacting radar

4.37.2 Application characteristics and challenges

- Water
- Top- down measurement

4.37.3 Suitable technologies

Technology	Installation guidelines in chapter:
Guided wave radar	5
Non-contacting radar	6
Hydrostatic	7
Ultrasonic	8

4.37.4 Best practice

Non-contacting radar

- Use 5401 with standard cone antenna, 6” or 8” (option 6S or 8S)
- Direct flange connection or bracket mounting (option BR)

4.38 Clarifiers

4.38.1 Primary function of application

Solids, dust, and biological wastes are removed in water clarifiers as part of water pre-treatment.

4.38.2 Application characteristics and challenges

- Two measurements are needed
- Sludge level is monitored to determine buildup of solids on the bottom of the clarifier
- Overall level is measured to maintain optimum efficiency

4.38.3 Suitable technologies

Technology	Installation guidelines in chapter:
Non-contacting radar	6
Ultrasonic	8
Sludge blanket	8

4.38.4 Best practice

- Two measurements
- Ultrasonic or non-contacting radar are good choices for overall level measurements. Both may be suspended over the surface with a bracket mount
- Ultrasonic sludge monitors can be used to detect the sludge buildup as it drops to the bottom of the clarifier

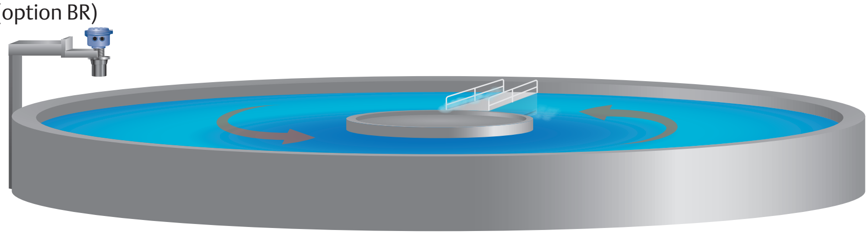


Figure 4.38.1: Ultrasonic transmitter mounted over a clarifier

Hydro power

4.39 Head & tail race

4.39.1 Primary function of application

Measuring the height of fluid levels going into and out of the hydro turbine. The difference between head race and tail race is called gross head. After correcting for frictional loss, this allows determination of net head pressure available to the turbine for generation of electricity and helps to measure hydro-turbine efficiency.

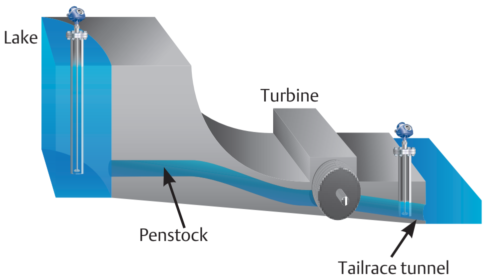


Figure 4.39.1: Head and tail race level with guided wave radar in stilling wells

4.39.2 Application characteristics and challenges

- Usually a top-down measurement
- Water
- Rapid movements - may need to be installed in stilling well to diminish turbulence

4.39.3 Suitable technologies

Technology	Installation guidelines in chapter:
Guided wave radar	5
Non-contacting radar	6

4.39.4 Best practice

Non-contacting and guided wave radar

- Use 5400 non-contacting radar with standard cone antenna in a size that matches the stilling well diameter or nozzle
  - o Can be installed directly in tank, or in stilling well
- Or use 5300 guided wave radar with standard seal (option S) and flexible probe (option 5A)
  - o Stilling well should be 4” or larger when using flexible probes
  - o The flexible probe should have a weight and a centering disk to pull probe taut. A heavier weight is available. (option code W3)

4.40 Leaky weir at bottom of dam

4.40.1 Primary function of application

Water head on two sides of penstock maintain the flow of water which moves hydro turbine.

4.40.2 Application characteristics and challenges

- Rapidly moving water
- Top down measurement

4.40.3 Suitable technologies

Technology	Installation guidelines in chapter:
Non-contacting radar	6
Ultrasonic	8

4.40.4 Best practice

Non-contacting radar

- Use 5401 with standard cone antenna, 6" or 8" (option 6S or 8S)
- Direct flange connection or bracket mounting (option BR)

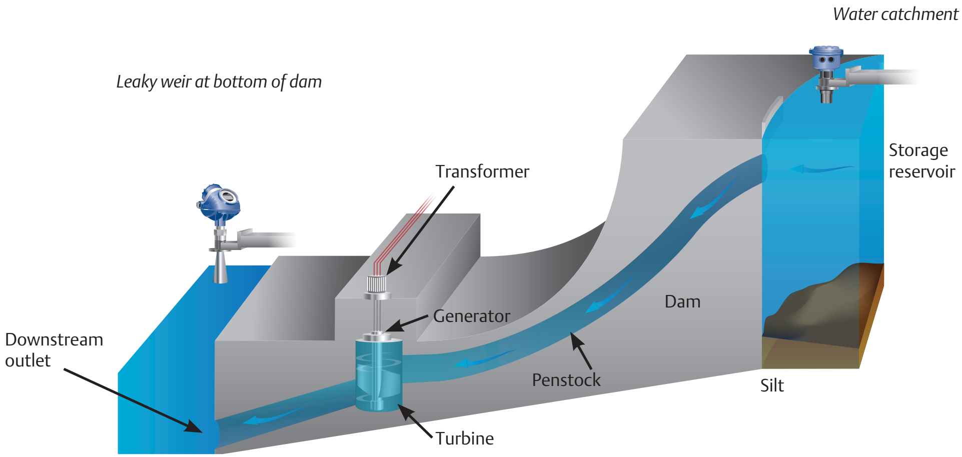


Figure 4.40.1: Leaky weir at bottom of dam and water catchment with non-contacting radar and ultrasonic

4.41 Water catchment (water supply level)

4.41.1 Primary function of application

Water catchment can be an area behind a dam or an area where rain water is collected. The surface level is monitored for supply.

4.41.2 Application characteristics and challenges

- Water surface may be calm or turbulent or may have some debris
- Often a top-down measurement

4.41.3 Suitable technologies

Technology	Installation guidelines in chapter:
Guided wave radar	5
Non-contacting radar	6
Ultrasonic	8

4.41.4 Best practice

<u>Non-contacting radar</u>

- Use 5401 with standard cone antenna, 6" or 8" (option 6S or 8S)
- Direct flange connection or bracket mounting (option BR)

Pumps

4.42 Pumps & rotating equipment protection

4.42.1 Primary function of application

Pumps are essential assets that must never be run in a dry state and must be kept well lubricated to avoid damage due to friction.

Rotating equipment such as turbines must be kept well lubricated to avoid damage due to friction. An adequate oil supply must be available at all times.

For these reasons, switches are often strategically positioned to ensure there is always fluid going into the pump or to ensure that the lubrication supply is adequate. Because the space is often limited, small compact switch designs are more manageable. Key applications that are often monitored with switches include:

- Boiler feedwater pump (BFP) which pumps water from lower pressure dearator into higher pressure feedwater system. Boiler feed pump should never run dry
- Condensate extraction pumps which are used for recirculation of condensed steam back into system
- Gearbox, rotor and starter of the turbine
- Transformer oil level is monitored to ensure fluid is available for continuous cooling on transformer secondary and primary windings
- Seal oil tanks in hydrogen system compressors and generators

4.42.2 Application characteristics and challenges

- Can be high temperature/high pressure
- Clean fluid
- Limited space
- Access points may be small

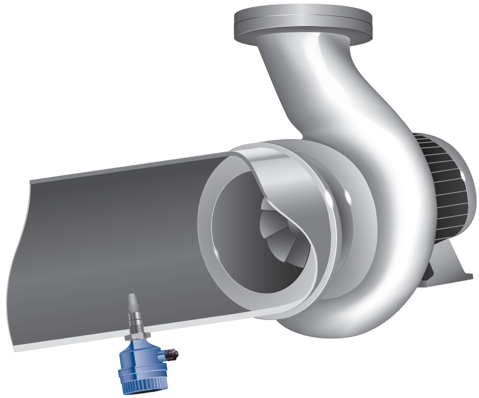


Figure 4.42.1: Pump with rotating equipment

4.42.3 Suitable technologies

Technology	Installation guidelines in chapter:
Vibrating fork switch	9
Float switch	9

4.42.4 Best practice

- Switches can be used to prevent damage by alarming when the fluid levels are at a low point
- Use compact vibrating fork switch to trigger low level alarm
- Switches can be used to detect dry line conditions and shut down the pumps to prevent damage.
- Compact vibrating fork switches can fit into smaller spaces

Misc

4.43 Sumps (drain pit for waste oil, condensate)

4.43.1 Primary function of application

As oil moves through the turbine rotors, some is lost from system and collected in the sumps. This removes oil contamination in the turbine area and keeps the area dry without spilled oil.

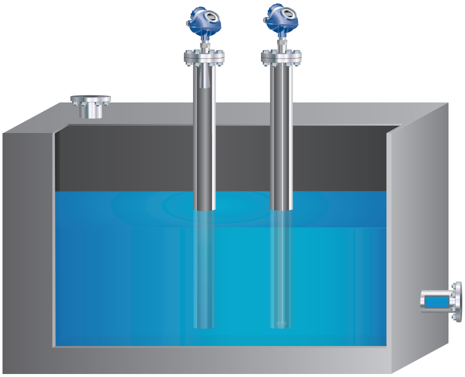


Figure 4.43.1: Condensate sump level with non-contacting or guided wave radar

4.43.2 Application characteristics and challenges

- Sumps may contain dirty, oily water
- Often accessible only with top-down measurements

4.43.3 Suitable technologies

Technology	Installation guidelines in chapter:
Guided wave radar	5
Non-contacting radar	6
Hydrostatic	7
Ultrasonic	8
Vibrating fork switch	9

4.43.4 Best practice

Non-contacting and guided wave radar

- Use 5400 non-contacting radar with standard cone antenna in a size that matches that the stilling well diameter or nozzle
  - o Can be installed directly in tank, or in stilling well
- Or use 5300 guided wave radar with standard seal (option S) and flexible probe (option 5A)
  - o Stilling well should be 4" or larger when using flexible probes
  - o The flexible probe should have a weight and a centering disk to pull probe taut. A heavier weight is available (option code W3)

4.44 Water wash tanks

4.44.1 Primary function of application

The water wash tank accumulates water that has been used for cleaning of equipment such as the compressor of a gas turbine. Particulates gradually build up on the compressor blades and degrades performance. Periodic cleaning is needed. Other equipment in the area is cleaned and the wash water is collected for disposal.

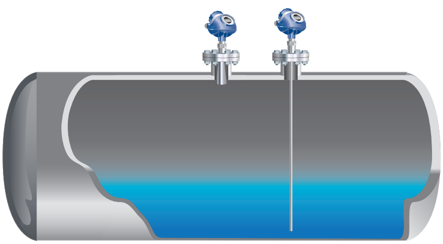


Figure 4.44.1: Water wash tank level with non-contacting or guided wave radar

4.44.2 Application characteristics and challenges

- Tanks are not very large
- Space could be limited
- Water is dirty
- Deposits on surfaces could occur

4.44.3 Suitable technologies

Technology	Installation guidelines in chapter:
Guided wave radar	5
Non-contacting radar	6
Differential pressure	7
Hydrostatic	7
Ultrasonic	8
Vibrating fork switch	9

4.44.4 Best practice

Non-contacting and guided wave radar

- Use non-contacting radar with standard cone (option xS) installed directly in nozzle
  - o Follow nozzle guideline in section 6.4
- Or use GWR with single lead probe (option 4A)
  - o Mount directly in vessel following nozzle guidelines in section 5.6
  - o Use 5300 with signal quality metrics (option DA1 or D01) to determine if probe needs to be cleaned

4.45 Fire water tanks

4.45.1 Primary function of application

Water storage in case of fire. Fire fighting system requires separate water storage facility for plant safety and protection.

See figure 4.19.1: Water and boric acid storage with a non-contacting radar for illustration

4.45.2 Application characteristics and challenges

- Water with high dielectric material storage

4.45.3 Suitable technologies

Technology	Installation guidelines in chapter:
Guided wave radar	5
Non-contacting radar	6
Differential pressure	7
Hydrostatic	7
Ultrasonic	8
Vibrating fork switch	9
Float switch	9

4.45.4 Best practice

- For top mount connections 2", 3", or 4", use 5402 with standard cone antenna (option xS) or ultrasonic
- Or use 5401 with standard cone antenna, 6" or 8" (option 6S or 8S)
- Direct mount
- Mount according to nozzle guidelines in *section 5.6 for GWR and 6.4 for non-contacting radar or section 8.1.2 for ultrasonic*

4.46 Lake or pond level

4.46.1 Primary function of application

Lake or pond levels are monitored to endure adequate supply of make-up water.

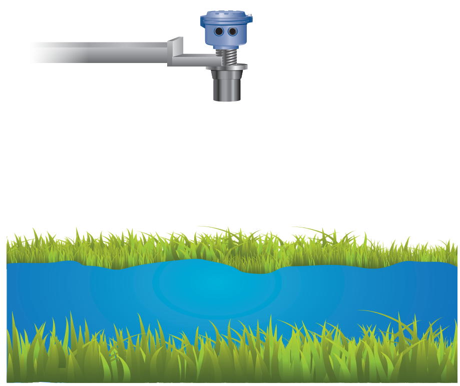


Figure 4.46.1: Non-contacting radar over a lake

4.46.2 Application characteristics and challenges

- Water
- Top- down measurement

4.46.3 Suitable technologies

Technology	Installation guidelines in chapter:
Guided wave radar	5
Non-contacting radar	6
Hydrostatic	7
Ultrasonic	8

4.46.4 Best practice

Non-contacting radar

- Use 5401 with standard cone antenna, 6” or 8” (option 6S or 8S)
- Direct flange connection or bracket mounting (option BR)

4.47 Nuclear balance of plant

The scope of this handbook includes Rosemount level products for non-safety related Nuclear Balance of Plant (BOP) applications. Nuclear qualified safety related Rosemount products are provided only by the Rosemount Nuclear Instruments, Inc. BOP applications are most commonly those which may use commercially available products that are not required to meet nuclear safety requirements-including nuclear technical specifications and/or special quality assurance (QA) programs. Furthermore, nuclear safety is not covered by SIS guidelines.

NOTE!
Depending upon the reactor design, there can be non-safety related applications which have exposure to background radiation. In these situations, the user must evaluate and determine whether the product proposed is suitable for their potential radiation levels.

Generally speaking, nuclear safety related classification requires the products to be manufactured and/or supplied under a special nuclear quality assurance program which can vary between countries and world areas. The most commonly recognized are the U.S. 10CFR 50 appendix B (which the US Nuclear Regulatory Commission oversees) and NQA-1. There are corresponding French RCC and German KTA nuclear QA programs used by these foreign suppliers in the areas where they have exported their reactor technology. Rosemount Nuclear Instruments, Inc. (RNII)’s nuclear QA program satisfies the intent of all of these nuclear QA programs as well as numerous others, amongst them the Canadian’s Z299.1-85.

In addition to nuclear QA, safety related applications also typically require special nuclear environmental and/or seismic qualification according to internationally recognized standards. As with QA, the standards can vary between countries and world areas, but often include IEEE 323, IEEE 344, KTA and RCC requirements.

Radiation specifications are only established for our non-microprocessor based nuclear qualified safety related pressure transmitters via nuclear qualification type testing. The only nuclear qualified safety related products within the Rosemount portfolio are the model 3051N, 1152, 1153 series B and D, 1154, 1154 series H and 3150 series pressure transmitters as listed at *www.RosemountNuclear.com*. These differential pressure transmitters are commonly used on nuclear qualified safety related level applications (depending upon reactor type / design) such as:

- Steam generator wide range and narrow range level
- Reactor level
- Accumulator level
- Pressurizer level
- Torus level
- Containment sump level
- Spent fuel storage
- Refueling makeup water storage tank level
- Various miscellaneous tank levels, etc.

Balance of plant applications where commercial grade products may be used include:

- Flash tanks
- Feedwater heaters
- Condensor hotwell
- Condensate extraction
- Gland steam condensor
- Lube oil tanks
- Hydraulic oil tanks
- Pump protection (various)

- Seal oil tanks
- Transformer oil
- Sumps (outside containment)
- Intake water screens
- Water clarifier tanks
- Chemical storage tanks
- Boric acid
- Resin storage tanks
- Make-up water
- Cooling tower basin
- Debris filters
- Lubicating oil coolers
- Effluent flow
- Fire water tanks
- Heavy water tank

5 Guided wave radar installation guidelines

Topic		Page

5. Guided wave radar installation guidelines

There are three series of Rosemount guided wave radars (GWR); the 5300 series, the 3300 series and the 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 Fieldbus is needed. The 3308 can be used in most liquid storage and monitoring applications, where wireless is needed. Table 3.1.1 will also give some guidance in which series of GWR to choose for a specific application.

The following chapter will go through some installation guidelines for the 5300 series, for more details on the 3300 series, please see the Product Data Sheet with document number: 00813-0100-4811. For details on the 3308 series, please see the Product Data Sheet with document number: 00813-0100-4308.

5.1 Probe selection

There are five different probe types for Rosemount GWRs. The single lead is the preferred choice for most applications and with the 5300's high signal strength, it is possible to use a single lead probe in more applications. This means less maintenance and higher reliability. The following guidelines should be used to choose the appropriate probe for the Rosemount guided wave radar transmitters:

G=Good, NR=Not Recommended, AD=Application Dependent, (consult your local Emerson Process Management representative)

	Rigid single lead	Flexible single lead	Coaxial	Rigid twin lead	Flexible twin lead
Measurements					
Level	G	G	G	G	G
Interface (liquid/liquid)	G	G	G	G	G
Process medium characteristics					
Changing density	G	G	G	G	G
Changing dielectric(1)	G	G	G	G	G
Wide pH variations	G	G	G	G	G
Pressure changes	G	G	G	G	G
Temperature changes	G	G	G	G	G
Condensing vapors	G	G	G	G	G
Bubbling/boiling surfaces	G	AD	G	G	G
Foam (mechanical avoidance)	NR	NR	AD	NR	NR
Foam (top of foam measurement)	AD	AD	NR	AD	AD
Foam (foam and liquid measurement)	AD	AD	NR	AD	AD
Clean liquids	G	G	G	G	G
Liquid with very low dielectric constants	G	G(2)	G	G	G(2)
Coating/sticky liquids	AD	AD	NR	NR	NR
Viscous liquids	AD	G	NR	AD	AD
Crystallizing liquids	AD	AD	NR	NR	NR
Solids, granules, powders	AD	G	NR	NR	NR
Fibrous liquids	G	G	NR	NR	NR

	Rigid single lead	Flexible single lead	Coaxial	Rigid twin lead	Flexible twin lead
Tank environment considerations					
Probe is close (<12 in./30 cm) to tank wall / disturbing objects	AD	AD	G	G	G
Probe might touch tank wall nozzle or disturbing objects	NR	NR	G	NR	NR
Turbulence	G	AD	G	G	AD
Turbulent conditions causing breaking forces	NR	AD	NR	NR	AD
Tall narrow nozzles	AD	AD	G	AD	AD
Angled or slanted surface (viscous or solids materials)	G	G	NR	AD	AD
Liquid or vapor spray might touch probe above surface	NR	NR	G	NR	NR
Disturbing electromagnetic interference in tank	AD	AD	G	AD	AD
Cleanability of probe	G	G	NR	AD	AD

Table 5.1.1: 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.

5.2 Transition zones

The measuring range depends on probe type and product properties, and is limited by the upper and lower transition zones. In these zones, measurement accuracy and linearity may be reduced.

The upper transition zone (UTZ) is the minimum measurement distance between the upper reference point and the product surface. At the end of the probe, the measuring accuracy is reduced in the lower transition zone (LTZ).

Single rigid probes have a 4.3” (110 mm) upper transition zone (the distance between the flange and the maximum level surface) when used in water-based applications. In most cases, existing displacer chambers meet this requirement; however it should be verified. If there is not this much clearance, consider a spool piece for additional height or use a coaxial probe (3B). If a coaxial probe is used, consider using signal quality monitoring (option DA1 or D01)

	Dielectric constant	Rigid single lead	Flexible single lead	Coaxial	Rigid twin lead	Flexible twin lead
Upper(1) transition zone	80	4.3 in. (11 cm)	4.3 in. (11 cm)	4.3 in. (11 cm)	4.3 in. (11 cm)	4.7 in. (12 cm)
	2	6.3 in. (16 cm)	7.1 in. (18 cm)	4.3 in. (11 cm)	5.5 in. (14 cm)	5.5 in. (14 cm)
Lower(2) transition zone	80	2 in. (5 cm)	0 in. (0 cm)	0.4 in. (1 cm)	1.2 in. (3 cm)	2 in. (5 cm)(4)
	2	2.8 in. (7 cm)(5)	2 in. (5 cm) - long weight 3.2 in. (8 cm) - short weight	2 in. (5 cm)	4 in. (10 cm)	5.5 in. (14 cm)(4)

Table 5.2.1: Transition zones for different probe types and dielectric constants, see figure 5.2.1 for illustration of transition zones

(1) The distance from the upper reference point where measurements have reduced accuracy, see picture above.
(2) The distance from the lower reference point where measurements have reduced accuracy, see picture above.
(3) The measuring range for the PTFE covered Flexible Single Lead probe includes the weight. For low dielectric media, special configuration may be required.
(4) Note that the weight length adds to non-measurable area and is not included in the table.
(5) If using a metal centering disc, the lower transition zone is up to 8 in. (20 cm). If using a PTFE centering disc, the lower transition zone is not affected.

to determine if probe needs cleaning or replacement.

Lower transition zone for single rigid probes in water applications is 2 in. (50 mm)

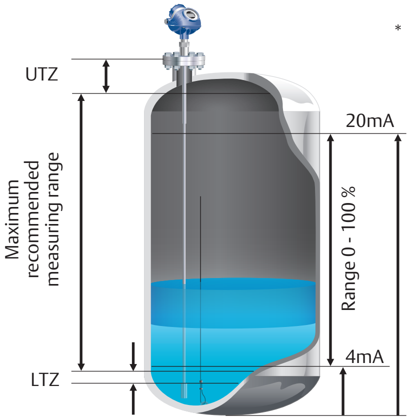


Figure 5.2.1: Illustration showing how the measuring range is related to the transition zones

(*) *The transition zones vary depending on probe type and product.*

5.3 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	Twin lead	Single lead
Guided wave radar		
500 cP	1500 cP	8000 cP(1)(2)
Coating/build-up		
Coating not recommended	Thin coating allowed but no bridging	Coating allowed

Table 5.3.1: Probe type guide for different product viscosity

(1) *Consult your local Emerson Process Management 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.*

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.

The use of a single rigid probe eliminates issues with buildup of magnetite or other deposits.

Bridging

Heavy product coating results in bridging between the two probes in a twin lead version, or 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

The 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 series radar transmitter 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.

5.4 Measuring range (5300)

The measuring range differs depending on probe type and characteristics of the application. *Table 5.4.1 a-d* can be used as a guideline for clean liquids.

Rigid single lead
Maximum measuring range
9 ft 10 in. (3 m) - for 8 mm probes 14 ft 9 in. (4.5 m) - for 13 mm probes
Min dielectric constant at max measuring range
1.4 (1.25 if installed in a metallic bypass or stilling well)(1)(2)

Table 5.4.1a: Measuring range guide for rigid single lead probes

Flexible single lead(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 5.4.1b: Measuring range guide for flexible single lead probes

Coaxial	Rigid twin lead
Maximum measuring range	
19 ft 8 in. (6 m)	9 ft 10 in. (3 m)
Minimum dielectric constant at maximum measuring range	
1.2 (Standard) 1.4 (HP/C) 2.0 (HTHP)	1.4

Table 5.4.1c: Measuring range guide for coaxial and rigid twin lead probes

Flexible twin lead
Maximum measuring range
164 ft (50 m)
Minimum dielectric constant at maximum measuring range
1.4 up to 82 ft (25 m)(1) 2.0 up to 115 ft (35 m)(1) 2.5 up to 131 ft (40 m)(1) 3.5 up to 148 ft (45 m) 6 up to 164 ft (50 m)

Table 5.4.1d: Measuring range guide for flexible twin lead probes

(1) The probe end projection software function will improve the minimum dielectric constant. Consult you local Emerson Process Management representative for details.

(2) Measuring range may be lower depending on installation.

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

5.5 Vessel characteristics

Heating coils, agitators

Because the radar signal is transmitted along a probe, the Rosemount 5300 radar transmitter is generally not affected by objects in the tank. Avoid physical contact with metallic objects when twin lead or 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.

5.6 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.

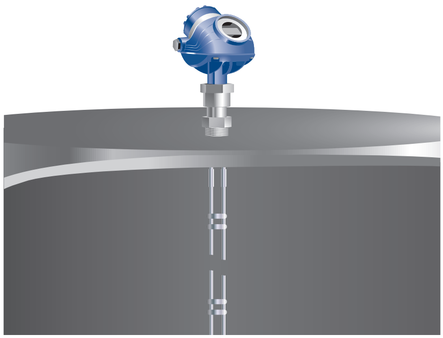


Figure 5.6.1: Mounting on tank roof using threaded connection

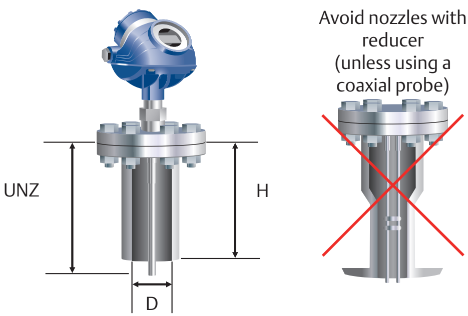


Figure 5.6.2: Mounting in nozzles

The transmitter can be mounted in nozzles by using an appropriate flange. The nozzle sizes given in *table 5.6.1* 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.

	Single (rigid/ flexible)	Coaxial	Twin (rigid/ flexible)
Recommended nozzle diameter (D)	6 in. (150 mm)	> Probe diameter	4 in. (100 mm)
Minimum nozzle diameter (D)(1)	2 in. (50 mm)	> Probe diameter	2 in. (50 mm)
Recommended nozzle height (H)(2)	4 in. + nozzle diameter(3)	N/A	4 in. + nozzle diameter

Table 5.6.1: Nozzle considerations

(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 Process Management 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 5.6.3: 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 low dielectric constant. An alternative is to install a smaller nozzle inside the nozzle.

5.7 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 5.7.1 and table 5.7.2 is recommended.*

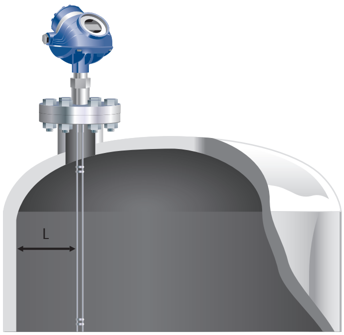


Figure 5.7.1: Free space requirement

Coaxial	Rigid twin	Flexible twin
0 in. (0 mm)	4 in. (100 mm)	4 in. (100 mm)

Table 5.7.1: Recommended minimum free space L to tank wall or other objects in the tank

Rigid single / 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 5.7.2: 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.*

5.8 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).

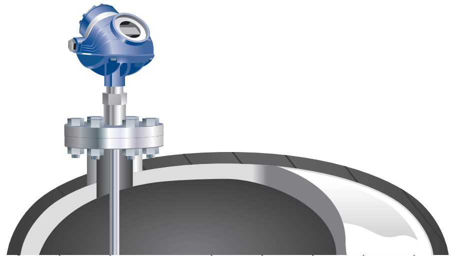


Figure 5.8.1 Tank insulation

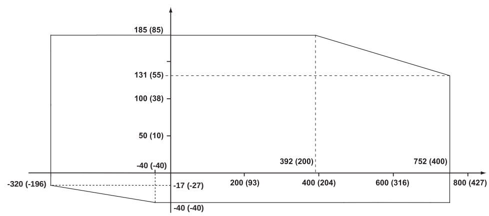


Figure 5.8.2 Ambient temperature vs. process temperature

5.9 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.

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 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

Figure 5.9.1: Mounting position in liquids

NOTE!

Violent fluid movements can cause forces that could break rigid probes.

For solids

Figure 5.9.2: 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/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

5.10 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.

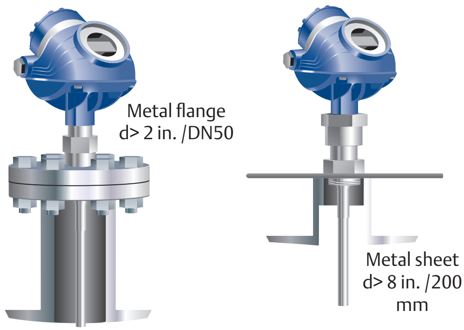


Figure 5.10.1: Mounting in non-metallic vessels

Electromagnetic disturbances should be kept to a minimum since they may affect measurement performance.

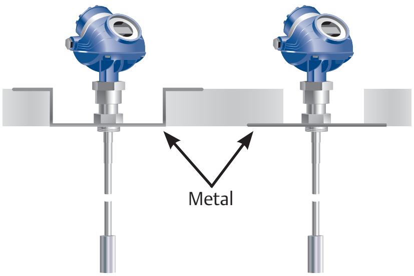


Figure 5.10.2: Installation in concrete silos

5.11 Mounting in chamber/stilling well

Stilling wells and bypass chambers are used in many applications and many different types of tanks and vessels. The two installation methods will jointly be referred to as pipes. Radar transmitters can be used in these installations, but function differently in pipes than in normal vessel installations. This guide is intended to assist with radar device selection and installation for optimal performance.

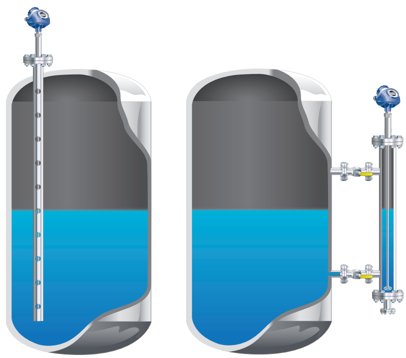


Figure 5.11.1: Example of a bypass chamber mount (right) and a stilling well mount (left).

A pipe can increase the reliability and robustness of the level measurement, especially for non-contacting radar. It should be noted that the coaxial probe of a guided wave radar (GWR) is essentially a probe within a small stilling well. It should be considered as an alternative to stilling wells for clean fluid applications.

Pipes completely isolate the transmitter from disturbances such as other pipes, agitation, fluid flow, foam and other objects. The pipes can be located anywhere in the vessel that allows access. For GWR, the microwave signals are guided by the probe, making it resistant to disturbing objects.

Bypass chambers may be located on a small portion of a tank or column and allow access to the measurement instrument. This may be especially important for interface measurements near the bottom of a taller vessel or for measurements in a distillation column.

Bypass chambers often include valves to allow instrumentation calibration verification or removal for service.

Bypass chambers and stilling wells are not without limitations. Generally, pipes should be used with cleaner fluids that are less likely to leave deposits and that are not viscous or adhesive. Apart from the additional cost of installation, there are some sizing and selection criteria for the radar gauges that must be considered. This document outlines those considerations.

GWR is the preferred technology for shorter installations where rigid probes may be used. This makes it a suitable replacement for caged displacers, which are often less than 10 ft. (3 m). The probes are available in a variety of materials to handle corrosive fluids.

For further information of how to replace displacers with guided wave radar in existing chambers, see section 12.2.

For taller applications or those with limited head space for installing rigid probes, non-contacting radar may be advantageous. Non-contacting radar is also the preferred technology for applications with heavy deposition or very sticky and viscous fluids.

5.11.1 Rigid or flexible probe?

In most cases, rigid probes are preferred for pipe installations. When used in a metal, small diameter pipes, single rigid probes offer a stronger return signal than when used in open applications. This makes them suitable for low dielectric and interface applications. Flexible probes may be used in longer pipes, but care must be taken to assure that the probe is suspended in a true vertical position and does not touch the pipe wall.

If flexible probes are to be used, the pipes should be 4" (100 mm) or larger to allow room for some flexing. Also, as fluid moves into the pipe, it may push the probe towards the pipe wall. If the probe touches the wall, false reflections may create false level measurements. Rigid probes are less susceptible to these issues. Flexible probes simply need more room. Very narrow pipes allow little room for movement or flexing of the probe.

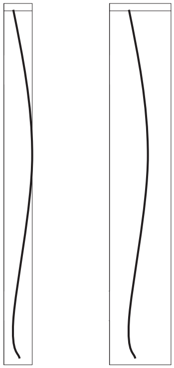


Figure 5.11.2: Narrow pipes allow little room for movement or flexing of the probe.

5.11.2 Pipe requirements

There are multiple styles and materials of probes available for the Rosemount GWR products. *Table 5.11.1* shows the various options and where each may be used with regard to pipe size and length. GWR may be used in pipes made of metal, plastic and other non-metallic materials. All pipes will provide isolation from the process materials and conditions. Metallic pipes help to increase signal strength and shield the probe from EMI disturbances. If EMI is present and a non-metallic pipe must be used, then the Rosemount 5300 should be used.

Probe style	Maximum recommended length of pipe	Centering disc?	Recommended pipe diameter	Minimum dielectric[1]		SST	PTFE coated	Alloy C-276	Alloy 400
				3300	5300				
Single rigid[2]	3 m (9.9 ft)	Yes	8 cm (3")	1.7	1.25	Yes	Yes	Yes	Yes
Single flexible	10 m (33 ft)	Yes	15 cm (6")	2.0	1.4	Yes	Yes	No	No
Twin rigid	3 m (9.9 f t)	No	8 cm (3")	1.9	1.4	Yes	No	No	No
Twin flexible	10 m (33 ft)	Yes	15 cm (6")	1.6	1.4	Yes	No	No	No
Coaxial [2][3]	6 m (19.8 ft)	No	>3.7 cm (1.5")	1.4 (STD) 2.0 (HTHP)	1.2 (STD) 1.4 (HP) 2.0 (HTHP)	Yes	No	Yes	Yes

Table 5.11.1: Probe styles and installation considerations

(1) When installed in metal pipe
(2) Single and coaxial probes are available with process seals for high pressure and high temperature conditions. SST or Alloy C-276
(3) Coaxial probes are not recommended for submerged probe applications

Probe style	Upper transition zone		Lower transition zone	
	High dielectric	Low dielectric	High dielectric	Low dielectric
Single Rigid[2]	10 cm (4”)	10 cm (4”)	5 cm (2”)	10 cm (4”)
Single Flexible[1]	15 cm (5.9”)	20 cm (8”)	19 cm (7.5”)[2]	26 cm (10.2”)[2]
Twin Rigid	10 cm (4”)	10 cm (4”)	5 cm (2”)	7 cm (2.8”)
Twin Flexible	15 cm (5.9”)	20 cm (8”)	14 cm (5.5”)[2]	24 cm (9.4”)[2]
Coaxial[3]	10 cm (4”)	10 cm (4”)	3 cm (1.2”)	5 cm (2”)

Table 5.11.2: 3300: Transition zones vary with probe type when installed in metallic pipes

(1) Single probes are the preferred choice
(2) Includes weight
(3) Coaxial should only be used for very clean or low DC applications

Probe style	Upper transition zone		Lower transition zone	
	High dielectric	Low dielectric	High dielectric	Low dielectric
Single rigid[2]	11 cm (4.3”)	16 cm (6.3”)	5 cm (2”)	7 cm (2.8”)
Single flexible[1]	11 cm (4.3”)	18 cm (7.1”)	14 cm (5.5”)[2]	19 cm (7.5”)[2]
Twin rigid	11 cm (4.3”)	14 cm (5.5”)	3 cm (1.2”)	10 cm (4”)
Twin flexible	12 cm (4.7”)	14 cm (5.5”)	5 cm (2”)[2]	14 cm (5.5”)[2]
Coaxial[3]	11 cm (4.3”)	11 cm (4.3”)	10 cm (4”)	14 cm (5.5”)

Table 5.11.3: 5300: Transition zones vary with probe type when installed in metallic pipes

(1) Single probes are the preferred choice
(2) Includes weight
(3) Coaxial should only be used for very clean or low DC applications

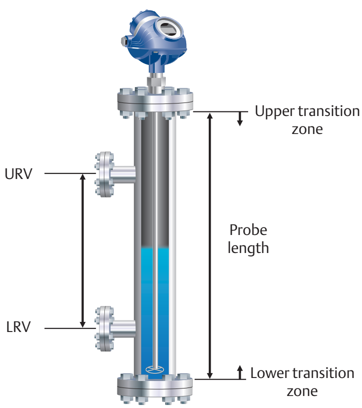


Figure 5.11.3: Allowing some extra length for the upper and lower transition zones of the probe

5.11.3 Mounting

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, flexible single, and flexible twin lead probes. *For further information on centering disks see section 5.11.4*

NOTE!

To avoid disturbances from an object near the pipe, metal-pipes are preferred, especially in applications with low dielectric constant.

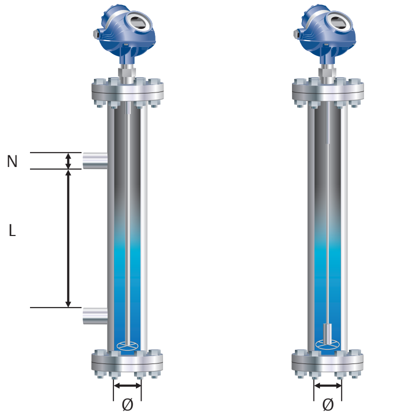


Figure 5.11.4: Mounting single probe in chamber / still pipe

Inlet pipe diameter N<Ø. Effective measuring range L<=12 in. (300 mm).

Probe type	Recommended diameter	Minimum diameter
Rigid single	3 or 4 in. (75 or 100 mm)	2 in. (50 mm)
Flexible single	4 in. (100 mm)	Consult your local Emerson Process Management representative
Rigid twin[(1)]	3 or 4 in. (75 or 100 mm)	2 in. (50 mm)
Flexible twin[(1)]	4 in. (100 mm)	Consult your local Emerson Process Management representative
Coaxial	N/A	1.5 in. (37.5 mm)

Table 5.11.4: Recommended and minimum chamber / still pipe diamter for different probes

(1) The center rod must be placed more than 0.6 in. (15 mm) away from the pipe wall.

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.

When determining the location of chamber and piping, efforts should be made to keep the overall height of the chamber and probe as short as possible while still meeting the basic requirements. Even with compensation for steam dielectric changes, the overall distance of travel of the microwave signal will determine the overall errors when high pressure steam is present.

It is recommended that single probes are used with the Rosemount 5300 series. Other probe types are more susceptible to build-up and are not recommended.[(1)] An exception is with liquefied gas > 40 bar when the coaxial probe should be used. 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. 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

See figure 5.11.5.

(1) The single probe creates a virtual coaxial probe with the chamber as the outer tube. The extra gain provided by the twin and coaxial probes is not necessary; the electronics in the Rosemount 5300 Series is very sensitive and is not a limiting factor.

(2) 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.

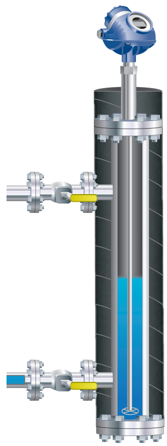


Figure 5.11.5: Insulated chamber

When mounting in a Rosemount 9901 chamber, the probe length to use can be calculated with these formulas:

- Side-and-Side dimension: Probe length = Center-to-Center dimension + 19 in. (48 cm)
- Side-and-Bottom dimension: Probe length = Center-to-Center dimension + 4 in. (10 cm)

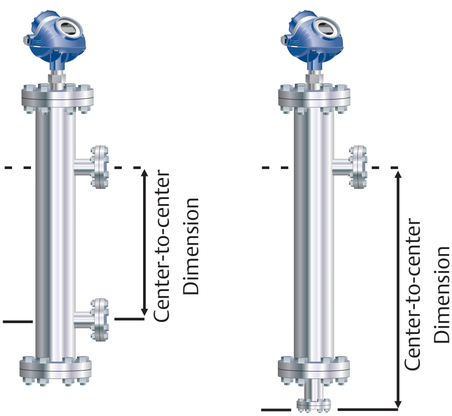


Figure 5.11.6: Chamber dimensions

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 5.11.7) is 22 in. (560 mm) for the short reflector and 28 in. (710 mm) for the long reflector (see figure 5.11.7 below), to dynamically compensate up to 100%.

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

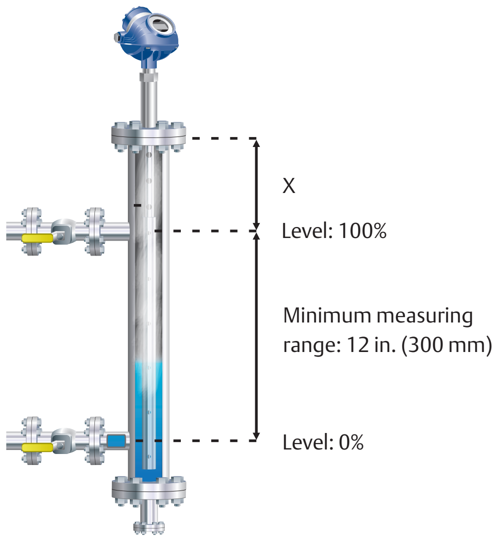


Figure 5.11.7: Minimum distance X for dynamic vapor compensation applications

5.11.4 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, flexible single, and flexible twin lead probes. The disc is attached to the end of the probe and thus keeps the probe centered in the bridle. The discs are made of stainless steel, Alloy C-276, or PTFE.

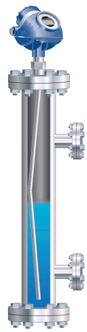


Figure 5.11.8: Prevent probe from coming into contact with the chamber/ pipe wall

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)	6 in.	6 in.	NA(1)	NA(1)
8 in.	8 in.	8 in.	8 in.	8 in.	6 in.	6 in.

Table 5.11.5: 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.

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 5.11.6: 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 disk 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 disk from reaching the bottom.

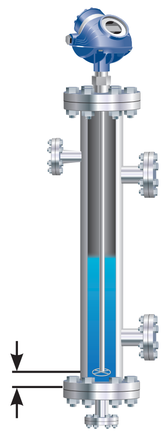


Figure 5.11.9: A clearance distance of 1 in. (25 mm) between the probe end and the chamber bottom is recommended.

5.11.5 Extra recommendations for installation in stilling well

- Stilling well must be metallic
- 4", 6", or 8" 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 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 disk is a potential site for material buildup
- Transmitter can be installed directly in existing displacer chambers if upper transition zone area can be met

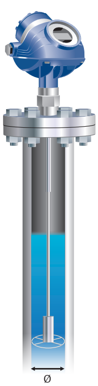


Figure 5.11.10: GWR mounted in a stilling well

Figure 5.11.11: GWR measuring level in stilling well

5.11.6 Transmitter configuration

The transmitter software contains a special pipe measurement mode which is turned on by entering the internal diameter of the pipe. This can be done using Rosemount Radar Master, the 375/475, AMS™ or any other DD-compatible host-system. When this mode is turned on, the transmitter will be optimized for pipe measurements. For example, the dynamic gain curve will be adapted for pipes and the lower propagation velocity of the radar signal in the pipe will be compensated. Entering the pipe diameter into the transmitter is therefore crucial and must not be omitted. Compensation is more important on higher frequency devices.

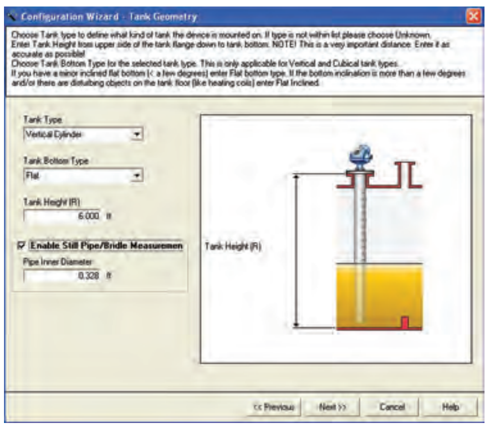


Figure 5.11.12: Transmitter configuration wizard

For measuring range tables of GWR, see section 6.10.5

5.12 Combination with 9901 chambers

The Rosemount 9901 chamber is designed for complete compatibility with Rosemount level measurement instruments. A combined Rosemount 9901 chamber and Rosemount GWR solution (also known as complete point solution) is designed for safety, meeting highest industry standards, and delivers an integrated bolt-on level solution.

CPS offers 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 (if "XC" option selected)
- Single site customer inspection option
- Proven performance and technology

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, GWR probe selection and installation can all impact the level measurement accuracy.

GWRs may be used in 2-in., 3-in., or 4-in. diameter chambers, although the 9901 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 5.12.1 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:

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.

Chamber diameter

Narrow diameter chambers are more susceptible to the probe touching or getting close to the wall of them 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.

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.

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.

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.

Probe and chamber selection guidelines

For most applications, single rigid probes are the best choice. When a GWR 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 twin or coaxial probes. In very low dielectric but clean fluids, such as liquefied gases like LNG, a coaxial probe may be used.

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 (DVC) by using the reflector pulse to complete an on-line dielectric calculation of the steam. When using a DVC 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 DVC probe must have a longer top section.

Several parameters can impact level measurement results in chambers.

See table 5.12.1 for size considerations.

Installation parameter	Chamber diameter	
	3"	4"
Rigid probe	OK	OK
Flexible probe	Fair-use heavy weight	Preferred
Side connections, large (2'')	Fair	Preferred
Side connections, small (1'')	OK	OK
Overall length (<2 m)	OK	OK
Overall length (>2 m)	Fair - use centering disks, 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

Table 5.12.1: Installation parameters and chamber size summary

(1) Use weight with flexible probe.

5.12.1 How to select and size your chamber and GWR

Step 1 - Select a 9901 chamber

For use with a GWR, select option 9901G. For full specifications, refer to the 9901 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 GWR, drain etc.

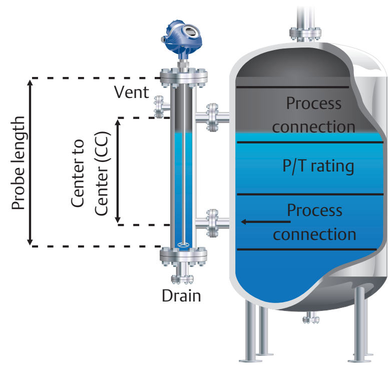


Figure 5.12.1: Key chamber considerations

Step 2 Select a GWR transmitter

Single rigid probes are the preferred probe style for chamber installations. For full GWR specification, please see to Product Data Sheets.

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 5.12.2. The minimum and maximum temperature depends on type of process seal, flange and the o-ring.

ASME B16.5	Gasket	P/T @ RT		P/T @ 150°C/300°F		P/T @ 200 °C/400°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

Table 5.12.2: Pressure/Temperature rating for GWR 316L flange welded connections when used with stainless steel or carbon steel 9901 chamber.

(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

Material of construction in GWR's model code	Bolting material(1)	Gasket STD/HTHP	Gasket HP/HTHP	Flange material GWR	Process seal housing material GWR
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 non-metallic 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

Table 5.12.3: Standard bolting materials supplied with Rosemount GWR and 9901 chamber.

(1) For other types of bolting materials, please contact customer care in your world area.
(2) The Rosemount GWR can be paired with stainless steel or carbon steel chamber. For other materials, please contact customer care in your world area.
(3) Flange non-wetted, protective plate in UNS N10276

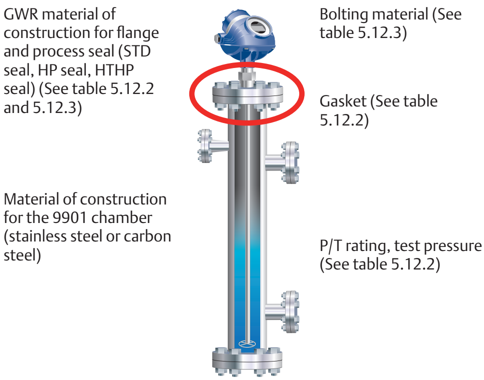


Figure 5.15.2: Pressure/temperature (P/T) rating considerations

Step 4 - Determine probe length

- Standard probes

Rosemount 9901 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 GWR for any probe type and application. Therefore, the probe length is determined by the center to center dimension (B) plus a common standard length adder for each chamber style, see table 5.12.4 and 5.12.5. 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

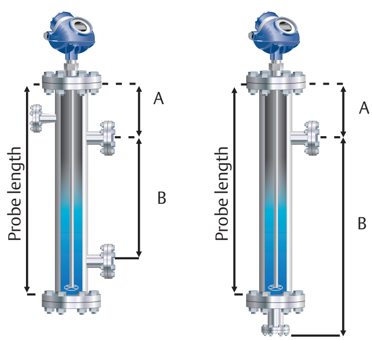


Figure 5.12.3: Side and side & side and bottom chambers for standard probes

- DVC probes

New options are available with the Rosemount 9901 chamber for use with Dynamic Vapor Compensation GWR probes. The probe reflector is contained within the upper section of the chamber so the Rosemount 9901 requires a longer top dimension. DVC probes are available with 2 reflector lengths. The long one provides slightly better accuracy, while the short one can be used in areas where more clearance for head space is needed.

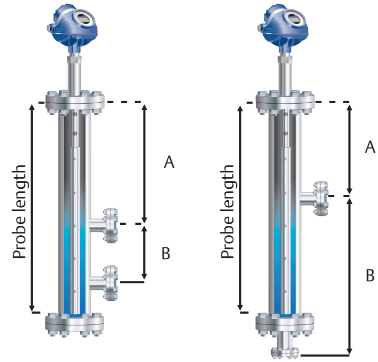


Figure 5.12.4: Side to side and side to bottom chambers for DVC probes.

Calculating probe length for compatibility with 9901G chamber

It is very important to ensure that the probe length of the GWR is compatible with the chamber length to ensure correct operation.

To size the probe length of a Rosemount GWR, 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 probe length for a given process connection center to center dimension is identified in table 5.12.4 and 5.12.5

Chamber	Dimension A	Probe Length
9901 Standard	10.8 in. (275 mm)	B + 19 in. (48 cm)
9901 with option G1	22 in. (560 mm)	B + 25 in. (65 cm)
9901 with option G2	27.5 in. (710 mm)	B + 31 in. (80 cm)

Table 5.12.4: Probe length determination for side-andside chamber

Chamber	Dimension A	Probe Length
9901 Standard	10.8 in. (275 mm)	B + 4 in. (10 cm)
9901 with option G1	22 in. (560 mm)	B + 10 in. (26 cm)
9901 with option G2	27.5 in. (710 mm)	B + 16 in. (41 cm)

Table 5.12.5: Probe length determination for side-to-bottom chamber

- Probe length calculation in metric - worked example

IIf the Rosemount 9901 (side-and-side type) is specified in metric units, GWR probe length equals center-to-center dimension (B) + 48 cm.

Note that the chamber dimensions require more measurement precision in order to perfectly match the center to center dimensions of the process vessel connections. Thus, the Rosemount 9901 is sized to within a millimeter (metric) or 1/10 in. (English). The GWR probes however do not require this precision and are sized to within 1 cm (metric) or 1 in. (English).

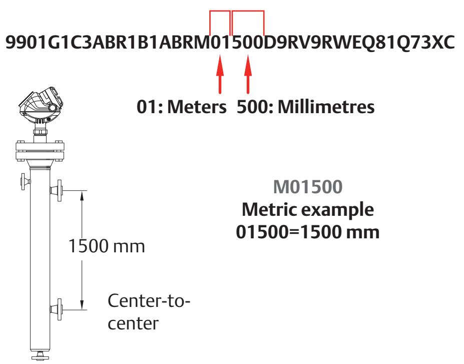


Figure 5.12.5: Probe length calculation in metric, worked example 1

GWR Unit is M = Metric then

9901 center to center = M01500 (150 cm)

Probe length (in cm) = B + 48 cm

Probe length (in cm) = 150 cm + 48 cm

Probe length (in cm) = 198 cm

5300 model code probe length =

5301HA1S1V4BM00198BBE5M1

NOTE!
For this GWR model, dimensions are in cm. Probe length to order is 198 cm. This is defined as M00198 in the 5300 GWR model code or M0198 in the 3300 GWR model code.

- Probe length calculation in imperial units - worked example

If the Rosemount 9901G (side-and-side process connections) is specified in English units, the standard probe length is the center to center dimension (B) + 19 in. Please note that for GWR's, the probe length in the model code is specified in feet and whole inches.

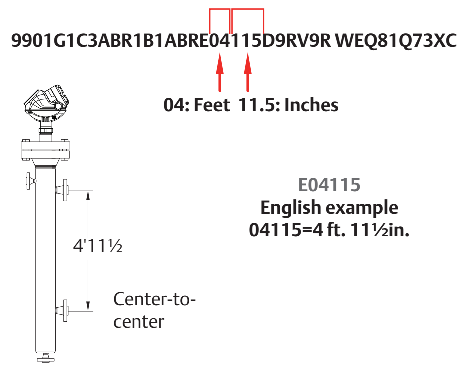


Figure 5.12.6: Probe length calculation in English units, worked example 2

If GWR Unit is E = English then

9901 center-to-center = E....... 4 ft. 11.5 in.

Probe length (in inches) = B + 19 in.

Probe length (in inches) = 4 ft. + 11.5 in.+ 19 in.

Probe length (in inches) = 6 ft. 6.5 in.

In this example the probe length would need to be 6 ft. 6.5 in.which should be rounded to 6 ft. 6 in.

Therefore probe length = 6 ft. 6 in.

5300 model code, probe length =

5301HA1S1V4BE00606BBE5M1

Step 4 - 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 5.12.5.

For further information on centering discs see section 5.11.4.

Chamber Size	Chamber Rating	Centering Disc
3 in.	Up to Class 600/PN 100	3 in.
4 in.	Up to Class 600/PN 100	4 in.
3 in.	Class 900, 1500/ PN160, 250	2 in.
4 in.	Class 900, 1500/ PN160, 250	3 in.

Table 5.12.6: Centering disc specifications for GWRs installed in chambers

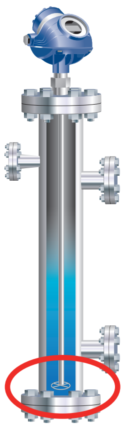


Figure 5.12.7: Centering disc

Step 5 - Configuration

Default factory settings are configured into the transmitter according to model codes of the chamber and transmitter characteristics, see figure 5.12.8.

Pipe diameter = Chamber diameter

Tank height = Dimension (A) + (B)

Only for HART units

LRV = 0 (4 mA)

URV = B (20 mA)

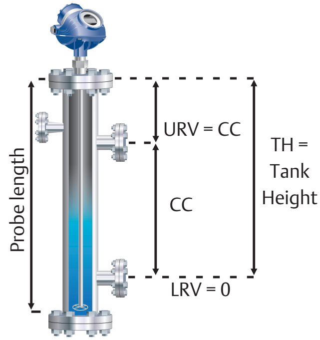


Figure 5.12.8:Transmitter will be configured so that the upper and lower range values align with the dimension (B).

Additional factory configurations can be ordered by including the C1 option code in the transmitter model code.

XC Option (Consolidate to)

Selecting the 'XC' option on the GWR and the 9901 will result in consolidating and shipping of the two products together in one crate. This ensures the GWR and 9901 are matched[(1)].

(1) The units are checked/consolidated together.

IMPORTANT!
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.

5.13 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 twin/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.

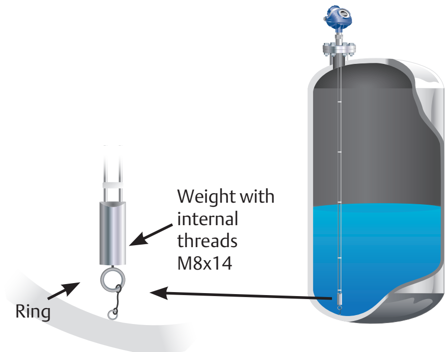


Figure 5.13.1: Flexible twin/single with weight and ring

Flexible twin/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.

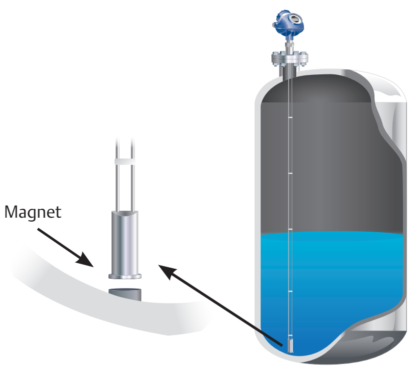


Figure 5.13.2: Flexible twin/single with weight and magnet

Coaxial probe fixed to the tank wall

The 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.

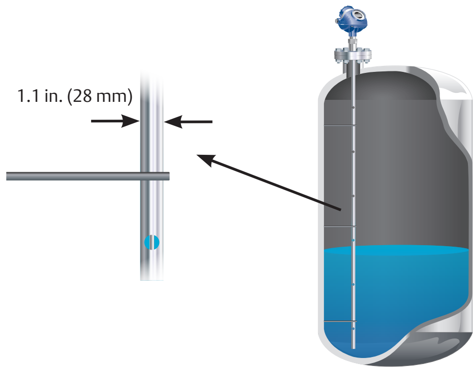


Figure 5.13.3: Coaxial fixed to the tank wall

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.

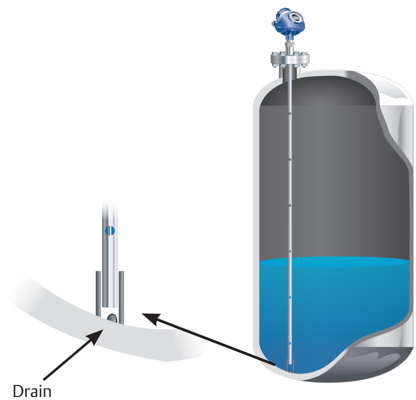


Figure 5.13.4: Coaxial with a welded tube at tank bottom

Rigid twin lead probe

The rigid twin lead probe can be secured to the tank wall by cutting the center rod and putting a fixture at the end of the outer rod. The fixture is customer supplied. Make sure the probe is only guided and not fastened in the fixture to be able to move freely for thermal expansion.

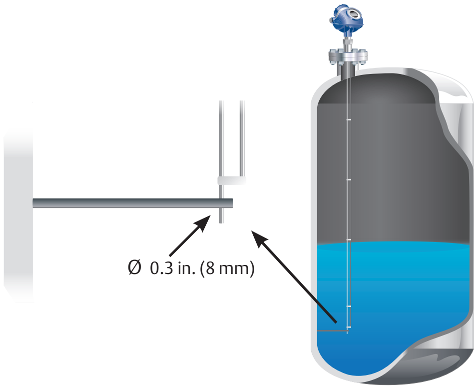


Figure 5.13.5: Rigid twin secured to the tank wall

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.

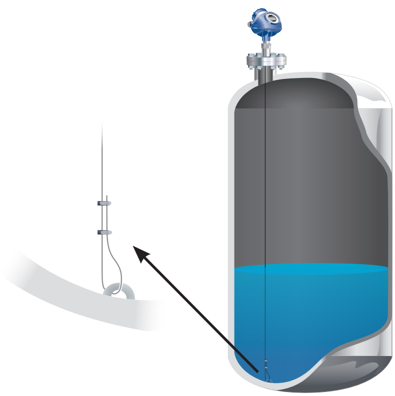


Figure 5.13.6: Flexible single anchored to tank bottom

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.

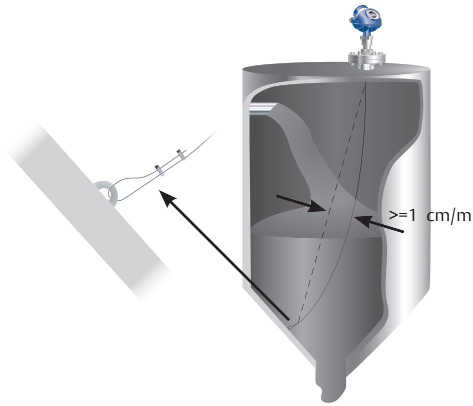


Figure 5.13.7: Anchoring in solid applications

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

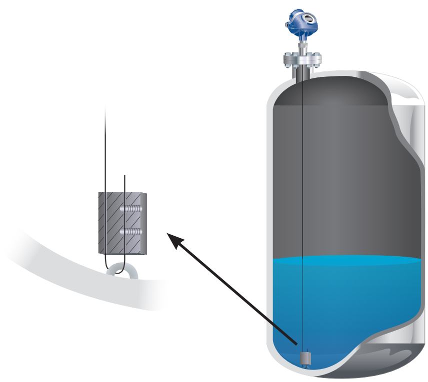


Figure 5.13.8: Flexible single with chuck

5.14 Process seal selection guidelines

Rosemount 3300 and 5300 guided wave radar transmitters are designed to be used in a wide variety of level applications. To meet the installation and application demands, four types of process seals are available and are chosen as part of the model number sequence:

S - Standard temperature and pressure process seal

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.*

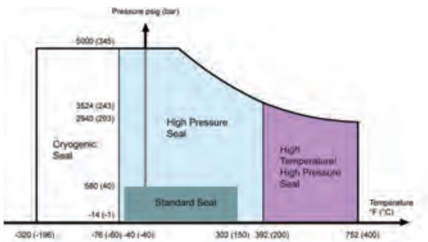


Figure 5.14.1: Recommended choice of process seal type

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).*

5.15 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.

For further information see section 12.5.

5.16 Considerations for solid applications

Guided wave radar is a very reliable method for measuring solids, such as powders, granulates, or pellets with a grain size of up to 0.8 in. (20 mm). Materials include plastics, fly-ash, cement, sand, sugar, cereals, grains, and many others. With the Rosemount 5303, measurements can be made even on fine powders in dusty environments and in silos where the media surface is not flat and where free-propagation radar transmitters may be unsuitable.

The measurement is made where the probe comes in contact with the material, which means that the shape of the material surface is not critical for the measurement. Measurements are also independent of moisture, material fluctuations such as density and temperature.

5.16.1 Measuring range

For a Rosemount 5303 with a flexible single lead probe, the maximum probe length is 164 ft. (50 m).

Table 5.16.1 shows the maximum measuring range depending upon the dielectric constant of the product. The Rosemount 5303 probe end projection (PEP) function may improve the maximum measuring range.

> **NOTE!**
>
> The maximum practical measuring range also depends on the tensile load in your application. *See tensile strength and collapse load section 5.16.3, for more information.*

Dielectric constant	Maximum measuring range w/o PEP	Maximum measuring range w. PEP
1.4	49 ft. (15 m)	138 ft. (42 m) + air gap(1)
1.8	82 ft. (25 m)	122 ft. (37 m) + air gap(1)
2.0	115 ft. (35 m)	116 ft. (35 m) + air gap(1)
3	138 ft. (42 m)	94 ft. (28 m) + air gap(1)
4	151 ft. (46 m)	82 ft. (25 m) + air gap(1)
6	164 ft. (50 m)	Not needed

Table 5.16.1: Maximum measuring range

(1) The 'air gap' is the distance to the material surface. Note, however, that the maximum measuring range cannot exceed the probe length i.e. 164 ft. (50 m).

Dielectric constants(1)	Typical bulk solids	5303 maximum measuring range
1.1 - 1.9	• Plastic powder, granulate • White lime, special cement • Dry sawdust • Sugar granulate • Cement, plain	See Table 5.16.1
1.9 - 2.5	• Fly ash • Burnt Lime • Coal dust, dry • Portland cement • Plaster	See Table 5.16.1
2.5 - 4.0	• Starch • Grain, seeds • Ground stones • Carbon black • Sand	See Table 5.16.1
4.0 - 7.0	• Naturally moist (ground) • Stones, ores • Salt • Cement powder	See Table 5.16.1
> 7.0	• Carbon black • Coal dust, moist • Brown coal • Metallic powders • Calcium Carbonate	164 ft. (50 m)

Table 5.16.2: Dielectric constants of typical bulk solids

(1) Dielectric values can differ depending on particle size and the amount of air or moisture in the material. More air will lower the dielectric value while more moisture will increase it. These tables provide a rough guideline.

NOTE!

For dielectric constants <1.4, the surface pulse may be too weak to be detected and measurements cannot be made unless the probe end projection function is used.

NOTE!

For longer measuring ranges, non-contacting radar may be a better choice. *See section 6.13 - Measuring solids with a Rosemount 5600 non-contacting radar.*

5.16.2 Probe end projection function

Probe end projection (PEP) is a function in the 5303 transmitter that allows for measurements when the surface pulse is too weak to be detected. This commonly occurs when the material dielectric is very low, especially in combination with a long distance to the surface, or electromagnetic interference. The method is based on the fact that microwaves propagate slower through product than through air. By using the product dielectric constant and the probe end echo, the surface position is calculated when the surface echo is unavailable. The PEP function will only be activated as a backup if the surface echo is too weak.

The PEP function is recommended for solids with a dielectric constant less than or equal to 2. The maximum measuring range with PEP is 164 ft. (50 m) (maximum probe length) divided by the square root (sqrt) of the material dielectric constant (DC) + the air gap to the material surface. If the DC is 2 and the vessel is filled, the maximum measuring range is 115 ft. (35 m) (e.g. 164 ft. (50 m) / sqrt(2)). For a lower DC or with an air gap in the top of a vessel, it is possible to measure longer distances, *see table 5.16.1 for details)*

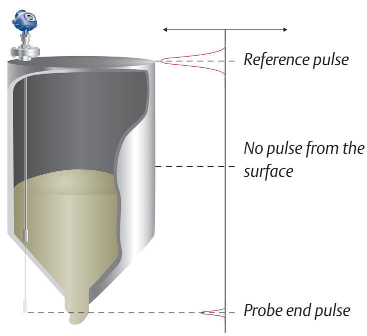
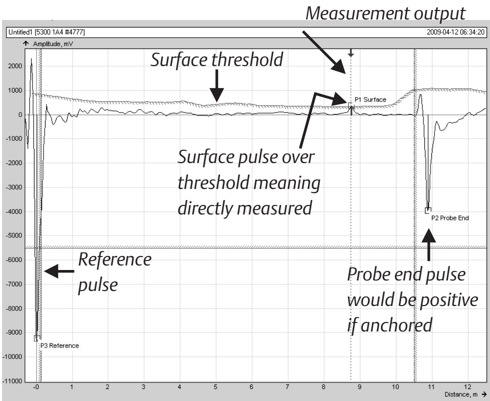
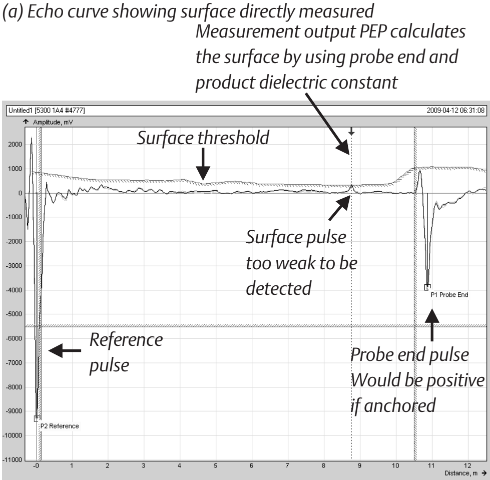


Figure 5.16.1: Probe end projection function



(a) Echo curve showing surface directly measured



(b) Echo curve showing surface detected by PEP

Figure 5.16.2: Probe end projection function, diagrams

The PEP is easily configured by using the guided setup in either Rosemount Radar Master, AMS™, or the field communicator. For best performance, complete the guided setup with an empty vessel to accurately calibrate probe end offset and probe end pulse polarity, and then a second time with material in the vessel to get a surface echo to calculate the product dielectric constant.

NOTE!

Accuracy is highly dependent on a correctly configured DC value, and may be affected when using PEP. The longer the measuring range, the higher the error (e.g. square root (DC error)*measure range). It is therefore recommended to only use PEP when required and allow the transmitter to go into direct measuring mode. Obtaining the real surface echo will allow automatic correction of the DC. Do not set the surface echo threshold too high in areas where it is possible to reliably detect the real surface. Instead, allow the surface to sometimes be within the maximum measuring range without PEP *(see table 5.16.1)*. However, even if the accuracy may be affected, the repeatability will not be affected.

For detailed information on configuring PEP, see the Rosemount 5300 series reference manual (document number 00809-0100-4530)

NOTE!

If PEP is used to measure in an application with EMI, the accuracy may be affected. For example, if the surface echo is too weak to distinguish from the noise and the surface threshold is raised to only use the probe end pulse, accuracy will be affected if the DC is not configured correctly.

NOTE!

Fixing the end of the probe to a surface (e.g. silo wall) affects the PEP accuracy. First, due to the slack of the probe needed to reduce the risk of probe breakage, the measurement is slightly non-linear. Secondly, if the fixing is not sufficient, the probe end pulse is not consistent. It is recommended to use the probe rope itself for anchoring (e.g. slot through a welded eye and then fasten with a chuck) rather than using a ring attached to the weight.

5.16.3 Tensile strength and collapse load

The flexible single lead probe is recommended for solids. It is available in two versions to handle different loads and lengths:

- 0.16 in. (4 mm) diameter; Minimum tensile strength is 2698 lb. (12kN); Maximum collapse load is 3597 lb. (16 kN)
- 0.24 in (6 mm) diameter; Minimum tensile strength is 6519 lb. (29 kN); Maximum collapse load is 7868 lb. (35 kN)

Tensile strength is the amount of force the probe can withstand before any deformation occurs. The definition for collapse load is the maximum amount of force needed to break the probe. The collapse load value should be less than what the roof can withstand. If the collapse load is reached, the probe will break before enough force is exerted on the roof to cause collapse. If the probe breaks, the process seal remains intact. It is important to keep the following in mind when planning for installation:

- In solid applications, media may cause pull down forces on silo roofs. The silo roof must be able to withstand the probe collapse load, or at least the maximum probe tensile load
- In solid applications, there might be considerable tensile load caused by the media. The tensile load of the media should not exceed the tensile strength of the probe. The tensile load depends on the silo size, material density, and the friction coefficient. Forces increase with the buried length, the silo and probe diameter. In critical cases, such as products with a risk of build-up, it is better to use a 0.24 in. (6 mm) probe
- Forces on probes, depending on their position, are generally two to ten times greater on probes that are anchored to the vessel. The probe end should not be fixed for 100 ft. (30 m) or longer probes

Table 5.16.3 shows guidelines for the tensile load from free-flowing solids acting on a suspended probe, free-hanging, not anchored to the vessel, in a silo with smooth metallic walls. A safety factor of 2 is included for the calculations. Consult the factory if more information is needed.

Material	Tensile load for 0.16 in (4 mm) flexible single lead probe, lb (kN)				Tensile load for 0.24 in (6 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= 39ft. (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
Plastic pellets	340 (1.5)	670 (3)	810 (3.6)	2360 (10.5)	450 (2)	920 (4.1)	1190 (5.3)	3510 (15.6)
Fly ash	770 (3.4)	1690 (7.5)	1980 (8.8)	5980 (26.6) Exceeds tensile strength limit	1130 (5)	2520 (11.2)	2950 (13.1)	8990 (40) Exceeds tensile strength limit
Coal dust	540 (2.4)	1190 (5.3)	1390 (6.2)	4230 (18.8) Exceeds tensile strength limit	790 (3.5)	1780 (7.9)	2070 (9.2)	6320 (28.1)
Cement	900 (4)	2020 (9)	2470 (11)	7310 (32.5) Exceeds tensile strength limit	1350 (6)	2920 (13)	3600 (16)	10790 (48) Exceeds tensile strength limit
Ground limestone	830 (3.7)	1820 (8.1)	2230 (9.9)	6650 (29.6) Exceeds tensile strength limit	1260 (5.6)	2740 (12.2)	3330 (14.8)	9960 (44.3) Exceeds tensile strength limit

Table 5.16.3: Tensile load values[(1)]

(1) A safety factor of 2 is included for the figures.

5.16.4 Mounting considerations

- 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 centered filling of the material cone
- The minimum recommended probe distance to tank wall or disturbing object is 20 in. (50 cm), unless the wall is comprised of smooth metal, then the distance is 4 in. (10 cm). In any case, the probe should not be able to touch the wall of the tank during operation
- 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 (LS option) is recommended to prevent the probe from contacting the nozzle

Figure 5.16.3: Recommended mounting position

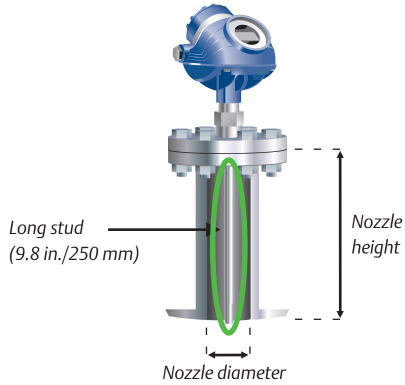


Figure 5.16.4: Recommended mounting position, nozzle

- Probe installation should occur when the silo is empty, and the probe should be regularly inspected for damage
- Avoid 10-in. (250 mm) / DN250 or larger diameter nozzles, especially in applications with low dielectric constant
- For environments where electrostatic discharges are likely to occur, e.g. plastics, it is recommended that the probe end is grounded with a proper grounding connection (R<1 Ohm)
- In case of non metallic tanks, a Rosemount 5303 should be mounted with a metal plate of minimum 8 in. (200 mm) diameter. Use metal shielding for the conduit connections

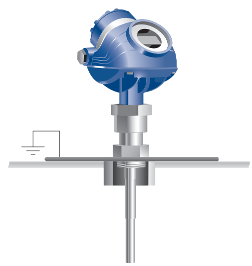


Figure 5.16.5: Installation with metal sheet in non-metallic vessels

- 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

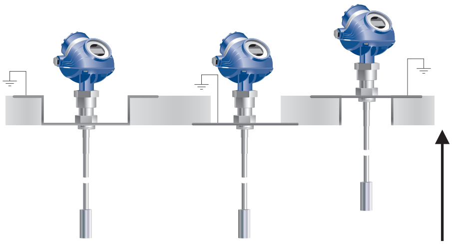


Figure 5.16.6: Installation in concrete silo with metal shielding

- To prevent an extremely high tensile load when fixing the probe, and to reduce the risk of probe breakage, the probe must be slack. Select a probe longer than the required measuring range so that there is a sag in the middle of the probe that is greater than or equal to 11/2 in. per 10 feet (1 cm per m) of the probe length

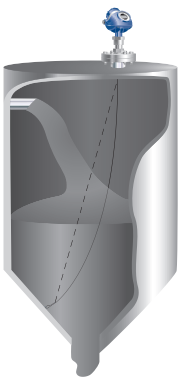


Figure 5.16.7: Fixing probe with slack

- For applications with a probe length longer than 115 ft. (35 m), please consult factory
- Consider using a non-contacting radar for abrasive media that can wear out the probe

5.16.5 Electrostatic discharges and electromagnetic interference

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 and attaching the end of the probe to the vessel will create ground paths for discharge away form the electronics. When the product can build up static electricity, the probe should be properly grounded (R<1 Ohm).

For further information grounding see section 12.5 .

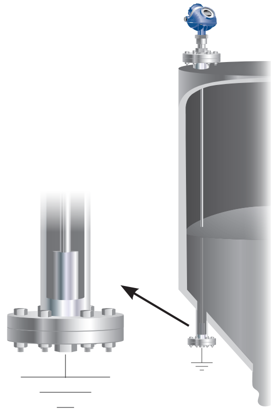


Figure 5.16.8: Grounding the probe end in products building up static electricity

The Rosemount 5303 uses a unique smart electromagnetic interference (EMI) filter, which filters out most common EMI from rotating equipment, motor controllers, and other sources. With severe EMI, the sensitivity may be reduced. Probe end projection offers additional measurement reliability

For probe end projection function see section 5.16.2.

In a metal silo there is no issue with EMI from rotating equipment, motor controllers, and other sources. To avoid issues with EMI in non-metallic silos, the transmitter's threshold settings should be checked and probe end projection should be activated.

NOTE!

Forces on probes, depending on their position, are generally two to ten times greater on probes that are anchored to the vessel.

5.17 Measuring ammonia with radar

Radar is a suitable method for measuring liquid ammonia. Since all Rosemount radar products have transmitter heads that can be serviced without breaching the tank atmosphere, radar is perfect for applications where tank openings must be minimized.

Emerson Process Management offers four different radar solutions: the Rosemount 5301 high performance guided wave radar, the Rosemount 3301 guided wave radar, the Rosemount 5601 non-contacting radar with 10 GHz frequency and the Rosemount 5400 non-contacting radar with 6 and 26 GHz frequencies.

This section offers guidelines for choosing the most suitable Rosemount radar depending on the liquid ammonia application.

5.17.1 Aqueous ammonia (NH4OH)

Liquid aqueous ammonia (ammonium hydroxide or ammonium hydrate) is a suitable application for both guided wave radar and non-contacting radar. Any Rosemount radar is suitable for these applications.

However, these tanks sometimes require isolation valves. It is not possible to use guided wave radar with valves unless a bypass pipe is used. If a valve is required, it must be a full port valve so the inside of the nozzle is smooth. The Rosemount 5402 non-contacting with a process seal antenna is preferred with valves because its higher frequency allows better signal propagation down the nozzle.

Other liquid ammonia solutions such as ammonia chloride will work with radar technology similarly to liquid aqueous ammonia.

5.17.2 Anhydrous ammonia (NH3)

Liquid anhydrous ammonia is difficult to measure because it produces heavy vapors that attenuate radar signals. As the storage pressure increases, the density of vapors will increase. With heavier vapors, signal attenuation is increased. Lower frequency radar signals are less attenuated than higher frequencies. Since guided wave radar operates with a low frequency pulse, it will have minimal signal attenuation in heavy vapors. Therefore, guided wave radar works better than non-contacting radar in high-pressure applications.

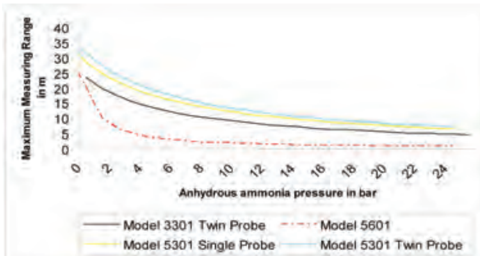
During operation, product boiling may affect the radar reflection. If guided wave radar or a 5601 in a still pipe is used, the effect will be minimized.

There are two main types of anhydrous ammonia applications:

1. Larger chilled tanks, 33-75 feet (10-23 m) high, with temperatures approximately -40 °F (40 °C) and with pressure up to 29 psig (2 bar). In these applications, the 3301, 5301 or the 5601 can be used (see figure 5.17.1: Measuring range graph)
2. Smaller pressurized tanks, 3 - 33 feet (1-10 m) high, with pressure to 145 psig (10 bar). Here, guided wave radar has an advantage as compared to non-contacting

The 5400 non-contacting radar transmitter is not recommended in anhydrous ammonia applications.

If there is a nozzle with full port valves, the 5601 may be used. Since valves give uncontrolled microwave performance, a test installation is required.



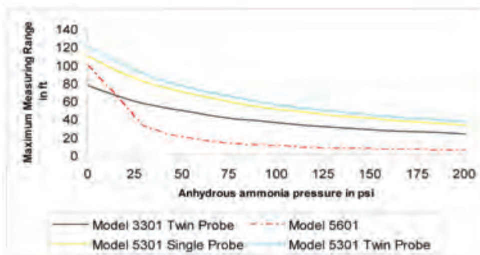


Figure 5.17.1: Measuring range graph

See section 5.17.5 - Material compatibility for further information

5.17.3 Probe/antenna selection

For the 3301, the coaxial probe (up to 19.7 feet/6 m) is preferred but the flexible twin lead probe will work as well. Any of the probe types may be used with the 5300.

The preferred mounting location for the 5601 is on a still pipe. A 4-in. pipe with a 4-in. cone antenna is recommended. Eight-inch pipes should be avoided. If the gauge is to be mounted on a nozzle, a larger cone antenna (6- or 8-in.) is recommended.

In aqueous ammonia vessels with taller nozzles, the 5402 with a PTFE seal may be used. This helps to reduce signal attenuation in taller vessels.

5.17.4 Measuring range

For aqueous ammonia, the measuring range is not limited by signal attenuation from the vapors. *(See the appropriate product data sheet.)*

The graphs give guidelines for the maximum possible measuring range in anhydrous ammonia depending on the maximum pressure. If a still pipe is used for the 5601, the maximum measuring range can be improved.

5.17.5 Material compatibility

Material compatibility is ultimately the user's decision. Compatibility may vary with material concentration, temperature and if in a liquid or gas form. In the case of the radar products, the process seal of the standard units is a combination of PTFE and o-rings. The optional high pressure probe of the guided wave radar products contains a ceramic process seal and no o-rings. It should be considered if unsure of o-ring compatibility. Viton o-rings are not recommended in ammonia applications.

5.18 High pressure steam applications

5.18.1 Phase changes

It is especially common during startup to experience varying temperature and pressure. Both the liquid and steam phases of the system will have density changes as the system reaches the operating temperature and pressure which can cause up to 30% error over temperature up to 600 °F (315 °C), as seen in figure 5.18.1 and table 5.18.1.

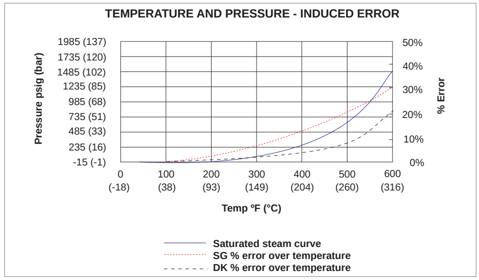


Figure 5.18.1: Temperature and pressure graph. Both the density (SG) and dielectric (DK) properties of water and steam change with pressure and temperature. If not compensated, significant errors may occur.

Any density-based level measurement device will need compensation to discern the actual level from the density-associated errors. Algorithms have been developed to make this compensation as seamless as possible in the control systems, b ut require input of operating pressure as well as level. Compensation can be slow which results in erroneous reading.

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

Even though the dielectric of water decreases with temperature increase, the level can be measured as long as the water dielectric remains sufficiently high, which results in a reflection back from the surface. However, as the temperature increases, the dielectric difference between the liquid and the steam becomes smaller, and at a certain point, it will be too small for reliable measurement with radar transmitters.

Between 2610 psi (180 bar) and 2900 psi (200 bar), the dielectric difference between steam and water becomes too small to offer reliable level measurement. In this case, GWR is no longer suitable.

Below 2610 psi (180 bar), GWR is a suitable means of measurement if compensation for the dielectric of the steam dielectric is completed.

Temp. °F/°C	Pressure psia/bar	DK of liquid	DK of vapor	Error in distance %
100/38	1/0.1	73.95	1.001	0.0
200/93	14/1	57.26	1.005	0.2
300/149	72/5	44.26	1.022	1.1
400/204	247/17	34.00	1.069	3.4
500/260	681/47	25.58	1.180	8.6
600/316	1543/106	18.04	1.461	20.9
618/325	1740/120	16.7	1.55	24.5
649/343	2176/150	14.34	1.8	34.2
676/358	2611/180	11.86	2.19	48
* 691/366	2900/200	9.92	2.67	63.4
* 699/370	3046/210	8.9	3.12	76.6
* 702/372	3120/215	Above critical point, distinct liquid and gas phases do not exist.		

Table 5.18.1: Table showing the error in distance with changing temperature and pressure, without vapor compensation.

**Maximum limit for GWR is 180 bar, other solutions should be used for applications over this pressure limit.*

5.18.2 Extreme high pressures and temperatures

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

5.18.3 Magnetite coating

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

5.18.4 Heavy vibrations

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

5.18.5 Advantages of GWR over other techniques

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

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

5.18.6 Vapor compensation functionality

In the Rosemount 5300 Series Superior Performance GWR, there are two functions to compensate for the vapor dielectric:

- Static Vapor Compensation
- Dynamic Vapor Compensation (DVC)

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

As it can be seen in table 5.18.1, at 247 psia (17 bar), there is an error in distance of 3.4 %. At 1543 psia (106 bar), there is an error of 20.9 % when there is no compensation for the vapor dielectric.

The error in distance increases with the pressure, and at some point this deviation is not negligible and must be taken into account in order to get high accuracy.

5.18.7 Standard function: Static Vapor Compensation

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

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

5.18.8 Optional function: DVC

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

Vapor dielectric does not affect the measurement accuracy until the pressure is higher than 145 psia (10 bar). Dynamic Vapor Compensation (DVC) should be considered when the pressure is above 247 psia (17 bar) when the error is more than 2%, *see table 5.18.1*. In these cases, DVC can bring the error back to 2%, or in some conditions even down to 1%.

Application and installation conditions, such as a lower temperature in the bypass chamber, can cause changes within the measured media. Therefore, the error readings can vary depending on the application conditions and may cause an increase of the measuring error by a factor of 2 to 3.

DVC works by using a target at a fixed distance. With this target, the vapor dielectric is measured continuously.

The transmitter knows where the reflector pulse should have been if there were no vapor present. However, since there is vapor in the tank, the reflector pulse appears beyond the actual reflector point.

The distance between the actual reflector point and the apparent reflector point is used to calculate the vapor dielectric. The calculated dielectric is then dynamically used to compensate for vapor dielectric changes and eliminates the need to do any compensation in the control system.

When the distance between the mounting flange and the surface is less than 22 in. (560 mm) for the short reflector and 28 in. (710 mm) for the long reflector, the function switches from dynamic to static vapor compensation using the last known vapor dielectric constant.

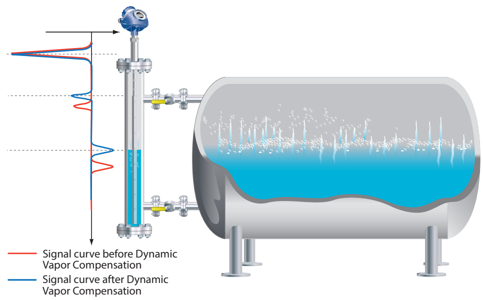


Figure 5.18.2: Radar signal curve before and after vapor compensation

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

5.18.9 Rosemount design advantages

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

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

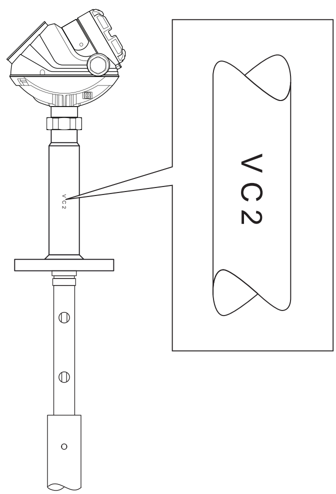


Figure 5.18.3: Probe with reference reflector marked “VC2” for recognition

5.18.10 The GWR probe design provides multiple layers of protection

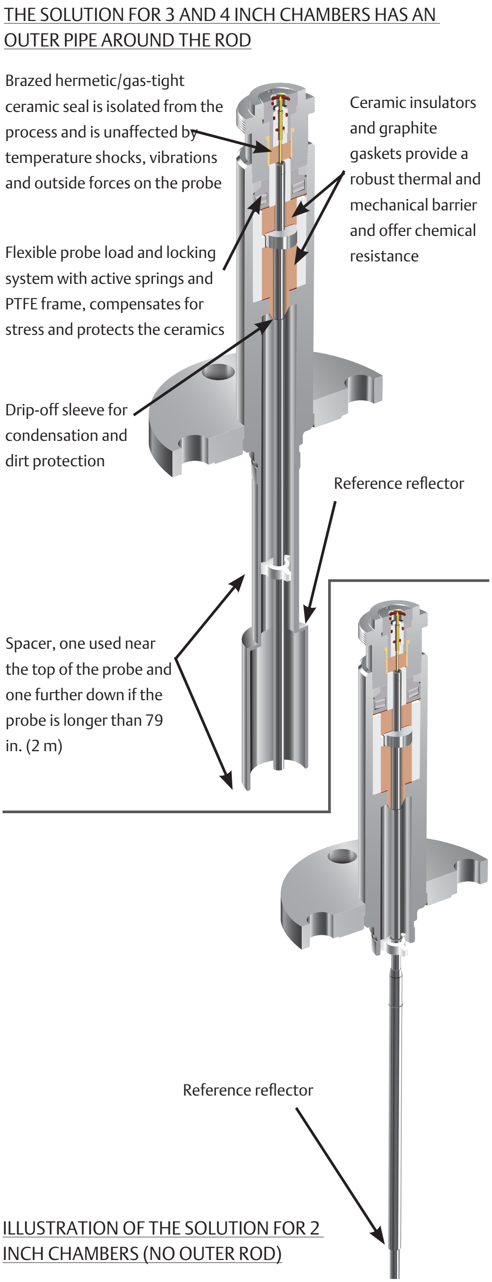


Figure 5.18.4: HTHP seal

5.18.11 DVC installation best practices

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

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

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

Probes up to 13.1 ft. (4 m) length are supported for DVC.

DVC 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 5.11.7*) is 22 in. (560 mm) for the short reflector and 28 in. (710 mm) for the long reflector (*see table 5.18.2 below*), to dynamically compensate up to 100%.

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

Probe length	Reflector	Minimum distance X
35 in. - 158 in (900 mm - 4000 mm)	14 in. (350 mm)	22 in. (560 mm)
43 in. - 158 in (1100 mm - 4000 mm)	20 in. (500 mm)	28 in. (710 mm)

Table 5.18.2: Minimum distance X.

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

If an existing chamber is used which does not meet these space requirements, a spool piece can be added. For an installation with a spool piece with the 2 in. DVC solution, it is important to make sure that the reference reflector and the spool piece do not have the same length.

The spool piece needs to be at least 2 in. (50 mm) longer or shorter. For a spool piece with the 3 and 4 in. DVC solution, this is not a requirement.

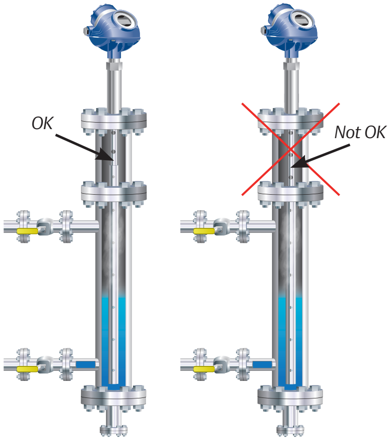


Figure 5.18.5: If a spool piece is used with the probe designed for 2" chambers, it is important that the reference reflector and the spool piece do not have the same length.

While keeping the minimum distance requirements described above, it is also important to limit the overall distance from the flange to where the level is controlled (*indicated by A in figure 5.18.6 below*). This is because, as previously explained, the high pressure affects the dielectric properties of the vapor causing an error in distance measured. The overall error increases with the pressure and is a percentage of distance measured.

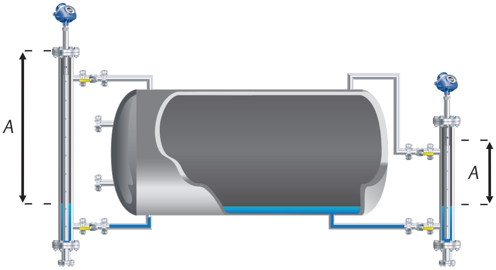


Figure 5.18.6: Limiting the overall distance A helps to minimize accuracy errors caused by the vapor.

Distance A	Error with no correction	Error corrected to 2% with DVC
100 in. (2540 mm)	- 7.6 in. (- 193 mm)	- 2 in. (- 50.8 mm)
50 in. (1270 mm)	- 3.8 in. (- 96.5 mm)	- 1 in. (- 25.4 mm)

Table 5.18.3: Table showing the error in distance with and without DVC at a pressure of 600 psi (41 bar).

5.18.12 How to choose reflector length

The long reflector, 20 in. (500 mm), has the best accuracy and is recommended for all chambers where the dimensions of the chamber allow for it.

If the distance from the flange to the upper inlet is less than 28 in. (710 mm), the short reflector should be chosen.

This distance is a minimum when dynamic compensation is required within the whole measuring range from the lower to the upper inlet. If this is not required, the long reflector can be used and dynamic compensation is possible up to 28 in. (710 mm) from the flange.

However, always ensure that there are no disturbances from inlets etc close to the reference reflector end when using the 2 inch DVC solution.

5.18.13 Calibration

When a transmitter is ordered with the optional DVC, the function is activated from factory and the special probe is supplied. For the 2 inch solution, a calibration procedure is needed on-site during the commissioning phase. For the 3 and 4 inch solution, the transmitter is calibrated from factory and no calibration on site is normally needed. There are however two cases where a calibration procedure is needed for the 3 and 4 inch solution; if the transmitter is reset to factory settings which will delete the DVC calibration, or if a different transmitter head is mounted on the DVC probe.

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

For best performance, it is recommended that the chamber is cleared of any steam and/or condensate prior to the calibration. See the Reference Manual supplied with the transmitter for details on the calibration procedure.

Note that Probe End Projection and Signal Quality Metrics are disabled when DVC is enabled.

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

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

5.18.14 Remote housing

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

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

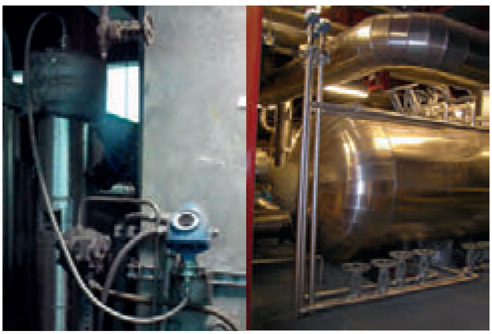


Figure 5.18.7: The Rosemount 5300 series superior performance GWR with DVC measures level accurately in high pressure steam applications and can help to prevent wet steam carryover to turbine, poor heat exchanger performance and un-optimized drum level control. The remote housing connection is available in lengths of 3.2 ft (1 m), 6.5 ft (2 m), or 9.8 ft (3 m).

6

Non-contacting radar installation guidelines

Topic | Page

6. Non-contacting radar installation guidelines

There are two series of Rosemount non-contacting radars; the 5400 series and the 5600 series. The 5400 series is the superior performance 2-wire transmitter, suitable for most applications. The 5600 series is the 4-wire transmitter for challenging applications.

There are different frequencies for different transmitters and the frequency can impact the measurement performance. Low frequency is preferred when measuring in vapor and foam. High frequency is preferred in most other applications due to greater mounting flexibility.

The Rosemount non-contacting radars come in two different frequencies:

5402: high frequency - 26GHz

- Best fit for most applications
- Fewer installation considerations
- Narrow beam angle avoids disturbances more easily
- More focused energy provides longer measuring range

5401/5600: low frequency - 6/10 GHz

- Longer wave lengths penetrate foam and heavy vapor and condensation more easily
- Wide beam angle can in some cases pass disturbances more easily (when the disturbance echo is located directly under the radar)

Table 6.1.1 also gives further guidance in choosing the right model for your application.

6.1 Antenna selection

Model and antenna guide	5402		5401		5601[1]	
This table gives guidelines on which model and antenna to select, depending on application.	**Cone (preferred)**	**Process seal**	**Cone (preferred)**	**Rod**	**Cone**	**Parabolic**
G=Good **AD=Application dependent** (consult your local Emerson representative) **NR=Not Recommended**						
	Best choice for a broad range of applications, free propagation and pipe installations.	Ideal for small tanks and corrosive applications. Also good for heavy antenna condensation/ build-up.	Suitable for some extrem process conditions.	Suitable for small process connections, and corrosive environment.	Suitable for some extreme process conditions. Higher temp difficult process conditions.	Superior microwave management. Require large tank opening. Best choice for solids, long range.[2]
Tank considerations						
Installation close to smooth tank wall	G	G	G	G	AD min 600 mm	AD min 600 mm
Multiple units on the same tank	G	G	G	G	G	G
Internal obstructions, directly in path	NR	NR	AD	AD	AD	AD
Internal obstructions, avoidance[3]	G	G	NR	NR	AD	AD
Beam angle	2" 19° 3" 14° 4" 9°	2" 19° 3" 14° 4" 9°	4" 37° 6" 23° 8" 17°	37°	3" 25° 4" 21° 6" 18° 8" 15°	10°
Antenna extends below nozzle	G	G	G	G	G	G
Antenna recessed in smooth nozzle up to 6 ft (2 m)	G	G	AD[4]	NR[5]	AD[4]	AD[4]
Antenna recessed in nozzle with irregularities, such as bad welds	AD[4]	AD	AD[4]	NR[5]	AD[4]	AD[4]
Stilling well mounting	G 2"-4" pipe	G 2"-4" pipe	G 3"-8" pipe	NR	G 3"-6" pipe	NR
Valves	G	G	NR	NR	AD	NR
Long ranges (>115´/ 35m)	NR	NR	NR	NR	NR	G
Cleanability of antenna	AD	G	AD	G	AD	G

Table 6.1.1: Transmitter model and antenna selection of the Rosemount 5400 series based on different tank considerations

(1) *The obstruction should not be within the radar beam. Preferred choices due to more narrow radar beam: Model 5402, and cone antenna.*

(2) *An extended cone antenna can be used.*

(3) *The active part must protrude beneath the nozzle.*

Model and antenna guide	5402		5401		5601[1]	
This table gives guidelines on which model and antenna to select, depending on application.	**Cone (preferred)**	**Process Seal**	**Cone (preferred)**	**Rod**	**Cone**	**Parabolic**
G=Good **AD=Application Dependent** (consult your local Emerson representative) **NR=Not Recommended**						
Process medium characteristics						
Vapor (light, medium)	G	G	G	G	G	G
Vapor (heavy)	NR	AD	G	G	G	G
Condensing vapor/product build-up[2]	AD	G	G	AD	G	G
Boiling/Turbulent surface (low/medium)	G	G	G	G	G	G
Boiling/Turbulent surface (heavy)	AD	AD	G[3]	NR	G	G
Boiling/Turbulent surface (still-pipe)	G	G	G	NR	G	G
Foam[4])	NR	NR	AD	AD	AD	AD
Foam (still-pipe)[4]	G	G	G	NR[5]	G	G
Corrosive products (options available)	G[5]	G[5]	G[5]	G[5]	G[5]	G[5]
Materials with very low dielectric	G	G	G	AD	G	G
Changing density/dielectric/ pH/ pressure/temperature	G	G	G	G	G	G
Coating/viscous/crystallizing liquids	G	G	G	G	G	G
Solids, granules, powders	NR	NR	NR	NR	AD[(6)]	G[(6)]

Table 6.1.2: Transmitter model and antenna selection of the Rosemount 5400 series based on different process medium characteristics.

(4) *Build-up can often be avoided or reduced by using heat-tracing or cleaning arrangements.*
(5) *Use a 6 or 8 in. (150-200 mm) cone antenna.*
(6) *Foam can either reflect, be invisible, or absorb the radar signal. Pipe mounting is advantageous since it reduces the foaming tendency.*

6.2 Measuring range

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. The figures in the tables below are guidelines for optimum performance. Larger measuring ranges may be possible. For more information, contact your local Emerson Process Management representative.

A. Oil, gasoline or other hydrocarbons, and petrochemicals (DC = 1.9-4.0). In pipes or with ideal surface conditions, for some liquefied gases (DC = 1.4-4.0)

B. Alcohols, concentrated acids, organic solvents, oil/water mixtures, and acetone (DC = 4.0-10.0).

C. Conductive liquids, e.g. water based solutions, dilute acids, and alkalis (DC > 10.0).

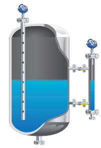
High frequency antennas Units: ft (m)									
	Dielectric constant								
	A	B	C	A	B	C	A	B	C
2-in. cone / process seal	33 (10)	49 (15)	66 (20)	82 (25)	115 (35)	115 (35)	9.8 (3)	20 (6)	33 (10)
3-in. cone / process seal	49 (15)	66 (20)	98 (30)	82 (25)	115 (35)	115 (35)	13 (4)	30 (9)	39 (12)
4-in. cone / process seal	66 (20)	82 (25)	115 (35)	82 (25)	115 (35)	115 (35)	23 (7)	39 (12)	49 (15)

Table 6.2.1: Maximum recommended measuring range for the Rosemount 5402 model.

Low frequency device Units: ft (m)									
	Dielectric constant								
	A	B	C	A	B	C	A	B	C
3-in. cone[1]	NA	NA	NA	82 (25)	115 (35)	115 (35)	NA	NA	NA
4-in. cone / rod[2]	23 (7)	39 (12)	49 (15)	82 (25)	115 (35)	115 (35)	13 (4)	26 (8)	39 (12)
6-in. cone	43 (13)	66 (20)	82 (25)	82 (25)	115 (35)	115 (35)	20 (6)	33 (10)	46 (14)
8-in. cone	66 (20)	82 (25)	115 (35)	82 (25)	115 (35)	115 (35)	26 (8)	39 (12)	52 (16)

Table 6.2.2: Maximum recommended measuring range for the Rosemount 5401 model.

(1) *Stilling well installations only. NA = not applicable*
(2) *Stilling well installations are not allowed with rod antennas*

Rosemount 5600 Series Units: ft (m)									
	Dielectric constant [1]								
	A	B	C	A	B	C	A	B	C
3-in. cone	52 (16)	72 (22)	92 (28)	30 (9)	39 (12)	52 (16)	16 (5)	20 (6)	21 (6.5)
4-in. process seal	49 (15)	51 (15.5)	59 (18)	31 (9.5)	34 (10.5)	41 (12.5)	8 (2.5)[2]	11 (3.5)[2]	20 (6)[2]
6-in. process seal	59 (18)	67 (20.5)	80 (24.5)	36 (11)	41 (12.5)	54 (16.5)	10 (3)[2]	20 (6)[2]	23 (7)[2]
4-in. cone	82 (25)	89 (27)	98 (30)	52 (16)	59 (18)	71 (21.5)	10 (3)	21 (6.5)	33 10
6-in. cone	98 (30)	112 (34)	131 (40)	66 (20)	80 (24.5)	92 (28)	21 (6.5)	33 (10)	43 (13)
8-in. cone	115 (35)	148 (45)	164 (50)	85 (26)	95 (29)	107 (32.5)	26 (8)	46 (14)	52 (16)
Parabolic	131 (40)	164 (50)	164 (50)	98 (30)	115 (35)	131 (40)	46 (14)	82 (25)	98 (30)
3-6-in. cone in still pipe	-	-	-	-	-	-	164 (50)	164 (50)	164 (50)

Table 6.2.3: Maximum recommended measuring range for the Rosemount 5600, ft (m).

(1) A. Oil, gasoline and other hydrocarbons, petrochemicals
B. Alcohols, concentrated acids, organic solvents, oil/water mixtures, and acetone
C. Conductive liquids, e.g. water based solutions, dilute acids, and alkalis
(2) Not recommended.

6.3 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)
- Because of circular polarization, there is no clearance distance requirement from the tank wall if it is flat and free of obstructions such as heating coils and ladders (F). Usually, the optimal location is 1/4 of the diameter from the tank wall
- The antenna is normally aligned vertically

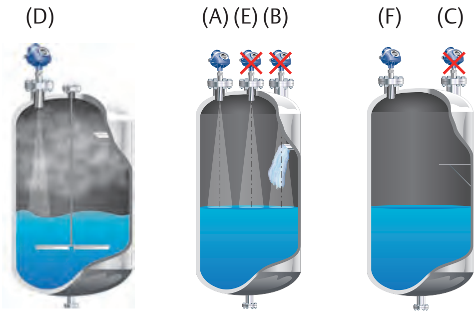


Figure 6.3.1: It is important to consider the proper mounting location

- A metal still-pipe can be used to avoid disturbing objects, turbulence, and foam (G)
- 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 5400 transmitters can be used in the same tank without interfering with each other (H)

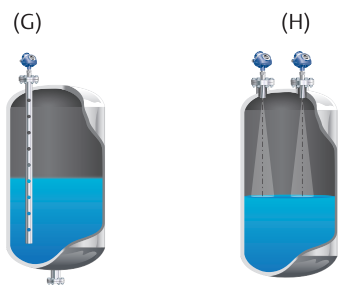


Figure 6.3.2: Mounting in a still pipe and mounting multiple 5400 transmitters in the same tank

6.4 Nozzle considerations

Special considerations may have to be taken because of the nozzle, depending on the selection of transmitter model and antenna.

<u>5402 with cone antenna</u>

The antenna can be recessed in smooth nozzles up to 6 ft (2 m). If the inside of the nozzle contains disturbing objects, use the extended cone (I).

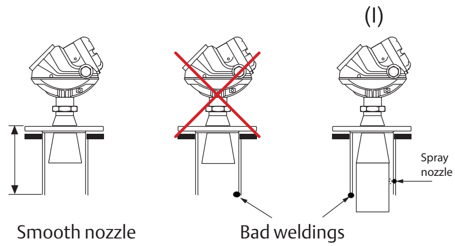


Figure 6.4.1: Nozzle considerations for 5402 with cone antenna

<u>5402 with process seal antenna</u>

The antenna can be used on nozzles up to 6 ft (2 m), (J). Disturbing objects inside the nozzle (K) 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 Process Management representative for advice.

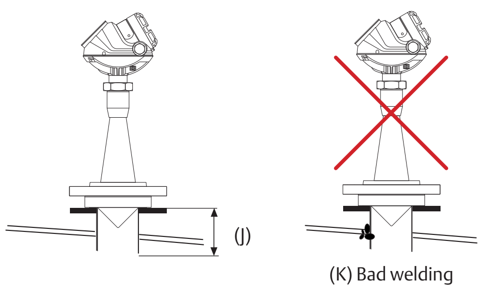


Figure 6.4.2: Nozzle considerations for 5402 with process seal antenna

<u>5401 with cone antenna</u>

The antenna should extend 0.4 in. (10 mm), or more, below the nozzle (L). If required, use the extended cone solution.

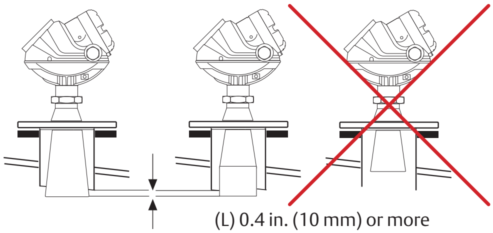


Figure 6.4.3: Nozzle considerations for 5401 with cone antenna

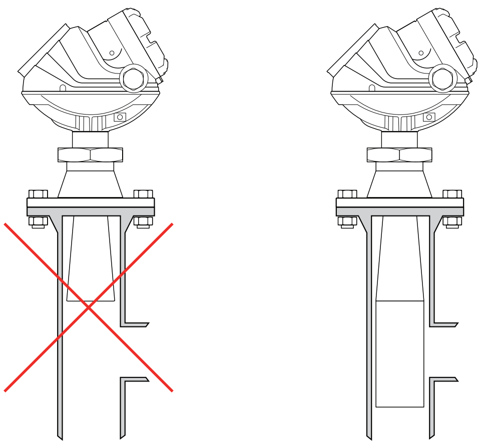


Figure 6.4.4: Cone antenna considerations for T-connections

5401 with rod antenna

The active part of the rod antenna should protrude below the nozzle (M).

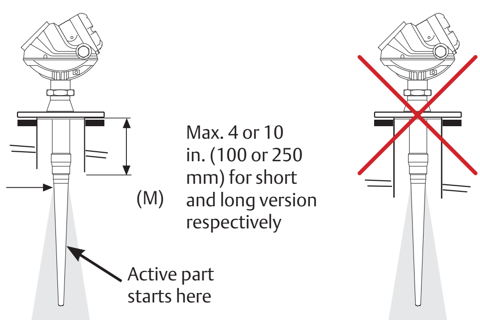


Figure 6.4.5: Nozzle considerations for 5401 with rod antenna

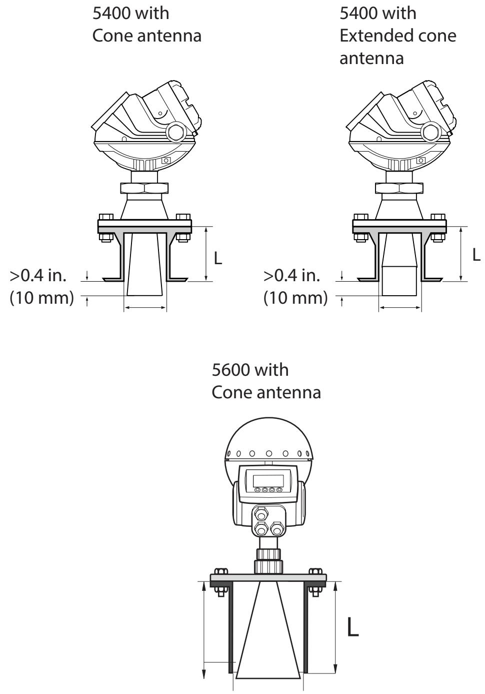


Figure 6.4.6: Nozzle requirements for Rosemount non-contacting radars

See also table 6.4.1 on next page.

Transmitter model	Antenna type/size/material	L (in. (mm))
5402[1]	Cone 2 in. (50 mm) SST	6.1 (155)
	Cone 3 in. (75 mm) SST	5.5 (140)
	Cone 4 in. (100 mm) SST	8.5 (215)
	Cone 2 in. (50 mm) Alloy C-276, Alloy 400	5.5 (140)
	Cone 3 in. (75 mm) Alloy C-276, Alloy 400	6.5 (165)
	Cone 4 in. (100 mm) Alloy C-276, Alloy 400	9.6 (240)
	Process seal. PTFE, 2,3,4"	19.7, (500 mm) for all sizes
5401	Cone 3 in. (75 mm) SST	Pipe installations only
	Cone 4 in. (100 mm) SST	5.5 (140)
	Cone 6 in. (150 mm) SST	6.9 (175)
	Cone 8 in. (200 mm) SST	10.2 (260)
	Rod antenna, 4” inactive area, PTFE	4” (100 mm)
	Rod antenna, 10” inactive area, PTFE	10" (250 mm)
	Cone 3 in. (75 mm) Alloy C-276, Alloy 400	Pipe installations only
	Cone 4 in. (100 mm) Alloy C-276, Alloy 400	5.5 (140)
	Cone 6 in. (150 mm) Alloy C-276, Alloy 400	6.9 (175)
	Cone 8 in. (200 mm) Alloy C-276, Alloy 400	10.2 (260)
5600	Cone 3 in.	3.7 (95) or less
	Cone 4 in.	5.9 (150) or less
	Cone 6 in.	10.2 (260) or less
	Cone 8 in.	14.6 (370) or less
	Parabolic	6.3 (160) or less
	Process Seal 4 in.	11.8 (300) or less
	Process Seal 6 in.	11.8 (300) or less
	Extended Cone 3 in.	19.5 (495) or less
	Extended Cone 4 in.	19.5 (495) or less
	Extended Cone 6 in.	19.5 (495) or less
	Flushing Cone 4 in.	5.9 (150) or less
	Flushing Cone 6 in.	10.2 (260) or less
	Flushing Cone 8 in.	14.6 (370) or less

Table 6.4.1: Minimum nozzle diameter and maximum nozzle height for the Rosemount non-contacting radars

(1) *Rosemount 5402 can be used in nozzles up to 2m, the values for nozzle height are recommendations.*

Extended cone antennas are available up to 20” (500 mm) for all units.

NOTE!

For 5600 with parabolic antennas mounted in solid applications, minimize the L distance to allow the parabolic antenna to reach into the tank. *See section 6.13 for information on measuring solids with non-contacting radar.*

6.5 Service space

For easy access to the transmitter, mount it with sufficient service space.

There is no requirement on clearance distance from the tank wall, provided it is flat and free of obstructions such as heating coils and ladders. The optimal location is often 1/4 of the tank diameter.

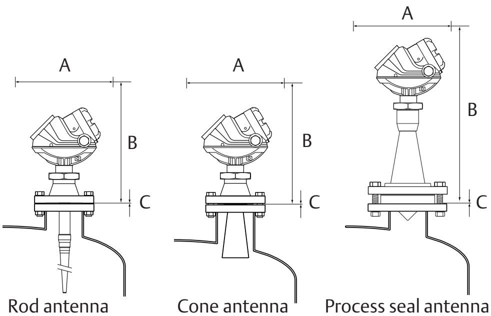


Figure 6.5.1: Service space recommendations for the Rosemount 5400

Service space		Distance inch (mm)
A	Cone, rod, process seal	20 (500)
B	Cone, rod	24 (600)
	Process seal	33 (850)
Inclination		Maximum angle
C	Cone, rod, process seal	3°

Table 6.5.1: Service space recommendations for the Rosemount 5400

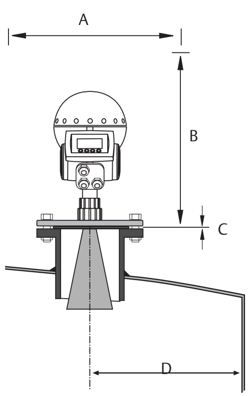


Figure 6.5.2: Service space requirements for the Rosemount 5600

A. Service space width	Distance in. (mm)
All antennas	22 (550)
B. Service space height	
Antenna	**Distance in. (mm)**
Cone, extended cone, flushing cone	25 (650)
Process seal	31 (800)
Parabolic	27 (700)
C. Inclination	
Antenna	**Maximum angle**
Cone	1°
Process seal	3°
Parabolic	3°
D. Minimum distance to tank wall [1]	
Antenna	**Distance in. (mm)**
All antennas	24 (600)

Table 6.5.2: Service space requirements for the Rosemount 5600

[1] *Mounting closer to the tank wall may be allowed if reduced accuracy is accepted.*

6.6 Beam width

The following recommendations should be considered when mounting the transmitter:

- The transmitter should be mounted with as few internal structures as possible within the beam angle
- 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

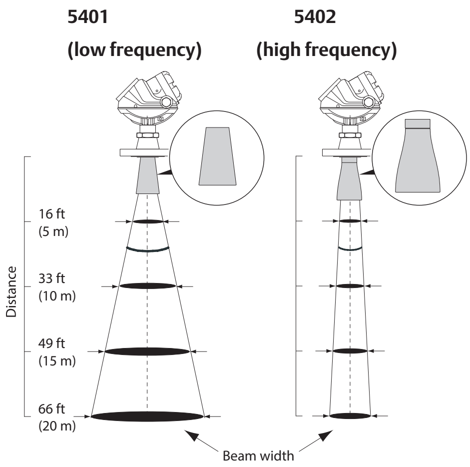


Figure 6.6.1: Beam width at various distances from the flange for the Rosemount 5400

Distance	Antenna		
	2 in. (DN 50) cone/ process seal	3 in. (DN 80) cone/ process seal	4 in. (DN 100) cone/ process seal
	Beam width ft (m)		
16 ft (5 m)	4.9 (1.5)	3.3 (1.0)	3.3 (1.0)
33 ft (10 m)	9.8 (3.0)	6.6 (2.0)	4.9 (1.5)
49 ft (15 m)	14.8 (4.5)	9.8 (3.0)	8.2 (2.5)
66 ft (20 m)	19.7 (6.0)	13.1 (4.0)	9.8 (3.0)

Table 6.6.1: Beam width for the Rosemount 5402 model

Distance	Antenna		
	4 in. (DN 100) cone /rod	6 in. (DN 150) cone	8 in. (DN 200) cone
	Beam width ft (m)		
16 ft (5 m)	11.5 (3.5)	6.6 (2.0)	4.9 (1.5)
33 ft (10 m)	23.0 (7.0)	13.1 (4.0)	9.8 (3.0)
49 ft (15 m)	32.8 (10)	19.7 (6.0)	14.8 (4.5)
66 ft (20 m)	42.7 (13.0)	26.2 (8.0)	19.7 (6.0)

Table 6.6.2: Beam width for the Rosemount 5401 model

Figure 6.6.2: Beam angle for the Rosemount 5400

Antenna	Beam angle
2 in. (50 mm) cone / process seal	19°
3 in. (75 mm) cone / process seal	14°
4 in. (100 mm) cone / process seal	9°

Table 6.6.3: Beam angle for the Rosemount 5402

Antenna	Beam angle
3 in. (75 mm) cone	Pipe installations only
4 in. (100 mm) cone / rod	37°
6 in. (150 mm) cone	23°
8 in. (200 mm) cone	17°

Table 6.6.4: Beam angle for the Rosemount 5401

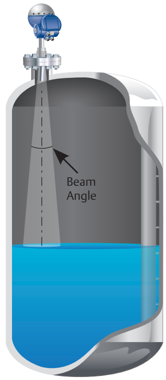


Figure 6.6.3: Beam width angle for the Rosemount 5600

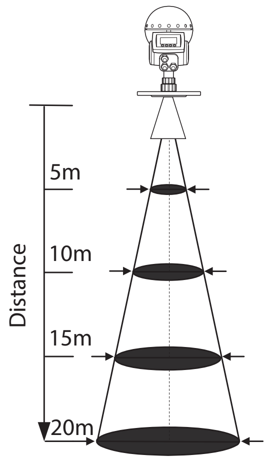


Figure 6.6.4: Beam width distance for the Rosemount 5600

Antenna	Beam width
Cone 3 in.	25°
Cone 4 in./Process seal 4 in.	21°
Cone 6 in. / Process seal 6 in.	18°
Cone 8 in.	15°
Parabolic	10°

Table 6.6.5: Beam width angle for the Rosemount 5600 for different antenna types

Antenna	Diameter of radiated area at different distances from flange, ft. (m)			
	16 ft. (5 m)	33 ft. (10 m)	49 ft. (15 m)	66 ft. (20 m)
Cone 3 in.	7.2 (2.2)	14 (4.4)	22 (6.7)	29 (8.9)
Cone 4 in. / Process seal 4 in.	6.2 (1.9)	12 (3.7)	18 (5.6)	24 (7.4)
Cone 6 in. / Process seal 6 in.	5.2 (1.6)	10 (3.1)	15 (4.7)	21 (6.3)
Cone 8 in.	4.3 (1.3)	8.5 (2.6)	13 (3.9)	17 (5.3)
Parabolic	3.0 (0.9)	5.6 (1.7)	8.5 (2.6)	11 (3.5)

Table 6.6.6: Beam width distance for the Rosemount 5600

6.7 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. The Rosemount 5400 series has built-in functions which optimize measurement performance for various bottom shapes.

6.8 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.

The Rosemount 5402 has a more narrow radar beam that 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.

6.9 Valves

The 5400 Series transmitter can be isolated from the process by using a valve:

- Use a full-port ball valve
- The 5402 is required, and the process seal antenna is the preferred choice, since it does not require a spool piece. The cone antenna can also be used
- Ensure there is no edge between the ball valve and the nozzle/pipe, the inside should be smooth

Valves can be combined with pipes.

6.10 Mounting in chamber/stilling well

When radar transmitters are used in metallic pipes, the microwave signal is guided and contained within the pipe. This restriction of the signal results in a stronger signal on the surface which can be an advantage for low dielectric and/or turbulent applications. Non-contacting radar can be advantageous over longer distances especially when the use of GWR is not convenient.

6.10.1 The impact of frequency

When radar is used inside the pipe, more than one microwave mode is generated and each mode has a unique propagation speed. The number of microwave modes that are generated varies with the frequency of the radar signal and the pipe diameter. Emerson Process Management recommends using a 2-in. or 3-in. pipe to minimize the number of microwave modes. The use of higher frequency radar transmitters should be restricted to smaller diameters. Conversely, lower frequency units perform better than higher frequency units on larger diameter pipes. Non-contacting radar transmitters should not be used on pipes larger than 8-in.

Low frequency radar handles dirty pipes, heavy vapors, and condensation better than high frequency units. High frequency may have slightly better performance, but should be used on clean applications. High frequency has better tolerance for installations that may not meet all mechanical requirements.

5401 is not recommended for chambers as its wider pulse frequency makes it sensitive for disturbances generated by the inlets and compromise level measurements nearby those areas.

6.10.2 Choosing the right antenna

The 5400 and 5600 Series transmitters offer a wide range of antennas, including rod antennas, Cone antennas, and process seal antennas. Of these, the cone antenna is the only suitable antenna for level measurement in pipes. All units are available with SST, alloy C-276, and alloy 400 antennas.

With any radar unit, the antenna should match the pipe size as closely as possible. The antennas are sized to fit within schedule 80 or lower pipes.

Ideally, the maximum gap between the antenna and the pipe wall should be as small as possible *see "A" in figure 6.10.1 on the next page*. For the 5600, gaps of up to 10 mm are acceptable.

For the 5400, gaps of up to 5 mm are acceptable. Larger gaps may result in inaccuracies.

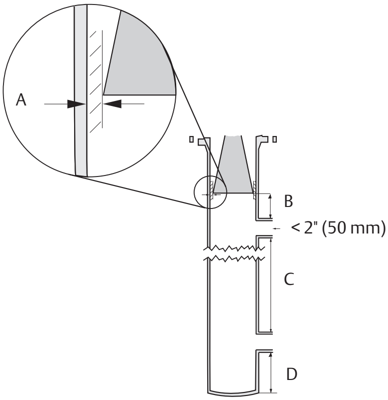


Figure 6.10.1: Pipe installation dimensions

	5401	5402	5600
A: Maximum gap between antenna and pipe[1]	5 mm (0.2”)	5 mm (0.2”)	10 mm (0.4”)[2]
B: Min distance between antenna and inlet pipe	NR[3]	50 mm (2”)	100 mm (4“)
C: Minimum distance between inlets	NR	500 mm	500 mm
D: Minimum distance between lower inlet and bottom of pipe	NR	150 mm	150 mm
Minimum dielectric constant	1.6	1.6	1.4
Availability per pipe size			
2” pipe	NA[3]	Yes[4]	NA
3” pipe	Yes	Yes	Yes
4” pipe	Yes	Yes	Yes
6” pipe	Yes	NR	Yes
8” pipe	Yes	NR	NR
Can be used with full port valve	Yes	Yes	Yes

Table 6.10.1: Installation guidelines for non-contacting radar

(1) In difficult measurement conditions (dirty pipes, steam, echoes from inlet pipes, welds, or valves), accuracy and range will be improved with a tighter fit between pipe and antenna.

(2) In bypass chambers, the gap should be as small as possible.

(3) NA = Not Available and NR= Not Recommended

(4) Fits schedule 40 or lower pipes

6.10.3 Stilling well requirements

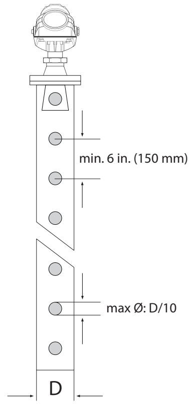


Figure 6.10.2: Recommended hole size for stilling well installations

Pipes should be an all-metal material. Non-metallic pipes 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. Other requirements include:

- Pipe should have a constant inside diameter
- Pipe must be smooth on the inside (smooth pipe joints are acceptable, but may reduce accuracy)
- Avoid deposits, rust, gaps and slots
- One hole above the product surface
- Minimum hole diameter is 0.25 in. (6 mm)
- Hole diameter (Ø) should not exceed 10% of the pipe diameter (D)
- Minimum distance between holes is 6 in. (150 mm)[1]
- Holes should be drilled on one side and de-burred
- Ball valve or other full port valves must be completely open

Failure to follow these requirements may affect the reliability of the level measurement. In flat bottom tanks (<20° incline), where the fluid has a low dielectric and a measurement close to the bottom of the tank is desired, a deflection plate should be used. This will suppress the bottom echo and allow measurements closer to the actual tank bottom. This is not necessary for dish-or cone-bottomed tanks where the slope is more than 20°.

(1) The minimum distance between holes is not always the optimal distance. Consult factory or product documentation for best installation practices.

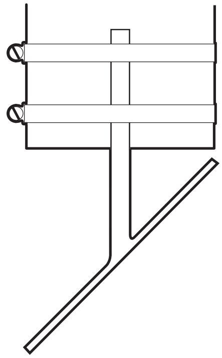


Figure 6.10.3: Deflection plate

6.10.4 Bypass chamber requirements

The guidelines for stilling wells also apply to bypass chambers, with a few additions. Most importantly, the inlet pipes must not protrude into the measuring pipe and the edge should be as smooth as possible. In addition, the distances between the antenna and the chamber wall and inlet pipes should meet those *shown in table 6.10.1*. If the inlet pipe tolerances are too restrictive, an alternative solution may be to mount a smaller pipe within the bypass chamber, or consider using guided wave radar.

When the transmitter is mounted in a pipe, the inclination should be within 1° of vertical. Even small deviations can cause large measurement errors. Also, the cone should be mounted in the center of the pipe to achieve a uniform gap around the antenna.

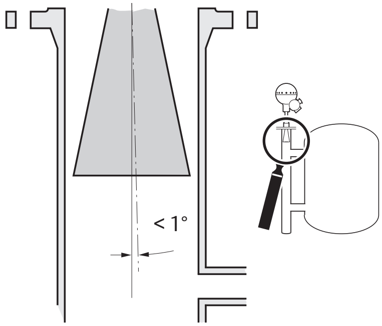


Figure 6.10.4: Inclination non-contacting radar

The 5600 electronics head should be oriented so that the cover lock is 45° from any disturbances such as pipe inlets or stilling well holes. It is also good if the installation allows for a ±90° rotation from this point to allow alternative orientations. This is not necessary for the 5400 thanks to circular polarization.

For transmitter configuration see section 5.11.6.

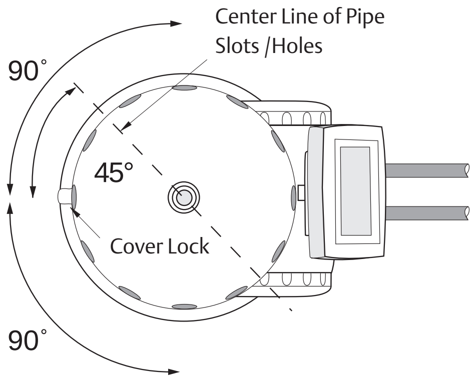


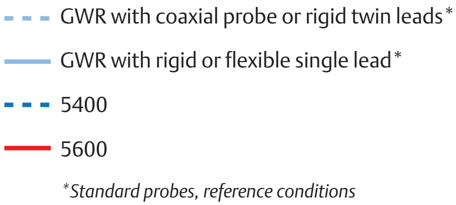
Figure 6.10.5: Orientation of the 5600 head

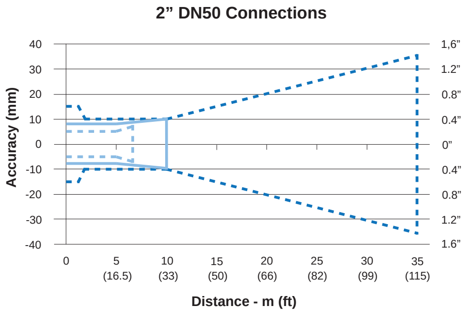
6.10.5 Performance and measuring range

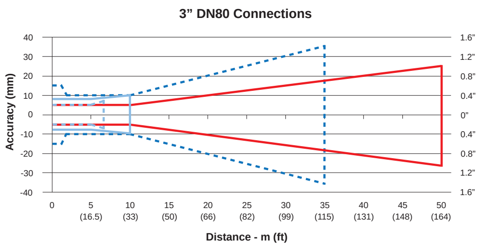
The following figures reflect the anticipated performance for different radar devices when used in a pipe installation and following the guidelines contained in this document. The values in the table assume that all the installation requirements stated above have been fulfilled and that the pipe is made per our recommendations.

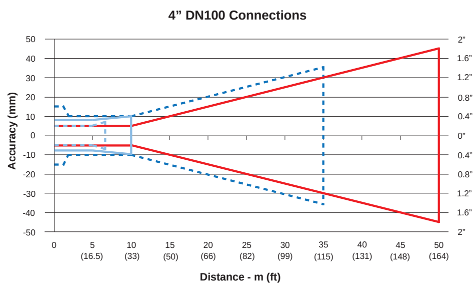
The maximum measuring range is independent of the dielectric constant of the product. However, the dielectric constant has to be greater than 1.4 for the 5600 and 1.6 for the 5400. For the GWR the minimum dielectric and maximum range varies with probe type. For lower dielectric constants, contact the factory.

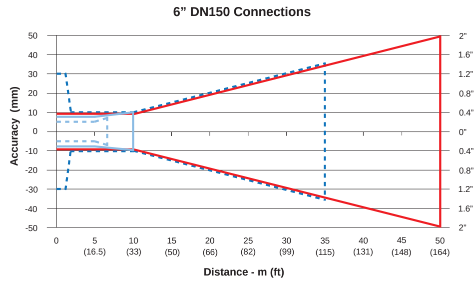
See table 5.11.1 in chapter 5











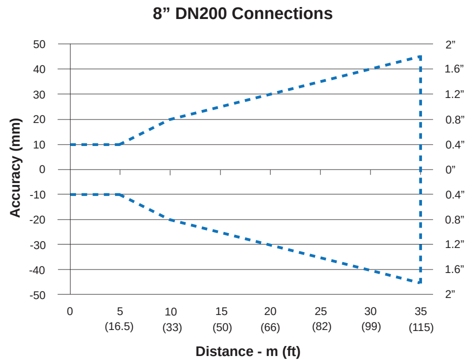


Figure 6.10.6: Performance and measuring range

6.10.6 Extra recommendations for installation in stilling well

Stilling wells in metallic materials

If used correctly, pipe measurement can be advantageous in many applications:

- Use cone or process seal antennas – not the rod antenna
- The gap between the cone antenna and the still-pipe is limited to 0.2 in. (5 mm). If required, order an oversized antenna and cut on location. Only applicable to 5401 cone antennas and cone antennas with wetted flange plate (i.e. straight antennas)

Stilling well mounting is recommended for tanks with extremely turbulent surface conditions. All cone antenna sizes for the Rosemount 5400 Series of transmitters can be used for stilling well installations. The 3 in. (75 mm) antenna for the 5401 is designed for use in stilling wells only. Rod antennas are not recommended for stilling wells.

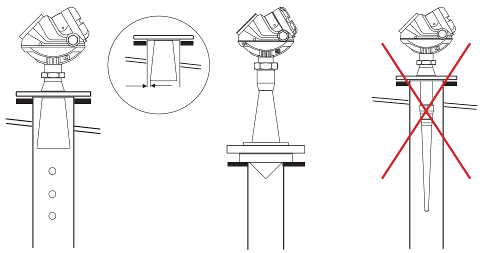


Figure 6.10.7: Mounting in stilling wells

When the transmitter is mounted on a stilling well, the inclination should be within 1°. The gap between the antenna and the stilling well may be up to 0.2 in. (5 mm).

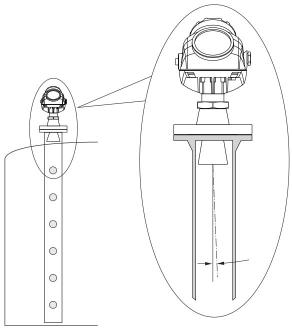


Figure 6.10.8: Mount the transmitter vertically

Recommendations for stilling well installations:

- The pipe interior must be smooth
- Not suitable for adhesive products
- At least one hole is above the product surface
- The hole diameter Ø should not exceed 10% of the pipe diameter D
- Holes should only be drilled on one side

6.11 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.

For further information see section 12.5.

6.12 Measurements 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 (or transmitter head!) moves along with the surface thereby corresponding to the level. The Rosemount 5400 Series is often ideal for these applications with reflectors if a few simple guidelines are applied.

Reflector

The reflector, or target, simulates a surface. For the Rosemount 5400 Series a flat metal plate of arbitrary thickness is recommended. The shape shall be either circular or square.

The dimensions are shown in the *table 6.12.1 and 6.12.2.* Larger reflectors can be used. There is no upper (theoretical) limit.

NOTE!

The reflector will be smaller than the antenna footprint. Avoid disturbing objects with large horizontal metal surfaces inside the antenna beam.

Max measuring distance	Plate diameter (circular)	Plate dimensions (square)
5 m	Ø=0.3 m	W=0.3 m
10 m	Ø=0.4 m	W=0.4 m
15 m	Ø=0.5 m	W=0.5 m
20 m	Ø=0.6 m	W=0.6 m
30 m	Ø=0.7 m	W=0.7 m
35 m	Ø=0.8 m	W=0.8 m

Table 6.12.1: Minimum reflector dimensions for Rosemount 5402 (26 GHz) with 4" cone antenna (preferred choice).

Max measuring distance	Plate diameter (circular)	Plate dimensions (square)
5 m	Ø=1.0 m	W=1.0 m
10 m	Ø=1.6 m	W=1.5 m
15 m	Ø=1.7 m	W=1.7 m
20 m	Ø=2.0 m	W=2.0 m
30 m	Ø=2.4 m	W=2.4 m
35 m	Ø=2.6 m	W=2.6 m

Table 6.12.2: Minimum reflector dimensions forRosemount 5401 (6 GHz) with 8" Cone Antenna(only use if 5402 not possible).

The reflector shape can be rectangular or elliptical but the shortest dimension must fulfill W or Ø respectively in the table above.

Installation

Follow the mechanical mounting recommendations in figure 6.12.1. In this configuration obviously the antenna is not pressure retaining, but temperature limits still apply. Also take into account the effects of vibration. A string, wire or rope may be used to align the reflector.

6.13 Measuring solids with a Rosemount 5600 non-contacting radar

The number of available technologies suitable for solids measurements is limited. Guided wave radar has proven to be a reliable and easy to install method for measuring solids, and should be the first choice for most applications. However, non-contacting radar is a good alternative if the application is one where the use of cables or probes is not desired.

Radar signals can penetrate vapor spaces containing dust or steam which is problematic for ultrasonic and laser devices. Non-contacting radar eliminates the breaking and pushing issues associated with technologies that use probes or other mechanical structures. In addition, it is not susceptible to mass changes or ambient temperature changes as are load cells. Unlike nuclear technologies, no special licenses or training are needed for radar devices. There are no empty tank requirements during installation for the non-contacting radar.

6.13.1 Good installation is the key to success:

As solids generally provide a difficult measuring environment and the signal levels are often very low, installation is of utmost importance. Antenna selection and its location in the tank are the keys to success.

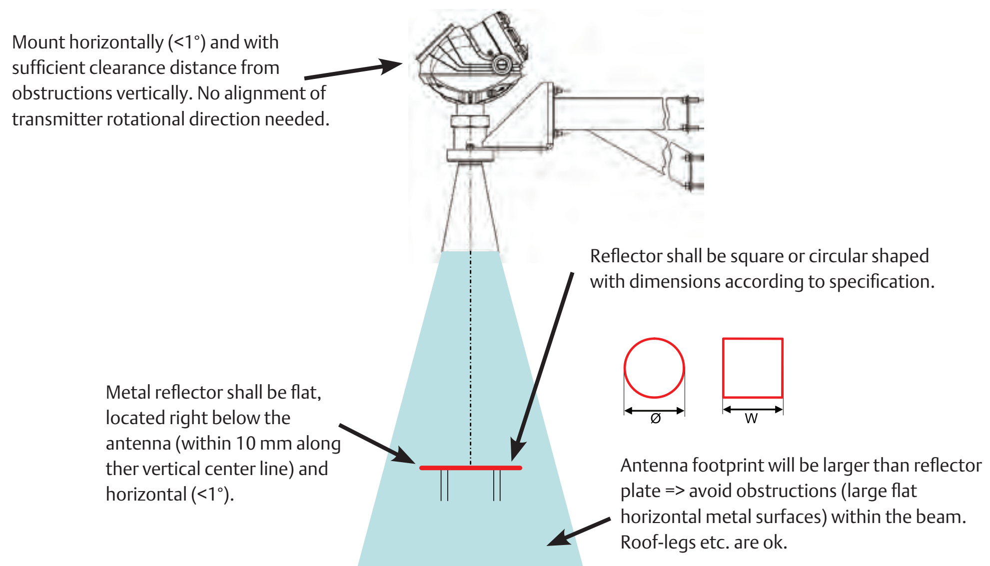


Figure 6.12.1: Mounting recommendations for Rosemount 5400 series with reflector plate

Step 1: Antenna selection

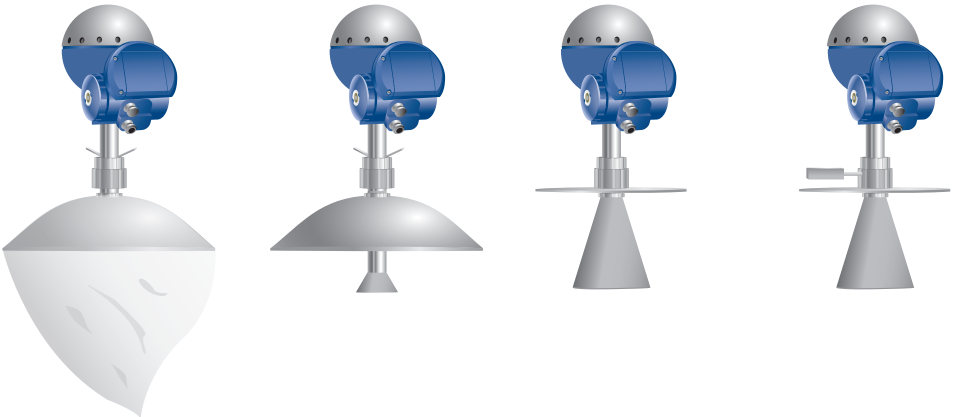


Figure 6.13.1: Antenna selection, non-contacting radar for measuring solids

Parabolic antenna with PTFE bag	Parabolic antenna	8-in. Cone antenna	8-in. Cone antenna with flushing adapter
Dusty applications	Best choice for long distances	Suitable for distances of less than 50 ft. (15 m)	Dusty applications
Best choice for long distances	Can handle weak surface reflection	Stronger surface reflection than smaller cones	Suitable for short distances of less than 50 ft. (15 m)
Can handle weak surface reflection	Positionable towards surface		Stronger surface reflection than smaller cones
Positionable towards surface			
PTFE bag prevents dust build up at the antenna			

Table 6.13.1: Antenna selection, non-contacting radar for measuring solids

Step 2: Tank connection

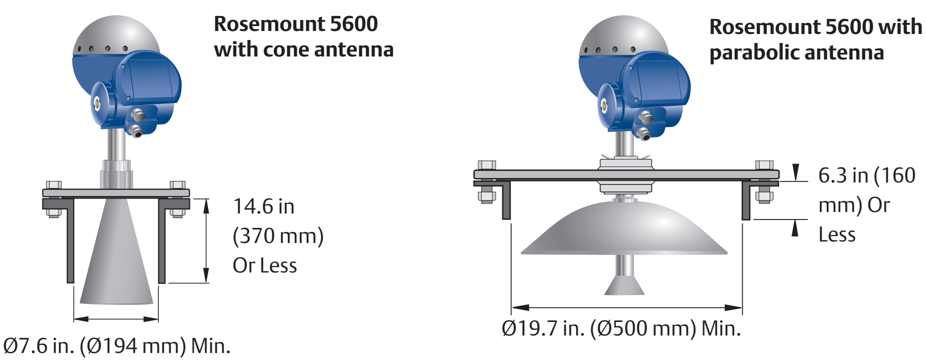


Figure 6.13.2: Tank connection, non-contacting rador for measuring solids

HINT!

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 that it is inside the vessel helps to eliminate the chance of condensation.

Step 3: Radar location

- The radar signal must never be shaded by the inlet nor the injected product
- The radar should not be mounted in the center of the silo. It should always be mounted as close to the silo center as possible. A general practice is to mount the radar at 2/3 tank radius from tank wall

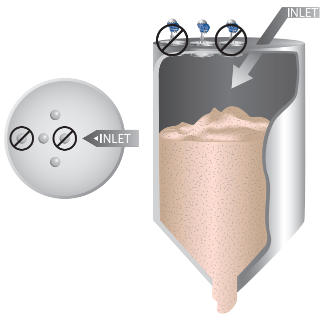


Figure 6.13.3: Radar location, non-contacting rador for measuring solids

- A deflection plate might need to be installed at the inlet point in order to deflect the product stream away from the antenna

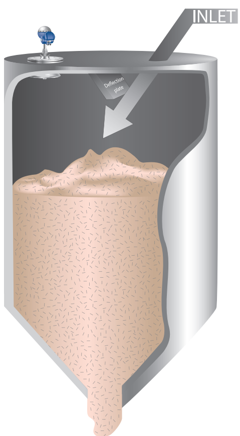


Figure 6.13.4: Deflection plate, non-contacting rador for measuring solids

Step 4: Inclination of antenna

If the surface echo is weak, the parabolic antenna can be inclined 0.5° to 2° towards the surface slope in order to increase the reflected signal

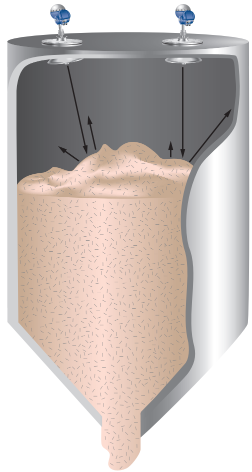


Figure 6.13.5: Inclination of antenna, non-contacting rador for measuring solids

NOTE!

Too great of an angle can create problems in detecting surface echo at the bottom region. The angle of the slope differs during filling and emptying. Therefore, monitor the entire cycle in order to verify and to determine an optimum antenna inclination.

Step 5: Software settings

- Note that solids applications generally are difficult and thus Emerson Process Management has developed a special solids mode in the radar database. This means that the radar database configuration is optimized for solids measurements when the “solids” check box in the Radar Master setup (tank environment window) is checked. Additional adjustments of the database might in some cases become necessary and in such cases, contact the factory for further details how to proceed
- Some solids build up electrostatic discharges, which might result in explosion risks. Therefore, the 5600 series has been approved for use in such environments

Applications[1]	Common characteristics					PTFE bag recommended[2]
	Particle size			Vapor space		
	Dust or powder	Small (<1 in.)	Larger (>1 in.)	Dust	Steam or condensation	
Wood chip bins[3]	Yes	Yes	Yes	Yes	Possible	Yes
Grain silo - small kernel grains[3]	Yes	Yes	No	Yes	No	Yes
Grain silo - large kernel grains	No	Yes	No	No	No	No
Lime stone silo	No	Yes	Yes	Possible	No	No
Cement - raw mill silo[4]	Yes	Yes	No	Yes	No	Yes
Cement - finished product silo[4]	Yes	Yes	No	Yes	No	Yes
Coal bin[5]	Yes	Yes	Yes	Yes	Yes	No
Saw dust	Yes	Yes	No	Yes	No	Yes
High consistency pulp stock	No	No	No	No	Yes	No
Alumina	Yes	Yes	No	Yes	No	Yes
Salt	No	Yes	Yes	No	No	No

Table 6.13.2: Sample solid applications where non-contacting radar is preferred over guided wave radar

(1) *These applications (except salt) typically involve tall vessels and therefore require the parabolic antenna option. The 8-in. cone antenna option can be used in the salt application where the vessel height is less than 50 ft. (15 m).*
(2) *The PTFE bag is only available for the parabolic antenna. If a cone antenna is used, consider the flushing connection option.*
(3) *For interstice silos, the antenna can be inclined 0.5 in. to 2 in. towards the surface slope.*
(4) *For interstice silos, the radar must be installed so that the radar signal clearly passes internal support structures without interferences*
(5) *Clean the antenna regularly.*

NOTE!

- *See the Rosemount 5600 radar transmitter product data sheet (document number 00813-0100-4024) for detailed information about approvals*
- *The PTFE bag is not approved for use in hazardous area*
- *See the section for 5.16 more information on considerations for solid applications with guided wave radar*

6.14 Measuring ammonia with radar

For ammonia application guidelines see section 5.17.

7

Pressure installation guidelines

7. Pressure installation guidelines

Differential pressure (DP) installations are a straight forward level measurement technique that is easily verified and properly ranged. 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 leg 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 direct mount seal is mounted to an open or vented vessel
- 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, which consist of a dual seal assembly having identical capillary length and process connections
- 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. *Please go to www.rosemount.com/3051SERS to learn more about ERS*

7.1 Pressure & 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 feet (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 boiler 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 boiler 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" pipe and pipe fittings, not ½" tubing and tube fittings. ½" schedule 40 pipe has an I.D. of 0.622", ½" schedule 80 is 0.546". ½" tubing may have an I.D. of 0.37", 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 7.1.1: Illustration of a wet leg installation

7.2 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
    - o Accuracy and total performance
    - o Stability
    - o Warranty
- Style
    - o Coplanar: used for DP measurement
    - o In-line: pressure applications
- Sensor range
    - o 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
    - o Flanged
    - o Threaded
    - o 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 in the nozzle

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 (above 500 °F (260 °C))
  - Select the all-welded option for vacuums less than 6 psia
- Capillary choices
  - Using the smallest ID capillary as a default is common. This limits the amount of oil in the system which can reduce the amount of potential error
  - Larger IDs are used to improve time response
  - Use shortest lengths possible to increase accuracy and response time
- Each fill fluid offerd has it's own physical chariteristics which are based on the minimuim and maximum temperature limits. There are 3 fill fluid types; silicon, non-silicon and hygienic

In general the fill fluid selected is based on the required fill, along with the process temperature conditions. Select the required fill fluid that will be within the minimum and maximum process and ambient temperature conditions. If the ambient conditions falls below the required minimum temperature limit, then heat tracing would be required.

For more information on fill fluids, please see technical note "Rosemount 1199 Fill Fluid Specifications", on www.rosemount.com.

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. However, when mounting the pressure transmitter in a vacuum application there are important factors to ensure a stable measurement.

The static pressure limit for a differential pressure transmitter is 0.5 psia (25 mmHgA), which ensures the transmitter sensor module fill fluid remains within the liquid phase of the vapor pressure curve.

If the vessel static limit is below 0.5 psia, mounting the transmitter below the bottom tap provides a capillary fill fluid head pressure on the module. A general rule is to always mount the transmitter approximately 3 ft. (1 m) below the bottom tap of the vessel.

For more information on installation and ranging please see technical note "Level measurement; technology: Pressure", or refer to the 1199 Remote seal manual on www.rosemount.com.

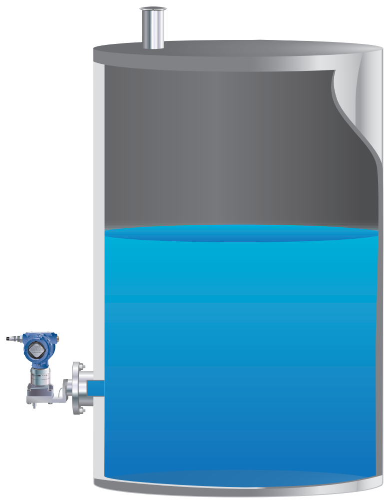


Figure 7.2.1: Illustration of a DP installation in a vented tank

7.3 DP installation using tuned-system assembly

Tuned-system assemblies are a best-practice installation in general. They have several benefits when comparing to balanced system (equal length capillary) configurations. Some of these benefits include less temperature induced errors, faster response time, 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. In reality, tuned-system assemblies provide a better overall performance by reducing temperature-induced errors.

The tuned-system assembly directly mounts the diaphragm seal to the high pressure process connection while still having capillary to the low side connection. Elimination of the excess capillary improves response time, performance, and reduces installed cost.

Total system error is reduced by offsetting some of the head/density effect (change in ambient) with seal/volume effect (change in process) as they have opposite effect.

Refer to the 1199 product manual on www.rosemount.com for more information

Figure 7.3.1: Illustration of a tuned system - unequal capillary length

7.4 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.

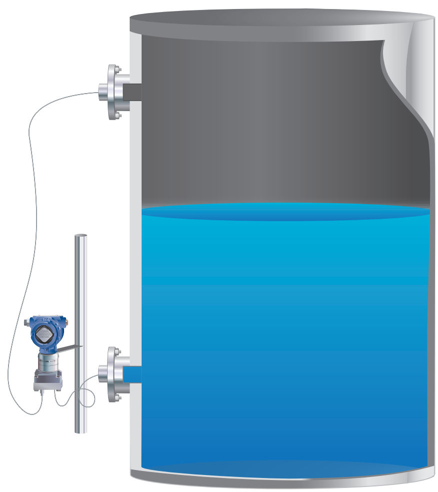


Figure 7.4.1: Illustration of a balanced system - equal capillary length and same size seals

For more information on installation and calibration please see technical note "Level Measurement; Technology: Pressure", on www.rosemount.com. To see tips on how to choose and install the right balanced system for your application, please refer to section 7.2 titled "Single pressure installation with seal system – vented / open tank."

For vacuum applications with a balanced system, the same mounting rules apply as for a tuned system.

7.5 Boiler drum level transmitter calibration

Steam drum level is both a critical and difficult measurement to make. Control of the water level in the drum must be precise. A water level that is too high can result in water carryover into the steam piping. A level that is too low can expose the generating tubes (down comers), preventing the water in the drum from cooling the furnace tubes, possibly damaging them.

Several factors make this measurement difficult to obtain. The steam drum itself may not be perfectly level, and even at steady state conditions, considerable turbulence in the drum can cause the level to fluctuate. In addition, a changing rate of water inflow and steam outflow adds to the potential for measurement error.

Measurement of boiler steam drum level using a differential pressure transmitter must take into account certain physical properties of the fluid.

- The steam drum contains a two-phase mixture of water and steam at saturation conditions
- The densities of water and steam vary with saturation temperature or pressure
- The density of saturated steam above water must be considered, as well as the density of saturated water in the drum

This section offers a method for calibrating transmitters that takes into account these factors.

7.5.1 Process

Figure 7.5.1 shows a simplified sketch of the process. Note that level, as we define it, is measured in units of length—in this case, inches. Differential pressure, on the other hand, is measured in inches of water column differential pressure. The two are sometimes confused, but do not refer to the same thing.

A column of water one inch high under one set of operating conditions does not exert the same hydrostatic head pressure as a column of water of the same height under another set of conditions. The objective is to measure differential pressure and "read" it as a unit of length.

The steps necessary to define the transmitter calibration use the thermodynamic operating conditions of pressure and temperature, the geometry of the steam drum, and the equation of continuity. Note that this calibration assumes only one set of operating conditions. In real practice, operating parameters change with boiler load and other factors, such as ambient temperature. For that reason, three element feedwater control systems often require that the drum level measurement be compensated for deviations from design operating drum pressure. It is also convenient to know the drum level during startup of the plant—that is, from 0 psig to full operating pressure. This dynamic pressure and temperature compensation requires a separate computational device.

The first step in the calibration is to define the process variables, shown in figure 7.5.1:

P_o = Static pressure in the steam drum at the top tap

P_h = Static pressure at the high side of the transmitter

P_l = Static pressure at the low side of the transmitter

τ_s = Density of saturated steam at operating conditions

τ_w = Density of saturated water at operating conditions

τ_o = Density of water in the "wet" or reference leg

H = Distance between the high and low drum taps

h = Drum water level (measured from the bottom tap)

h_{max} = Maximum water level allowed (measured from the bottom tap)

h_{min} =Minimum water level allowed (measured from the bottom tap)

C = Center line of the steam drum

V = Vertical distance from the bottom tap to the transmitter

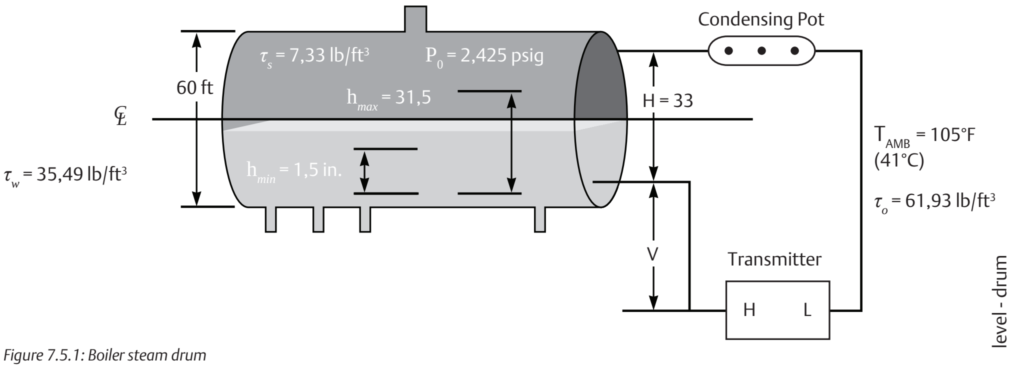


Figure 7.5.1: Boiler steam drum

7.5.2 Solution

From the equation of continuity:

$P_h = P_h + (H - h)(\tau_s) + h(\tau_w) + V(\tau_o)$

$P_l = P_o + H(\tau_o) + V(\tau_o)$

Thus, $\Delta P = H(\tau_s - \tau_o) + h(\tau_w - \tau_s)$

This equation calculates the differential pressure on the transmitter. The differential pressure is highest when the drum water level is lowest, and the differential pressure is lowest when the level is highest. Therefore, the transmitter zero must be elevated so that an increasing level results in an increasing output signal.

To perform the calibration, use a table of thermodynamic properties of steam and the following steps:

1. Determine h_{min} and h_{max}. These are the minimum and maximum water levels allowed for safe operation of the boiler. They are measured from the bottom tap of the steam drum
2. Using the saturated steam tables, find the values of and at the drum operating pressure. Use the value for compressed water in the reference (wet) leg at the expected ambient temperature and the drum operating pressure. If the compressed water table is not available, use the reciprocal of the specific volume of saturated water at the ambient temperature. Since water is nearly incompressible, this provides reasonable accuracy for the drum measurement
3. For this example assume:
   - o The inside diameter of the steam drum is 60 in.
   - o H = 33 in. (83.82 cm)
   - o P_o = 2,425 psig (design operating pressure)
   - o Tambient = 105 °F (41 °C)
   - o h_{min} = 1.5 in. (3.81 cm)
   - o h_{max} = 31.5 in. (80.01 cm)
   - o The desired level readout is –15 to 15 in. (a standard indicator faceplate range)
4. Solve the equation:

The specific volume of the saturated water at 2,425 psig is 0.02817 ft³/lb, → τ_w = 35.49 lb/ft³.

The specific volume of the saturated steam at 2,425 psig is 0.1364 ft³/lb, → τ_s = 7.33 lb/ft³.

The specific volume of the saturated water at 105 °F is 0.01615, → τ_o = 61.93 lb/ft³.

To convert all units to consistent inches of water column, correct the above formula to reference conditions. To do this, divide by τ_o.

At h_{min} the transmitter output will be 4mA dc.

$\Delta P = (H[\tau_s - \tau_o] + h_{min}[\tau_w - \tau_s]) \div \tau_o$

= [33(7.33 – 61.93) + 1.5(35.49 – 7.33)] ÷ 61.93

ΔP = <u>–28.41</u> inH_2O

This is the required zero elevation of the transmitter. At h_{max}: (Transmitter output will be 20 mA dc)

ΔP = [33(7.33 – 61.93) + 31.5(35.49 – 7.33)] ÷ 61.93

ΔP = <u>–14.77</u> inH_2O

Therefore, the span of the transmitter:

28.41 – 14.77 = 13.64 inH_2O Differential pressure

Finally, check the zero elevation and span against the transmitter specifications to ensure the selected transmitter can be calibrated to the required values.

7.6 Hydrostatic pressure

Hydrostatic pressures transmitters are used in vessels that are open to the atmosphere and where a simple level measurement is needed. It can be mounted either as a top-down device or on the side of the vessel.

Best practice

- Use for liquid level measurement in vented / atmospheric pressure tanks and sumps
- May be internally (submerged) mounted in underground tanks where side access is not possible
- Use where excessive turbulence, surface foams or vapors are present
- Use in tanks where complex internal structures can cause problems for non-contacting instruments

The 9700 hydrostatic level transmitter is available with a number of different mounting configurations to suit application conditions.

All models

- Always check that the cable and sensor materials of construction are compatible with the process liquid type and temperature
- Use only in vented tanks/ sumps (at atmospheric pressure)
- The ceramic capacitive sensor is extremely rugged, however care must be taken to avoid physical impact with solid objects on the sensor face
- Take care that solid structures within the tank are not in contact with the sensor face as this will cause large errors
- All 9700 units should be installed well away from tank inlets, pumps, areas of turbulence and pressure surges to avoid errors in measurement
- Mount the sensor so it is above any sludge layer that may form
- Do not swing the sensor by the cable
- Do not bend the cable to a radius of less than 80mm
- Ensure cable screen is terminated to an appropriate earth point inspect connection periodically to ensure effective contact
- Ensure breather tubes are terminated correctly. Refer to Installation Manual for further details

9710

- Use in still liquids only
- If liquid is turbulent, a stilling tube must be used. Alternatively, select the 9720 clamped cable version instead

Figure 7.6.1: 9710 cable suspended mounting configuration

Figure 7.6.2: 9720 clamped cable mounting configuration

9720

- Use if liquid within the tank is turbulent
- Note that the tank must be drained first if sensor needs to be removed

Figure 7.6.3: 9780 pole mounted configuration

9780

- This configuration allows the sensor to be removed without the need to drain the tank first
- Allow sufficient headroom above the tank to allow removal of the pole mounted sensor

Figure 7.6.4: 9790 flange mounted configuration

9790

- Allows external mounting of the sensor
- Ensure bolts are tightened evenly and output is stable prior to use
- Ensure adequate protection of the cable where it exits the sensor
- Use an isolating valve if it is necessary to remove the sensor without draining the tank first

A threaded mounting configuration is also available on request. Please contact the factory.

Ultrasonic installation guidelines

8. Ultrasonic installation guidelines

8.1 Ultrasonic level transmitter

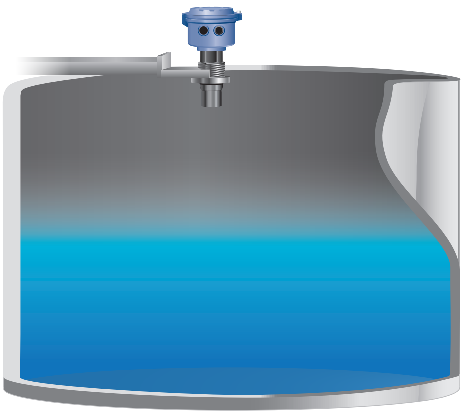


Figure 8.1.1: Measuring level in an open sump with an ultrasonic transmitter

8.1.1 Typical applications

- Lube oil tanks
- Underground sumps
- Cooling tower sump
- General storage tanks
- Slurry processing/ handling
- Waste water handling
- Cooling water intake / discharge flow
- Inlet screen condition monitoring

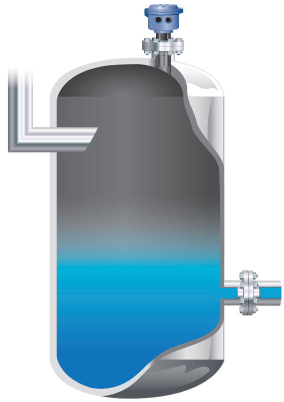


Figure 8.1.2: Measuring level in a tank with an ultrasonic transmitter

8.1.2 Best practice

- Use 3101 for simple liquid level measurement on simple aqueous, chemical and oil applications
- Use 3102 for liquid level and volume (contents) measurement
    - o Two integral relays are used where local alarm or control is required
- Use 3105 for liquid level and volume (contents) measurement in hazardous areas
- For applications with difficult liquid surface conditions such as turbulence and foam, install the ultrasonic transmitter on a vented stilling tube
- For liquid level measurement in wet well and sump applications or where there is the risk of the ultrasonic transmitter becoming submerged for a period, use the factory sealed 3107
- Use the 3108 on open channel flow applications such as measurement of water intake and discharge back to the water course
    - o Included is a factory fitted temperature probe for faster response to ullage space temperature changes
- Use any of the above with the 3490 series universal controller where local pump control or measurement display is required
    - o 3490 universal controller can be used to communicate with and configure HART level transmitters

Ultrasonic transmitters will give trouble free and reliable service provided care is taken during installation.

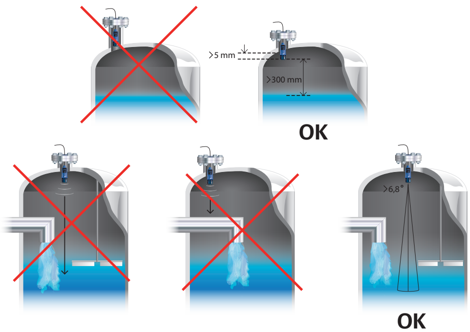


Figure 8.1.3: Proper and improper mounting positions of the ultrasonic transmitters

- Do not mount directly above an inlet or outlet, or above any internal tank structures which can cause false reflections
- Avoid positioning above any areas where foam may gather and stagnate
- The optimum position for the transmitter is generally 1/3 of the tank radius in from the side wall. If mounting closer to the tank wall, ensure that the tank wall is smooth and free of protrusions, weld beads or scum lines
- The 3100 is designed to be mounted in a non-metallic flange. Plastic flanges are available as accessories. If there is no option but to use a metallic flange, ensure the transmitter is only screwed into the flange to “hand tight”
- It is always preferable to mount the transmitter so that the front face protrudes at least 0.25 in. (6 mm) into the tank. If mounting on a nozzle or stand-off, the internal diameter should be 6 in. (150 mm) minimum and the maximum nozzle length should be no more than 14 in. (350 mm)
- If the instrument is exposed to direct sunlight such that it may heat up to 122 °F (50 °C) or greater, the use of a sunshade is recommended
- The 3100 can be used to measure flow in open channels. In such applications, there are specific guidelines which must be followed to achieve accuracy of readings – refer to the instrument installation manual for full details

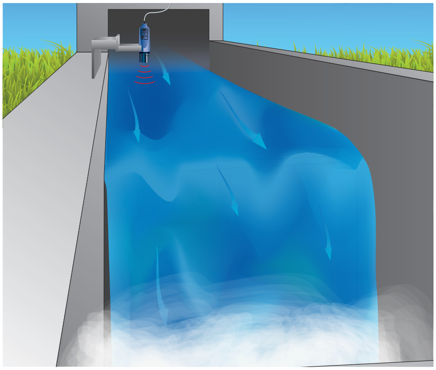


Figure 8.1.4: Measuring open channel flow with a 3108 ultrasonic transmitter

8.1.3 Ultrasonic in pipe applications

When installing an ultrasonic transmitter in a stilling well or a by-pass chamber, certain considerations need to be taken into account regarding the length of the pipe, compared to the diameter. *Follow the guidelines given in table 8.1.1.*

Pipe diameter	Maximum pipe length
≤4 in. (100 mm)	Not recommended
4 in. (100 mm) to 6 in.(150 mm)	16.4 ft (5 m)
> 6 in. (150 mm)	26 ft (8 m)

Table 8.1.1: Stilling well and by-pass chamber lengths compared to the diameter when installing an ultrasonic transmitter

8.1.4 Additional considerations for open channel flow installations

- Overall flow measurement accuracy is determined by the complete flow measurement system which includes the primary measuring device
- Positioning of the transmitter is critical, and should be the correct distance upstream from the flow structure as stated in the relevant standard for your country
- It is important that the bottom reference of the transmitter should be related to the invert of the primary measuring device and not the distance to the channel bottom directly below the transmitter

- The liquid surface at the point of measurement must have a stable, smooth surface, and uniform approach velocity. It must not be affected by baffles, foam, hydraulic jumps, or any other object that may cause flow disruption
- The primary element should be free from any situation where it is likely to 'drown' (refer to the relevant standard for further information)
- The 3108 has a remote temperature sensor that can be installed in a conduit box and clamped in a cable gland, or installed on a simple angle bracket inside a weir chamber or flume approach

8.2 Ultrasonic sludge blanket & suspended solids

8.2.1 Typical applications

- Clarifiers, settling tanks, sludge thickeners
- Suspended solids measurement of slurries (coal, fly ash, effluent) in settlement tanks
- Blanket level in effluent sump

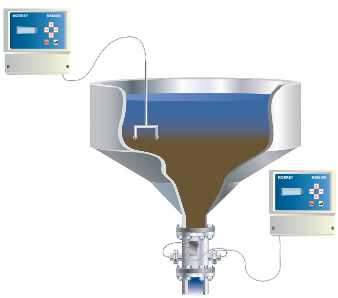


Figure 8.2.1: Using a sludge blanket system to monitor and control the blanket level

8.2.2 Best practice

- Use MSM in-tank mounted blanket detection sensors to detect high blanket level, and discharge pipe mounted sensors to detect thin sludge on emptying
- Use to automate de-sludging routines

8.2.3 MSM448 pipe section sludge density sensor

- The MSM448 pipe section sensor should be the same diameter as the surrounding pipe work. It should ideally be installed in a straight section of line and the sensor must be arranged in a horizontal plane

See figure 8.2.2

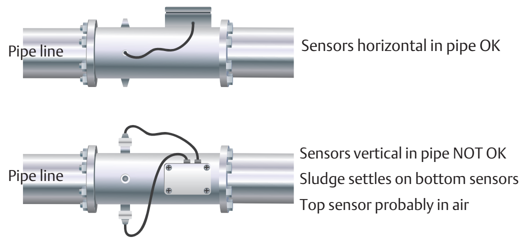


Figure 8.2.2: Proper and improper installation of the MSM448

- Air or gas that comes out of suspension in a slurry gives a high ultrasonic attenuation and a false high solids reading. The installation must maintain the full hydrostatic pressure in the slurry up to the pipe measurement section. Unnecessary pressure reduction should be avoided (i.e. via free fall of slurry in to sump, partly open valves, abrupt changes in pipe diameter)
- If possible, position the sensors at the lowest point of the outlet pipe work to maintain full hydrostatic head on monitored liquid
- In case it is necessary for the sensors to be removed for maintenance/ cleaning, the fitting of isolation valves is desirable
- The MSM448 is supplied with a flushing spray nozzle for cleaning of the sensor faces
- Twisting of the cables during installation should be avoided. Cable runs should be separated from any high voltage or mains cables to avoid crosstalk
- The MSM400 control unit is IP65 rated and is suitable for mounting outside but should be mounted away from any overflow water path and away from direct sunlight

- It is not necessary or advisable to remove the lid to the upper part of the control unit. There are no serviceable parts inside. The control unit must not be modified in any way

8.2.4 MSM433 suspended tank mounted sludge density sensor

- Do not carry the sensor and cable assembly by the cable alone; support the sensor at all times
- The Mobrey MSM433 sensor is available with a gap between sensor faces from 2 in. (50 mm) up to 18 in. (450 mm) for higher sensitivity to light slurries
- Sensors are usually mounted directly into a settlement tank and may be located at the top of the tank to monitor the upper parts of the settled blanket or close to the the discharge outlet to monitor the density of sludge leaving the tank
- The sensor can be installed by mounting on to a pipe or conduit by means of a ¾in. BSPT mounting thread
- Ensure the sensor is positioned away from the tank wall to avoid non-moving or “dead” settlement areas within the tank, but clear of any rotating or moving rakes or agitators
- It should be possible to lift the sensor out of the tank for periodic cleaning and/ or rag removal
- Twisting of the cables during installation should be avoided. Cable runs should be separated from any high voltage or mains cables to avoid crosstalk
- The MSM400 control unit is IP65 rated and is suitable for mounting outside but should be mounted away from any overflow water path and away from direct sunlight
- It is not necessary or advisable to remove the lid to the upper part of the control unit. There are no serviceable parts inside. The control unit must not be modified in any way

9 Switch installation guidelines

Topic Page

9. Switch installation guidelines

9.1 Vibrating fork switches

9.1.1 Rosemount 2100 application examples

Overfill protection

Spillage caused by overfilling can be hazardous to people and the environment, resulting in lost product and potentially high clean up costs.

- High integrity
- Manual test facility

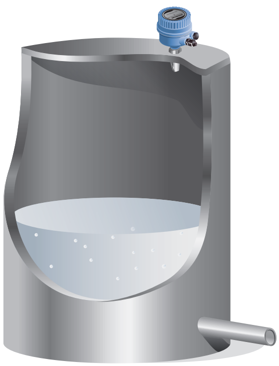


Figure 9.1.1: Overfill protection

High and low level alarm

Maximum and minimum level detection in tanks containing different types of liquids are ideal applications. The Rosemount 2130 is robust and operates continuously across the temperature range of –94 to 500 °F (–70 to 260 °C) and operating pressures of up to 1450 psig (100 barg), making it perfect for use as a high or low level alarm. It is common practice to have an independent high level alarm switch as a backup to an installed level device in case of primary failure.

- High temperature
- High pressure

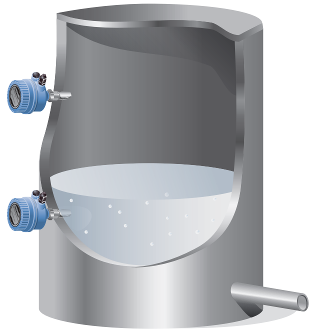


Figure 9.1.2: High and low level alarm

Pump control (limit detection)

Batch processing tanks often contain stirrers and agitators to ensure mixing and product 'fluidity'. The standard user selectable time delay, from 0.3 to 30 seconds, virtually eliminates the risk of false switching due from splashing.

- Time delay switching option
- Resistance to false switching

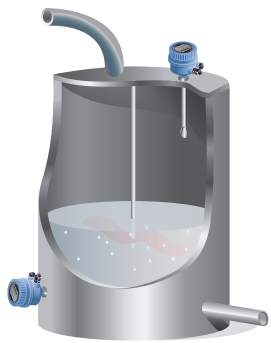


Figure 9.1.3: Pump control (limit detection)

Pump protection or empty pipe detection

With the fork projecting only 2 inches (50 mm) (dependant on connection type), the 2100 can be installed in small diameter pipes. Short forks mean minimum intrusion on the wetside and allow for simple, low cost installation at any angle into pipes or vessels. By selecting the option of direct load switching electronics, the 2100 is ideal for reliable pump control and can be used to protect against pumps running dry.

- Small forks
- Low cost

Figure 9.1.4: Pump protection or empty pipe detection

Extreme temperature applications

The 2130 is designed for extreme temperatures and is suitable for continuous operation within the temperature range of –94 to 500 °F (–70 to 260 °C).

- Extreme temperature range
- Thermal tube

Figure 9.1.5: Extreme temperature applications

Wireless applications

The advent of wireless communications allows process plant managers to save up to 90% on installation cost compared to wired technologies. More data can be collected at central locations than ever before. The 2160 or the 2130 together with a 702 wireless transmitter can be used to enable these benefits for your applications

- Add wireless switches to existing or new plant
- Acts as a wireless repeater in an existing wireless network

Figure 9.1.6: Wireless applications

9.1.2 Selecting a Rosemount 2100 vibrating liquid level switch

Switch housing

The switch housing is available in aluminum or SST, with two cable/conduit entries (M20 or 3/4-in. NPT). It can be ordered with explosion-proof / flameproof or intrinsically safe approvals.

> NOTE!
>
> *See 2100-series product data sheets on www.Rosemount.com for available accessories and ordering information.*

Electronics

Standard two-core cable can be used with any power supply from 20 to 264V ac (50/60 Hz) or 20 to 60V dc to connect the Rosemount 2130 in series with a load to achieve direct load switching. The output acts as a simple SPST switch that changes state with liquid presence.

Alternatively, the switching function of the DPCO dual relay electronics output can be used. The 2130 has an electronics option that can be interfaced directly to a Programmable Logic Controller (PLC) using the PNP transistor output model. The 2130 is also available with a NAMUR switching output.

See table 9.1.1. in section 9.1.3

> NOTE!
>
> *See 2100-series product data sheets on www.Rosemount.com for available accessories and ordering information.*

Fork length

Short fork, for minimum intrusion installation (minimum length is 2 in. [50 mm]). Fork extensions are available up to 118 in. (3 m).

Threaded connection

Threads: R 3/4-in. and 1-in. (BSPT); G 3/4-in. and 1-in. (BSPP); 3/4-in. and 1-in. NPT

Material: 316/316L SST (1.4401/1.4404), or Alloy C and Alloy C-276

Accessories: A stainless steel adjustable clamp gland is available for use with the extended length 2130 (1-in. models only). This is a threaded 11/2-in. BSPP to connect to the vessel, and allows the 1-in. extended length 2130 to be raised or lowered, as desired, and then clamped into position.

Flanged connections

Flange: ASME B16.5 (1-in. or larger), or EN 1092-1(DN25 or larger)

Material: 316/316L SST (1.4401/1.4404), or Alloy C and Alloy C-276

9.1.3 Application and installation best practices

- Use where the application demands a degree of failsafety 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

Before installing the Rosemount 2100 level switch, consider specific installation recommendations and mounting requirements.

- Install in any orientation in a tank containing liquid
- 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 9.1.4.

- Always install in the normally “on” state
  - o For high level the recommendation is dry = on
  - o For low level the recommendation is wet = on
- Always ensure the system is tested by using the local magnetic test point during commissioning
- Ensure sufficient room for mounting and electrical connection
- Ensure that the forks do not come into contact with the tank wall or any internal fittings or obstructions
- Ensure there is sufficient distance between build-up on the tank wall and the fork

See figure 9.1.10.

- Avoid installing the 2100 where it will be exposed to liquid entering the tank at the fill point
- Avoid heavy splashing on the forks - Increasing the time delay reduces accidental switching caused by splashing
- Raising the time delay reduces accidental switching caused by splashing
- Check the risk of build-up on the forks. Drying and coating products may create excessive build-up
- Ensure no risk of bridging the 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 9.1.4.

- If used in a pump application, mount on sufficient distance from pump to avoid cavitation
- Ensure the process is operating within the instrument temperature and pressure ranges
- Ensure the liquid viscosity is within the recommended viscosity range
- Check that the liquid density is higher than 37.5 lb/ft3 (600 kg/m3), or above 31.2 lb/ft3 (500 kg/m3) when ordered with the low density range option
- Check the solids content in the liquid - As a guideline, 0.2 in. (5 mm) is the maximum solid particle diameter in the liquid When dealing with particles larger than 0.2 in. (5 mm), consult the factory
- Problems may occur if the product coats and dries, causing caking
- In almost all cases, the 2130 is insensitive (does not see) foams - In rare cases, some very dense foams may be seen as liquid. An example of this is ice-cream and orange juice manufacturing
- Ensure the system is tested by using the local magnetic test-point during commissioning
- Ensure there is sufficient room for mounting and for electrical connections

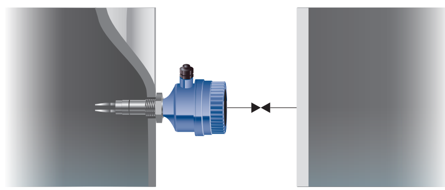


Figure 9.1.9: Ensure adequate space outside tank

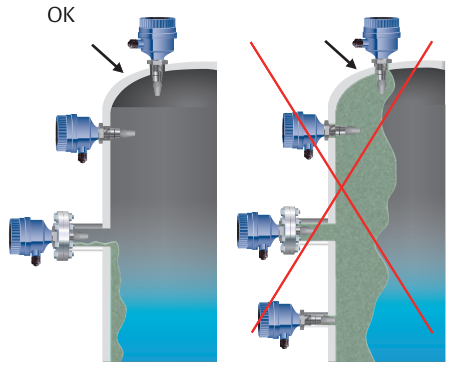


Figure 9.1.10: Example of ok and not ok build-up on tank wall

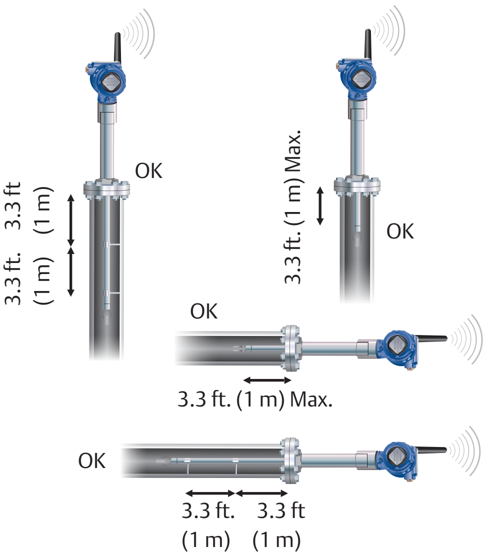


Figure 9.1.11: Support fork every 3 ft (1 m)

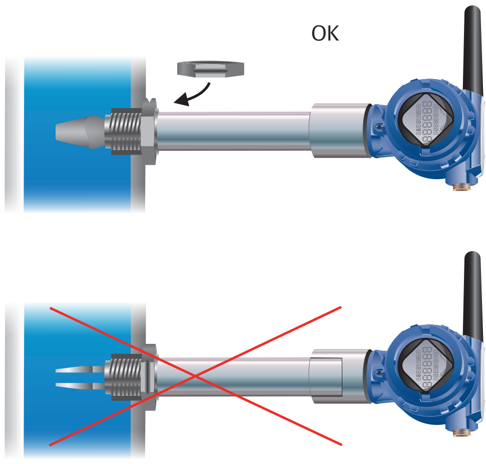


Figure 9.1.12: Illustration showing how to align the fork in a pipe application

9.1.3 Output selection

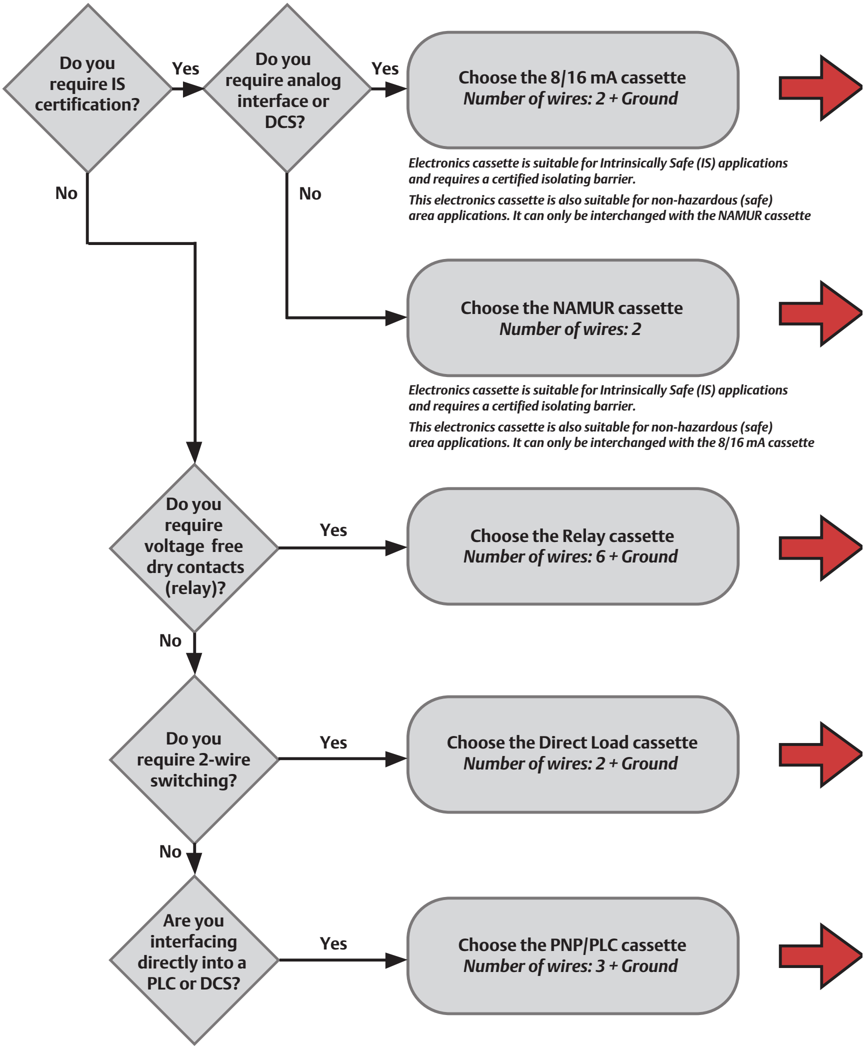
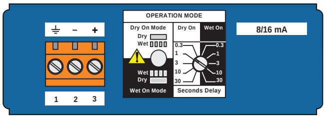
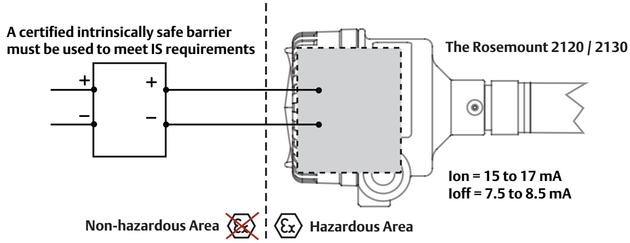
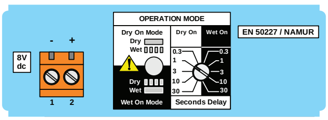


Table 9.1.1: Vibrating fork switches output selection

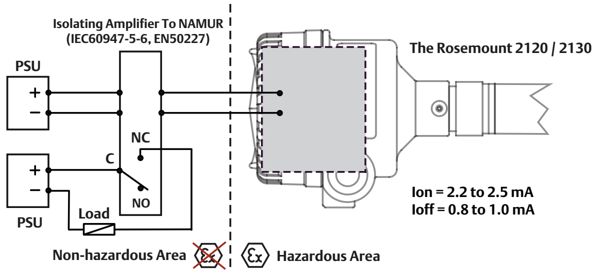


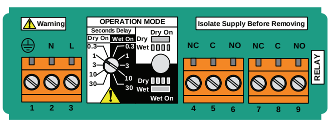
8/16 mA



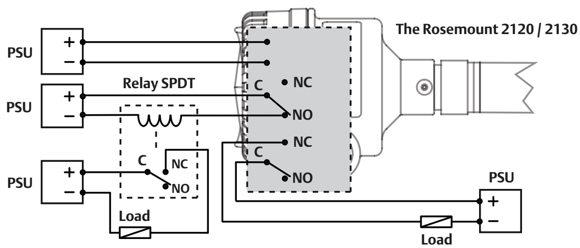


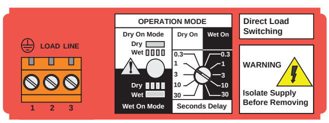
NAMUR



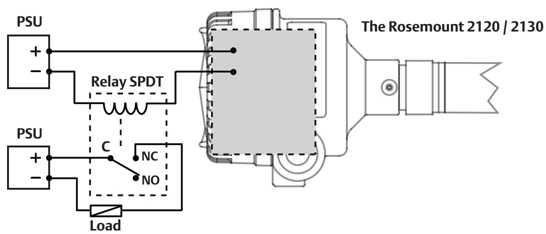


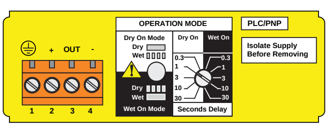
DPCO Dual Relay





Direct Load Switching





PNP/PLC

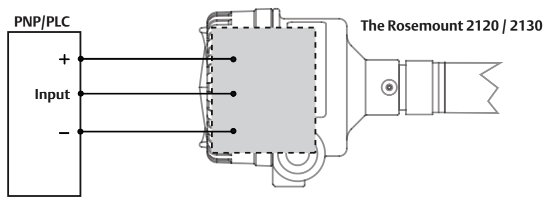


Table 9.1.2: Vibrating fork switches output selection

9.2 Float switches

Before installing a Mobrey float switch, consider installation recommendations and mounting requirements.

- A wide selection of float styles and mounting configurations is available. Select according to specific application requirements

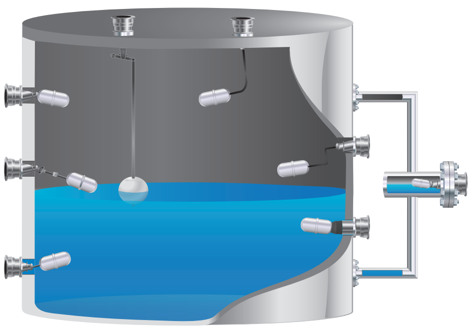


Figure 9.2.1: Float switch installation

- Use on liquid applications which operate at high pressures and temperatures such as feedheaters
- Select a float switch in areas not suited for the use of electronic devices
- Float must move freely and not foul the sides, bottom or roof of tank
- Positions of turbulence/ positioning near agitators must be avoided
- Take care that debris does not accumulate around magnet (use a shrouded version to protect against this)
- In applications where there is potential for sediment build-up, position the switch carefully to avoid build up around the float mechanism
- When mounting the float switch on a nozzle or stand-off, ensure float clears the nozzle and is free to move over its full travel
- Refer to installation manual for specific instructions relating to the various float styles available

9.2.1 Floating roof tank alarm switch

- Use on floating roof tanks to signal if the roof rises too high to prevent overfilling
- Mount on bracket on the side of the tank
- Ensure the weight is positioned at the correct alarm point
- Ensure the weight and mechanism do not foul the sides of the tank
- A second switch mechanism may be specified to operate in the event of the weight becoming detached
- If a deluge system is fitted, ensure switch enclosure is protected from direct spray

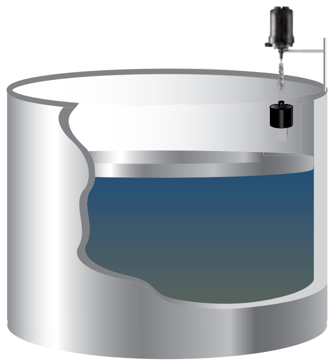


Figure 9.2.2: Floating roof tank alarm switch installation

Hydrastep & Hydratect installation guidelines

10. Hydrastep & Hydratect installation guidelines

10.1 Hydrastep

Typical applications

- Boiler drum level indication
- Emergency shutdown system

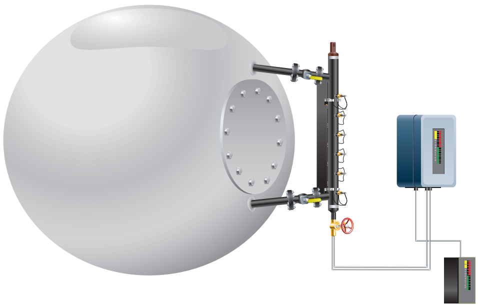


Figure 10.1.1: A Hydrastep system on a boiler drum

Best practice

- Use in conjunction with existing boiler water level control system
- Use to replace difficult to read gauge glasses (Note local requirements which may require a gauge glass to be fitted as well at all times)
- Use a system at each end of the drum to average level readings
- Use on-board relays to give alarm and shut down functions
- Use with remote displays to show level reading at ground level or in the control room

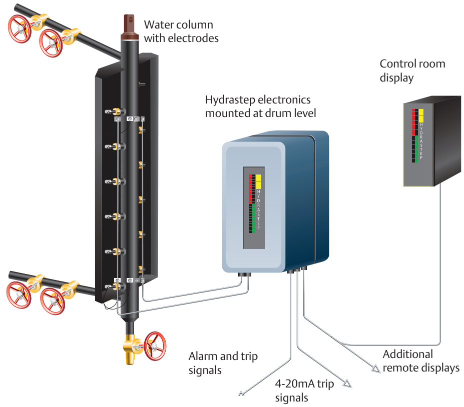


Figure 10.1.2: Typical Hydrastep installation

- Ensure installation complies with all local legislation or other relevant recommendations
- It is critical to ensure that the process pipes between the boiler drum and the Hydrastep column are oriented and prepared as described and shown in the technical manual. Process connections must be inclined to aid condensate flow, with a portion of the upper connection remaining uninsulated to encourage condensate formation. *See figure 10.1.3.* Upper process connection pipes must not be insulated. *Refer to the technical manual for full details of mechanical and electrical installation*

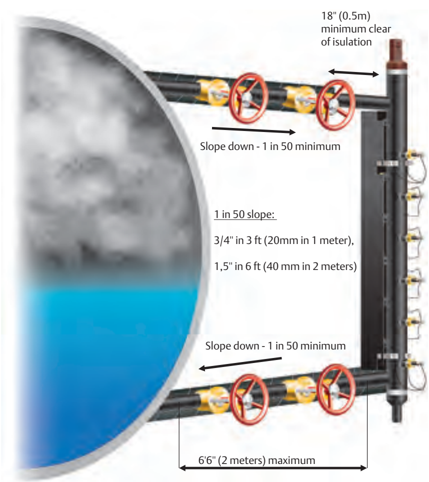


Figure 10.1.3: For optimum performance, process connections must be inclined

- Ensure effective water treatment to avoid high conductivity since this can cause false indications
- The electronic enclosure cover should not be removed or opened until the equipment is ready for installation at its fixing point. Under no circumstances should the enclosure be left open unless internal work is actually in progress
- The enclosure must be sited within electrode cable length of the water column fixture
- Use only high temperature electrode wiring as supplied by the factory
- The preferred site for the electronic enclosure is a wall or vertical bracket structure to allow easy access for viewing and servicing. The installation site must be capable of supporting four times the equipment weight. Refer to technical manual for weight specification
- When work/ servicing is in progress with the enclosure open, the lid should be supported in its open position
- To clean the instrument, use only a damp cloth with a mild, water-based cleaner. Only the exterior of the instrument should be cleaned. Do not allow liquids to spill on to, or enter in to the instrument

10.2 Hydratect

Typical applications

- Detection of water in live steam mains (TWIP)
- Condensate pot level control
- High integrity high level alarm on feed heaters
- Use as part of a dual/ triple redundancy control system with other level control device

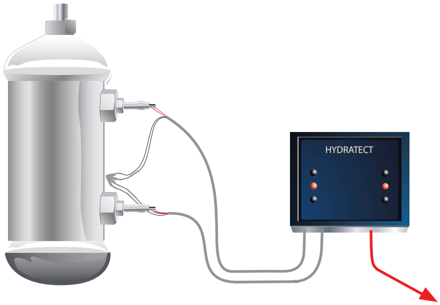


Figure 10.2.1: A Hydratect system for detection of water in live steam mains (TWIP)

Best practice

- Use to detect unwanted presence of water in turbine steam lines
- Use with either factory supplied manifold or with factory supplied mounts in an existing or locally made vessel
- Use with additional wireless transmitter for remote statue indication
- The Hydratect installation consists of a compact twin-channel electronic unit, connected to a pair of electrodes that are mounted in the plant pipe-work.

See figure 10.2.2.

- Always use the shrouded inserts and high temperature connecting cables supplied, or factory-supplied spares
- Mount the unit in a suitable position to allow easy access for viewing and servicing. The case must be bonded through a suitably rated cable and grounding point. *Refer to technical manual for case dimensions, full mounting procedure and grounding procedure*
- To allow correct functioning, Hydratect electrodes must be mounted either in an insert (mounting of a single electrode) or manifold (mounting of up to four electrodes)

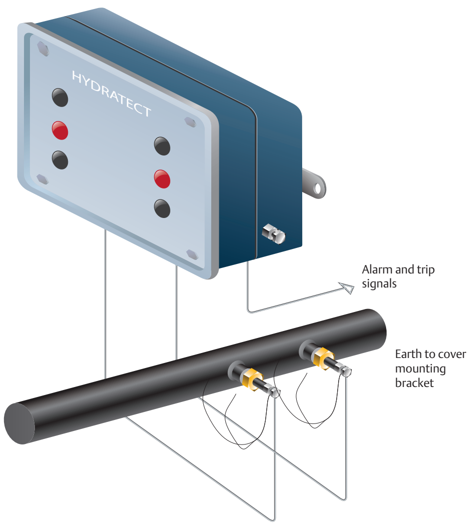
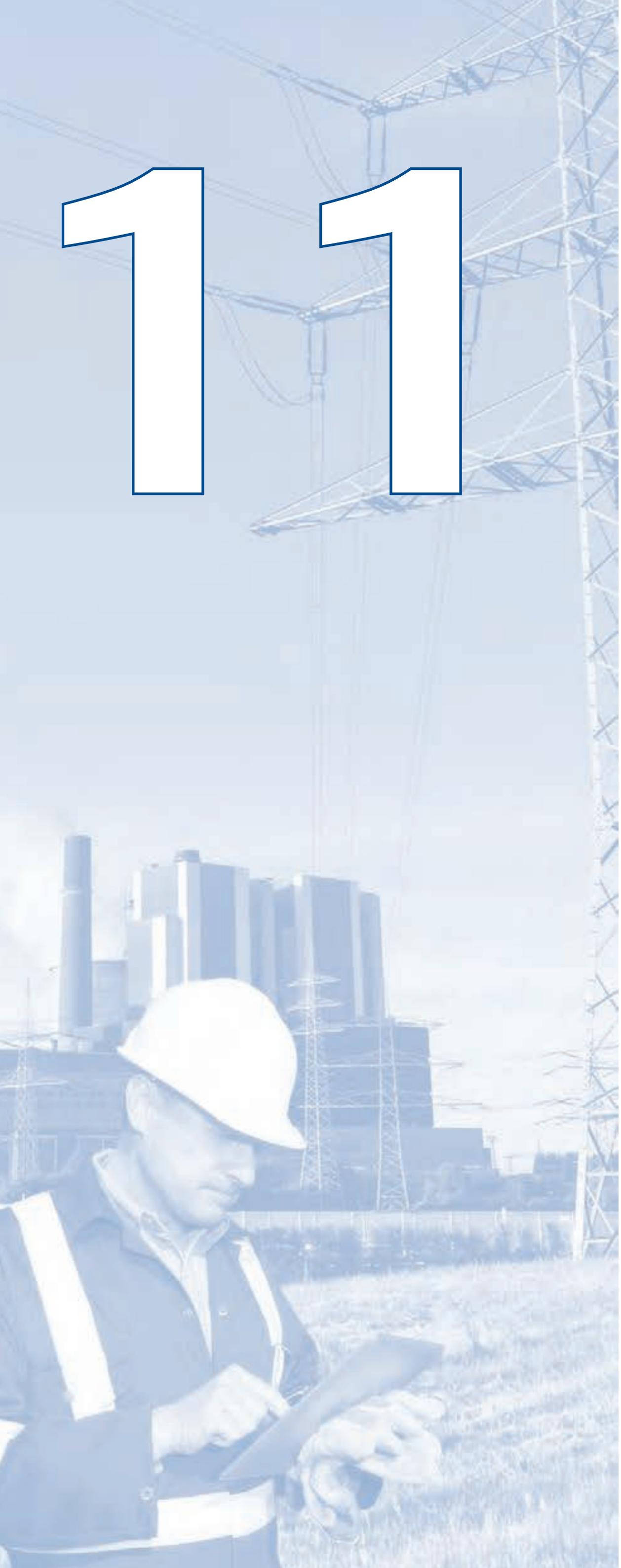


Figure 10.2.2: The Hydratect electronics unit



11

Product approvals & certifications

Topic | Page

11. Product approvals and certifications

11.1 Hazardous area approvals

Product certification process

When designing a new product, manufacturers decide on the appropriate standards to follow and design the new product to comply. The manufacturer's product approvals group works with the product designers to ensure that all applicable requirements are met. In addition, compliance engineers anddesigners work with the approval agency during the design phase. Once the design is complete, prototype samples of the product are tested.

After testing, the manufacturer submits the product's documentation and hardware to the approval agency for their review. If approval is granted, the approval agency sends certification documents to the manufacturer, who can then label and sell the product as approved.

11.1.1 Safety in hazardous areas

A hazardous area is an area in which explosive atmospheres 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, spontaneous heating)
- Oxygen

These three components comprise the fire triangle. An explosion will not occur if any one of the three components is missing.

See figure 11.1.1

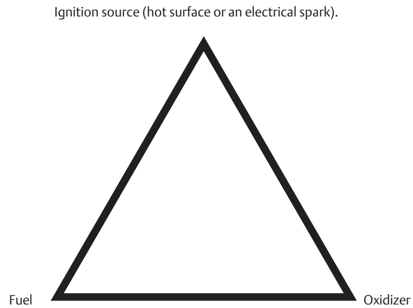


Figure 11.1.1: The fire triangle

Advantages of using certified equipment

By using certified products in hazardous areas, users can ensure that people and property will be protected from the risks associated with the use of electrical equipment in hazardous locations. Certification ensures expert conformity with standards and provides evidence of compliance with legal obligations such as safety regulations. In addition, certification markings provide ready identification of products that are fit for a purpose.

Approval agencies and markings

Approval agencies

Several approval agencies located throughout the world act as testing authorities in the design, manufacture, and operation of process control instruments. You need to be conversant about the requirements of agencies in your geographic area in particular, but you should also be somewhat familiar with agencies in other parts of the world.

The most common standards used in the process control industry are:

- International Electrotechnical Commission (IEC)
- European Standards (EN)
- Canadian Standards Association (CSA) in Canada
- Factory Mutual (FM) in the United States

Approval agencies around the world certify process control instruments to meet these standards. The approval agencies with which you should be familiar include:

- British Approval Services for Electrical Equipment in Flammable Atmosphere (BASEEFA) in the United Kingdom
- BVS and PTB in Germany
- FM in the United States
- CSA in Canada
- TIIS in Japan
- NEPSI in China
- CERCHAR and LCIE in France
- CESI in Italy
- DEMKO in Denmark
- NEMKO in Norway
- ISSeP in Belgium
- DEKRA (formerly KEMA) in the Netherlands
- SEV in Switzerland
- SIRA in England

Each approval agency uses a specific format to indicate which certifications it has granted to a particular instrument.

European ATEX directive

ATEX is the European Union's directive 94/9/EC that applies to equipment and protective systems intended for use in potentially explosive atmospheres. ATEX is mandatory for the CE marking and putting on market in countries within EU and EFTA. The purpose of the directive is to facilitate trade within the European Union by aligning the laws of the member states regarding the safety requirements for hazardous area products.

IEC approval markings

Transmitters that are certified to comply with IEC standard, are marked as follows:

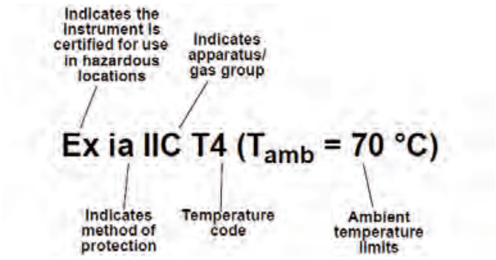


Figure 11.1.2: Example of IEC approval markings

North American approval markings

North American approval markings are used to designate FM and CSA hazardous area certifications for electrical equipment. North American markings appear in the following format:

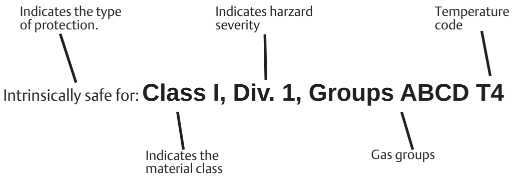


Figure 11.1.3: Example of North American approval markings

ATEX approval marking

Transmitters that are certified to comply with ATEX Directive 94/9/EC are marked as follows:

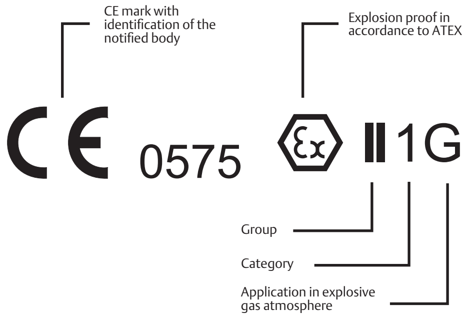


Figure 11.1.4: Example of ATEX approval marking

11.1.2 Method 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
- Dilution
- Avoidance

The most common methods of protection used in the process control industry are containment, energy limitation, and avoidance, which are described below.

See table 11.1.1.

NOTE!

The letters in brackets following the headings below are the IEC codes used to indicate that method of protection on product labeling.

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 d)

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

Energy limitation

Users may 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.

Intrinsic safety (Ex i)

Intrinsically safe (I.S.) equipment and wiring prevents explosion by limiting the release of sufficient electrical energy to ignite explosive gases in the atmosphere under normal or defined fault conditions. 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

Users may also prevent explosions by using equipment or parts of equipment that do not arc or spark in normal service, thus preventing the ignition source from ever occurring.

Increased safety (Ex e)

Increased safety is perhaps the most widely used method of protection. The design and manufacture of increased safety equipment excludes normally sparking components.

Manufacturers design other components to reduce substantially the likelihood of the occurrence of fault conditions that could cause ignition by:

- Reducing and controlling working temperatures
- Ensuring reliable electrical connections
- Increasing insulation effectiveness
- Reducing the probability of contamination by dirt and moisture ingress (entry)

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.

Type of protection	Symbol (Ex or EEx)
Explosion-proof enclosures	Ex d
Intrinsic safety in Zone 0	Ex ia
Intrinsic safety in Zone 1	Ex ib
Increased safety	Ex e
Non-sparking equipment	Ex n

Table 11.1.1: Area classifications

11.1.3 Material classifications / groups

North American approval agencies such as FM and CSA designate a material class in their certifications. The material classes are:

- Class I: Gases and vapors
- Class II: Dust
- Class III: Fibers and flyings

Explosive substances groups

Explosion substances codes differ between IEC/ATEX and North American markings.

See table 11.1.2.

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/flyings	Class III	N/A

Table 11.1.2: Gas groups

Temperature groups

Temperature groups organize explosive substances according to their auto-ignition temperatures. The same temperature group codes are used in both IEC/ATEX and North American markings. *Sample temperature codes are shown in table 11.1.3.*

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 11.1.3: Temperature group codes

NOTE!

For process industry T4 temperature group is the most applicable temperature group. T6 is used only for carbon disulfide applications.

Material classification code examples

BASEEFA, CENELEC, and some other agencies designate material groups using the IEC/ATEX standards. FM and CSA designate material standards using the North American standards.

Examples of material classification codes include:

- Model code I1:

  Ex ia IIC T4 (Tamb = –50 °C to 70 °C) 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

- Model code I7:

  Ex ia IIC T4 (-50C _< Tamb _< 70C) 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

- Model code E5:

  Explosion Proof for Class I, Division 1, Groups B, C, and D is an FM marking that indicates the instrument may be safely used with gases in gas groups B, C, and D

- Model code I6:

  Intrinsically Safe for Class I, Division 1, Groups A, B, C, and D; Temperature Code T4 is a CSA 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

11.1.4 Hazardous area classifications

Approval agencies have designated hazardous area zone and division classifications that describe the degrees of risk in different types of hazardous areas. The 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. FM and CSA indicate the hazardous area division in their certification markings. IEC/ATEX indicate the hazardous area zone in their certification markings.

The following two examples show how hazardous area classifications are designated in product specifications:

- E5 Explosion Proof for Class I, Division 1, Groups B, C, and D indicates the instrument may be safely used in hazardous areas with ignitable concentrations of gases or vapors (Class I) present most of the time or for short periods of time under normal conditions
- I5 non-incendive for Class II, Division 2, Groups A, B, C, and D indicates the instrument may be safely used in hazardous areas with ignitable concentrations of dust (Class II) present only under fault conditions

See table 11.1.4

North American	IEC	Definition
Division 1	Zone 0	Ignitable concentrations present most of the time under normal conditions
	Zone 1	Ignitable concentrations present under normal conditions for short periods
Division 2	Zone 2	Ignitable concentrations present only under fault conditions

Table 11.1.4: Hazardous area classifications

NOTE!

Division 1-approved devices may also be safely used in a Division 2 area. However, a Division 2-approved device cannot be used in a Division 1 area.

Installation practices

Users must follow local installation standards, depending on their geographic location. Two examples are:

- North America—National Electrical Code (NEC) NFPA 70
- Europe—BS EN 60079-14 : 1997

These two agencies set standards for certain types of installations in hazardous areas, including explosion-proof, I.S., and sealing installations. The NEC specifies hazardous areas in which certain procedures must be followed.

Explosion-proof installation

Figure 11.1.5 shows the 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.

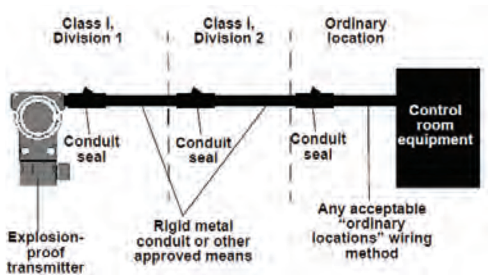


Figure 11.1.5: NEC explosion-proof installation

Intrinsic safety installation

Figure 11.1.6 shows the 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.

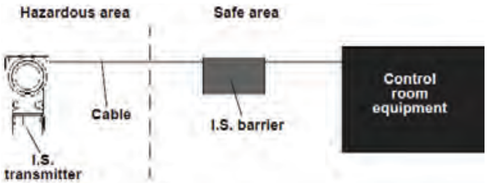


Figure 11.1.6: Intrinsic safety installation

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

Figure 11.1.7 shows a sealed enclosure that meets NEC guidelines.

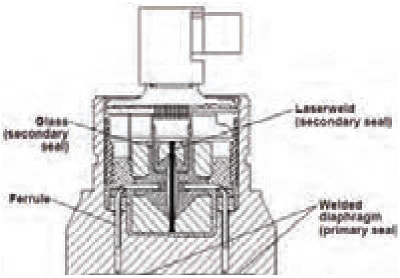


Figure 11.1.7: Example of a sealed enclosure

11.2 Enclosure ratings

Two standards govern the ingress (entry) protection (IP) of enclosures. These standards use rating systems to identify an enclosure's ability to resist external environmental influences. The two standards are:

- IEC
- National Electrical Manufacturer's Association (NEMA)

IEC ratings are based on performance criteria similar to NEMA, with different interpretations of enclosure performance.

11.2.1 IEC ingress protection codes

IEC uses the codes in *table 11.2.1* 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.

Examples of IEC IP codes include:

- IPX4 indicates protection against splashing water only
- IP2X indicates protection against solid foreign particles only
- IP56 indicates protection against dust and heavy seas or powerful water jets

1st no.	Description	2nd no.	Description
0 or X	No protection	0 or X	No protection
1	Objects ≥ 50 mm	1	Vertically dripping water
2	Objects ≥ 12.5 mm	2	75–105° angled dripping water
3	Objects ≥ 2.5 mm	3	Spraying water
4	Objects ≥ 1.0 mm	4	Splashing water
5	Dust-protected	5	Water jets
6	Dust-tight	6	Heavy seas, powerful water jets
		7	Effects of immersion
		8	Indefinite immersion

Table 11.2.1: IEC enclosure protection codes

11.2.2 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.

See table 11.2.2.

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)
11	Acid and fume resistant, oil-immersed, used indoors
12	Industrial use
13	Dust proof

Table 11.2.2: NEMA enclosure protection codes

Comparing NEMA enclosure types with IEC classifications

IEC does not specify degrees of protection against risk of explosions or conditions such as moisture or corrosive vapors; NEMA does. 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 11.2.3 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 11.2.3: Comparing NEMA with IEC designations

For further information please contact Emerson.

12

Focus areas

Topic | Page

12. Focus areas

12.1 Minimizing level measurement system errors in steam & water applications

Steam drum level measurement is a difficult application and is complicated by a number of different sources of errors. Understanding the sources of error is the first step in minimizing their impact and managing potential differences from the level measurement devices used. The sources of error can be attributed to two basic areas: installation and water/steam property changes. A combination of these two sources will compound the errors.

12.1.1 Installation sources

Boiler tilt

Many boiler drums are built with one end slightly lower than the other. This is done to allow any sediments to settle towards the blowdown lines for efficient removal. The degree of tilt is up to about 5 degrees from horizontal. However, the water level will remain horizontal so the level at one end will be higher than the other with respect to the drum end. The apparent difference in this level will depend on the amount of tilt and the length of the drum.

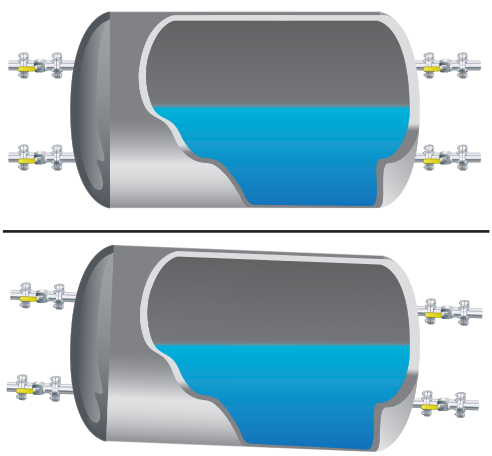


Figure 12.1.1: Offset in level measurement due to boiler tilt

When there are redundant measurements, this difference can be accommodated by the calibration or set-up of the device. Normal Water Level (NWL) is usually expressed as either a plus or minus (+ / -) measurement from the drum centerline. Set "zero level" to be from the normal water level rather than the height from the bottom of the drum.

Side mounted devices

All side mounted level measuring systems (such as hydrastep, guided wave radar, displacers, floats, gauge glasses, etc.) exhibit an effect called density error. Density error occurs because the temperature decreases as the water is transferred away from the boiler. Since cooler water has a higher density, a reduction of the water level in the side mounted chamber occurs. The effect of density error is greater as the critical point of water is reached because small temperature differences will cause large changes in water density.

Steam and water temperature can be found by looking up the saturated steam temperature at the current operating pressure in standard steam tables. The density or volume of water and steam can also be found in standard steam tables listed against temperature.

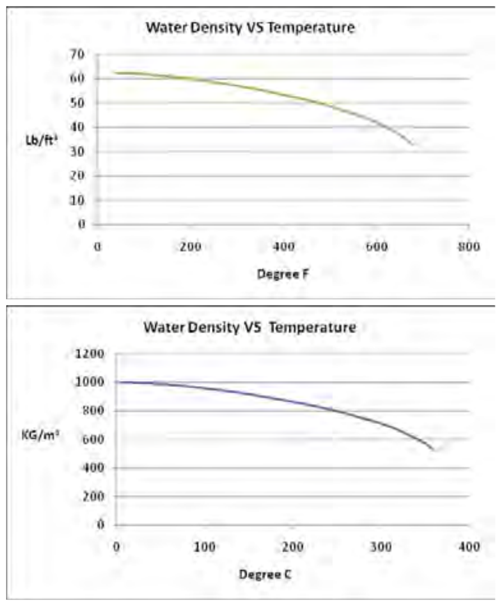


Figure 12.1.2: Water density depending on temperature, in English and Metric units

For example, a boiler drum is operating at 1595 psi (110 bar), therefore the saturated steam temperature is 605°F (319°C) and the physical height of the water in the drum is 15 in. (381 mm). If the water in the side mounted device is cooled to 500°F (260°C), then the level height will drop to 11.6 in. (295 mm). Progressively cooler temperatures will result in progressively lower levels.

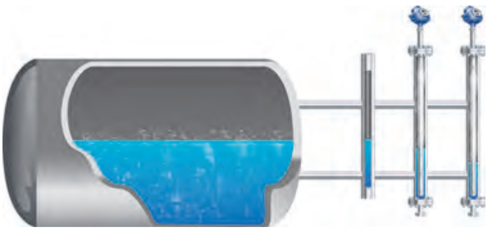


Figure 12.1.3: Offset in level measurement due to temperature differences

Density error associated with side-mounted devices can be minimized by incorporating some simple tactics. The goal is to keep the temperature in the side mounted device as close as possible to the drum temperature. This can be achieved by a combination of:

- Minimizing the overall distance to the side-mounted device to 3 to 6 ft (1 to 2 m)
- Including a small slope on the connection lines to a Hydrastep or chamber can enhance water circulation and thereby keeping average water temperature higher
- Insulating the pipes and the chamber/device where possible

Note that some level devices cannot be fully insulated or have sloped lines. Sight glasses and magnetic floats must have some parts exposed and require stable levels. The recommendation for Hydrastep insulation includes leaving a small amount of un-insulated pipe on the steam leg to encourage condensation which transfers latent heat from the steam to the water in the water column.

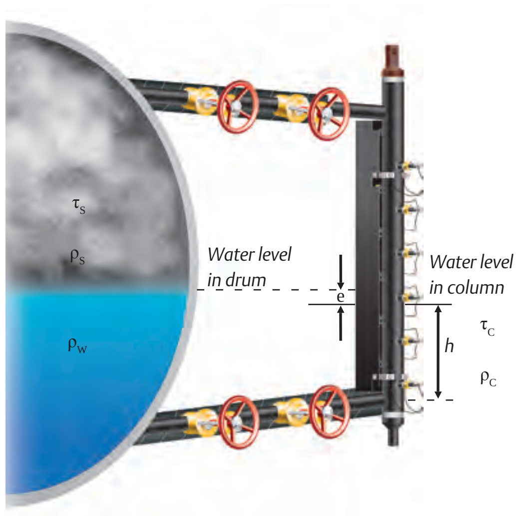


Figure 12.1.4: Minimizing the offset in level measurement due to temperature differences

Wet leg systems

DP transmitters are a common level measurement technique for boiler systems. They are often connected to the boiler with ½ in. piping that is filled with water. The objective is to keep the water legs (or wet legs) at a constant height so that the differential between the high and low side can be detected easily. One common issue with wet legs is that when boiler 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. In the narrow piping, the water moves back into the drum and a significant reduction in wet leg level height occurs.

Recommendation:

When using wet legs, some simple tactics to improve the measurement include:

- The wet legs should not be insulated. Condensation of fluid in the legs is required for stability
- The legs should be kept parallel and of equal lengths from the bottom tap to the transmitter
- The length of the wet legs should be kept short. They need to be below the drum, but no more than one floor below the drum

- 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

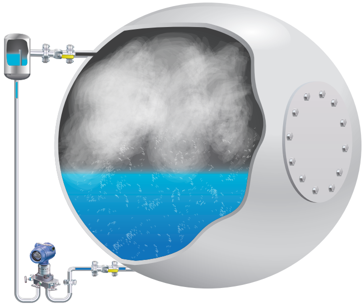


Figure 12.1.5: Wet leg DP installation on a boiler drum

12.1.2 Water and steam property changes

Two properties of water and steam that can affect level measurement devices used for boiler level measurements are density and dielectric constant. Density changes of both the steam and the water will affect differential pressure, displacers and floats. Dielectric changes of the steam can affect guided wave radar. In either case, both changes are predictable and compensation can be made.

Density

Density of the steam and the water phase will vary with the operating condition. Many control systems have algorithms that incorporate the operating pressure and use it to calculate the steam and water density corrections for density based level measurements. While this change is predictable, it can create some challenges during calibration and start-up due to rapid density changes. If the wet legs of a DP system are flashing, then this will compound the startup challenges.

Density error is dependent on both water level and operating conditions. For example, at room temperature, a DP transmitter for a 30 in. (762 mm) boiler drum could be calibrated -15 to +15 in. (-381 to +381 mm) with 0 at the normal water level of the drum. This would match the normal water level. The water portion would have a density of 998 kg/m³ or SG of 0.998 and steam would have a density of 0.0173 kg/m³ or SG of 0.

If the pressure and temperature are raised to operating conditions of 1000 psi (69 Bar), then the 15 in. (381 mm) of physical water level will now be represented by a density of 46.18 lb/ft³ (739.72 kg/m³)or SG 0.739, and the steam portion would have a density of 2.28 lb/ft³ (36.52 kg/m³) or an SG of 0.036.

The differential pressure would change from 15 in. to 11.6 in. (381 mm to 295 mm). This change in density of the steam and the water as the system is ramped up must be incorporated in the interpretation of the density based level measurement.

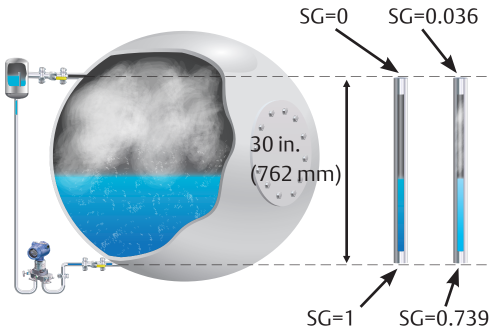


Figure 12.1.6: Density changes in a wet leg DP installation

- *At room temperature and pressure, there is 15" H_2O pressure (381 mm H_2O)*
- *At 1000 psi (69 Bar) and 544 F (284 C) there is 11.6" H_2O pressure (295 mm H_2O)*

Offsetting the water column during commissioning does not fully compensate for density error. It is not recommended that one corrects for density error in a Hydrastep water column. When correcting for this type of error, the correction is for one point in full range of operating conditions and with different levels. If corrected at one point and a specific condition, the error could be very large at a different level and temperature. In fact, if an offset for normal operating conditions and level was made, a dangerously high reading could be obtained. In the majority of cases, the density error in a correctly installed Hydrastep system with good water circulation will be small enough to require no offset under normal operating conditions.

Dielectric

The dielectric properties of the steam and water are a factor in guided wave radar (GWR) measurements since the dielectric constant affects the speed of travel of the microwave pulse. However, since GWR is a top-down measurement, only the travel time through the steam phase is affected because the signal is reflected back from the higher dielectric water. Unlike most other vapors, steam can have dielectric values that significantly affect the travel time of the pulse. Like density though, the vapor space dielectric (DC) is a predictable value, and it can be configured into the GWR during commissioning. As long as the operating conditions are constant, the actual DC value will not change, and the device will function properly. However, if operating conditions vary, a better alternative is to compensate for the DC dynamically. GWR that uses an online DC measurement of the steam can give a much better performance for systems with frequent changes in operating conditions.

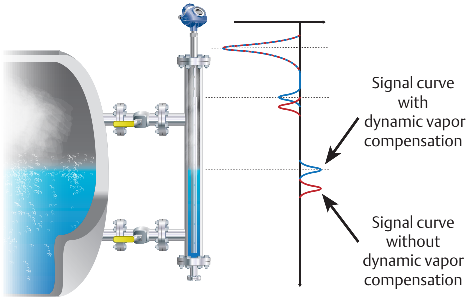


Figure 12.1.7: 5300 guided wave radar signal curve with and without dynamic vapor compensation functionality

When planning the installation of a GWR in a vessel, consider the overall height of the chamber and the level measurement area. It may be desirable to minimize the height of the chamber as the relative error of the GWR is based on the overall distance to the surface.

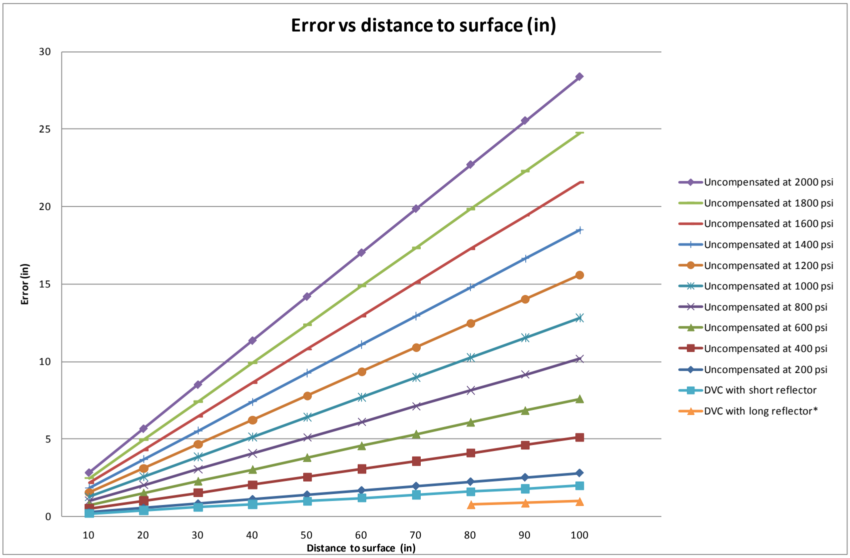


Figure 12.1.8: Error vs distance to surface

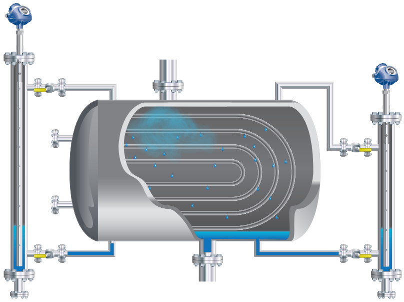


Figure 12.1.9: Long and short chamber installed on a feedwater heater

Even with compensation for steam dielectric changes, the distance of travel of the microwave signal will determine the overall errors when high pressure steam is present. *See figure 12.1.8 for example*

12.2 Replacing displacers with guided wave radar

Displacers are used for level, interface, and density applications, where the buoyancy of the displacer in the fluid is the primary measurement principle. Density of the fluid is a key factor in determining the sizing of the displacer and stability of the application, and any deviation from the initial density will impact the measurement accuracy.

Displacers have moving parts that require frequent cleaning and replacement. They are affected by mechanical vibration and turbulence, the mechanical parts can give false readings, and maintenance costs can be expensive.

Guided wave radar (GWR) technology has no moving parts, which means a reduction in maintenance costs as well as improved measurement. GWR is not density dependent and provides reliable measurement even with mechanical vibration of high turbulence. Since existing chambers can often be used, replacement is simplified.

There are many displacer flanges and styles, so it is important to correctly match the guided wave radar flange choice and probe length to the chamber. Both standard ANSI and DIN, are used, as well as proprietary chamber flanges with a non-standard diameter and gasket surface.

Applications:

Typically, displacers are found within the steam generation area of a power plant. Below are the most common displacer applications:

- Flash tanks / surge tanks
- Condenser / hot well
- HP feedwater heaters
- LP feedwater heaters

If displacer technology is still the preferred choice by the customer, it is included in Emerson's complete offering of level products.

See the following websites for more information:

www.mobrey.com

www.fisher.com

12.2.1 Steps to determining replacement with the 3300 or the 5300 series

1. Determine which measurement is needed: level, density? GWR is an easy, direct replacement for level measurements. If density is the desired measurement, then GWR is not a solution; consider a differential pressure transmitter instead.

2. Check displacer chamber mounting style with the diagrams *shown in Figure 12.2.1.*

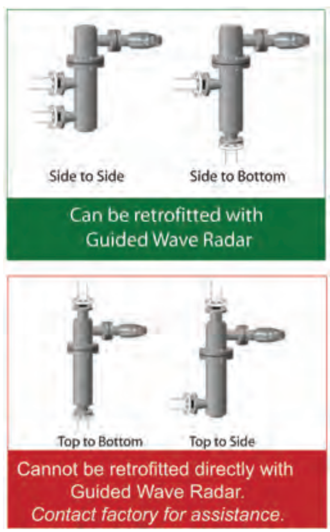


Figure 12.2.1: Displacer chamber mounting styles

3. Determine manufacturer and type of displacer chamber flange (proprietary, ANSI or DIN). The outside diameter (OD) of the chamber flange on top of the chamber can help determine if a proprietary flange is used:

   Major torque tube chambers

   249B and 259B OD: 9.0 in. (229 mm)

   249C OD: 5.8 in. (148 mm)

   249K: 10 in. (254 mm)

   249N: 10 in. (254 mm)

   Masoneilan OD: 7.5 in. (190 mm)

   All others: per ANSI or DIN specifications

4. Determine from *figure 12.2.2 a & b* if it is a torque tube or spring loaded displacer chamber.

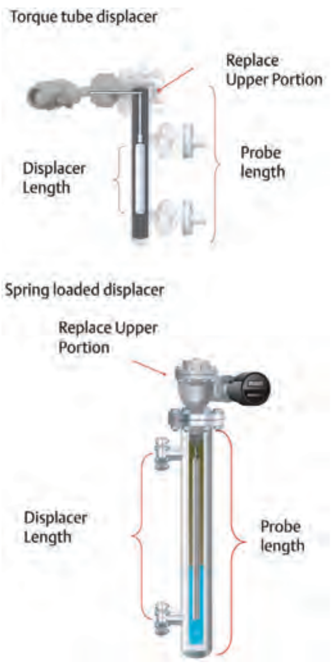


Figure 12.2.2 a: Probe length is longer than displacer length

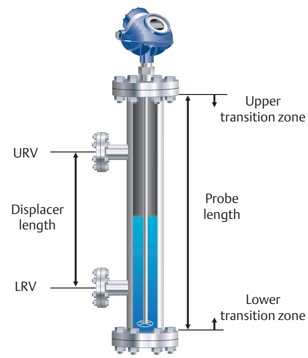


Figure 12.2.2 b: Probe length is longer than displacer length

Determine probe length. The probe length is measured from the flange face to the bottom of the chamber (internally) *as shown in figure 12.2.2 or listed in table 12.2.1*. While the probe needs to extend the full height of the chamber, it should not touch the bottom of the chamber. There should be a small gap (about 1/2 to 1 in. [12 – 25 mm]) between the end of the probe and the bottom of the chamber.

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 + 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 12.2.1 Chamber manufacturer with probe length correction.

(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.*

12.2.2 Recommended probe styles

Single rigid probes are recommended mostly for chamber installations. Exception is for high pressure (over 580psi / 40 bar) liquified gases where the coaxial probe is preferred. Single lead probes are the easiest to clean and are the best choice for dirty or viscous fluids. Since the chamber walls help to amplify the signal, single probes can be used for interface measurement and measurements on low dielectric materials. Centering discs are recommended. *See section 5.11.4 for more information on centering discs.*

See figure12.2.3 & figure 12.2.4

Figure 12.2.3: Probe styles - single probes are available in standard and high pressure/high temperature versions

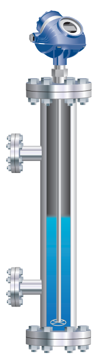


Figure 12.2.4: Rigid single probe style with centering disc

Flushing connections and vents

It is often desirable to vent the chamber near the top. This will ensure there is no trapped air or gas for submerged probe applications. Venting is also needed if the level in the chamber will be manipulated in order to verify the output of the 3300/5300 or to drain the chamber. The following options will accomplish this task:

- A separate flushing ring may be inserted between the 3300/5300 flange and the chambers that use ANSI or DIN flanges
- Proprietary flanges are available with an integrated vent option.They are used with 1 1/2 NPT threaded probes

For ANSI flanges

For Fisher 249 B, 249 C, and Masoneilan proprietary flanges

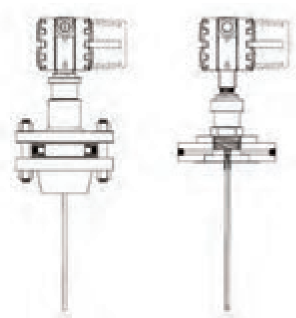


Figure 12.2.5: 3300/5300 flushing ring/vent options

Pressure and temperature

The standard guided wave radar products may be used in applications up to 302 °F (150 °C) and 580 psi (40 bar). For higher pressures and temperatures, the high pressure/high temperature or high pressure probe is available.

See figure 12.2.5 for details.

The 5300 has a higher sensitivity and is recommended for all liquified gas applications above 580 psi (40 bar) that need the high pressure or high temperature / pressure probe.

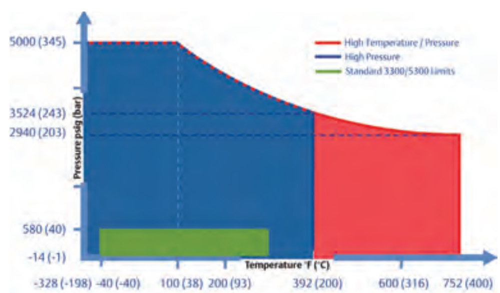


Figure 12.2.6: Pressure and temperature limits for standard, high pressure, high temperature/high pressure probes.

12.2.3 Setting range values - two options

Chambers are mounted on the tank to correspond with the desired measurement and area of control. This is often a small portion of the overall height.

With displacers, the output span corresponds to the displacer length. The lower (LRV) and upper range values (URV) represent the bottom and top of the displacer. In the side-to-side chambers, this corresponds to center-of-the-pipe connections to the vessel.

Option 1 - setting LRV to 0 in.(0 mm) at the lower tap

Set the tank height to the distance to the zero level point. In this example, it is the lower side-pipe which is located 19 in. (483 mm) below the reference point. Output range values will equal the pipe connection heights relative to the zero level point. LRV should be set at 0 in. (0 mm) and the URV should be set at 14 in. (365 mm). The probe should be set to the correct probe length.

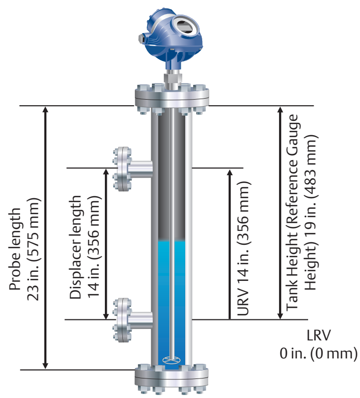


Figure 12.2.7: Setting range values, Option 1

Option 2 - matching displacer output

The tank height (reference gauge height) and the robe length should be set to the same value. The LRV is the distance from the bottom of the probe to the lower tap. The URV is the LRV plus the distance to the upper tap. In this example, tank height (reference height) equals the probe length of 23 in. (584 mm), the LRV is 4 in. (102 mm), and the URV is 18 in. (457 mm).

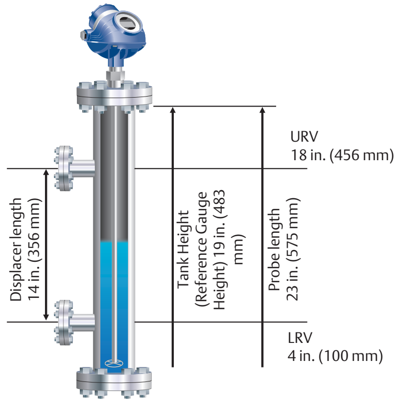


Figure 12.2.8: Setting range values, Option 2

12.3 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.

12.3.1 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.

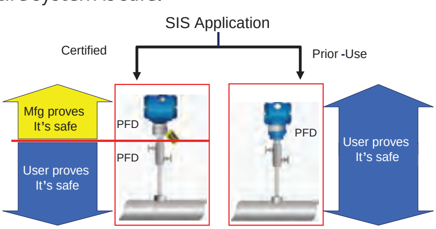


Figure 12.3.1: Responsibility of proof for SIS sensors

12.3.2 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.

12.3.3 Hardware fault tolerance

The hardware fault tolerance (HFT) is the ability of a system to respond to an unexpected hardware or software failure. There are many levels of fault tolerance, the lowest being the ability to continue operation in the event of a power failure.

12.3.4 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.

12.3.5 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 12.3.2 on next page.*

> 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, can not 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 12.3.1: 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.*

12.3.6 Rosemount 2130 series vibrating fork level switch SIL2 certified

The 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 2130 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 safety certified to IEC 61508 for use in SIL Safety Systems. This option provides the safety instrumentation engineer with the required failure data as per IEC 61508 / IEC 61511 and with proof test recommendations.

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 safety certified, meeting the requirements of IEC 61508 and providing a systematic integrity of SIL2 @ HFT=0.

- SFF: >90%
- PFDAVG (Tproof (1 year)): 1.5E-04
- Proof test interval: 8 years (Output Types P & L) or 23 years (Output type N)
- Valid for output types N, P, and L: SIL 2 @ HFT=0

The Rosemount 2130 vibrating fork level switch with output type D – DPDT/DPCO relay is a Type B device according to IEC 61508, with a SFF >76% and is safety certified, meeting the requirements of IEC 61508 and providing a systematic integrity of SIL2 @ HFT=1 and SIL1 @ HFT=0.

- SFF: <90%
- PFDAVG (Tproof (1 year)): 1.5E-04
- Proof test interval: 2 years
- Valid for output type D: SIL 2 @ HFT=1, SIL 1 @ HFT=0

See table 12.3.2 for information on proof test intervals for the 2130 series

Output option	NAMUR / IS	PNP / PLC	Direct load	Relay
SFF	>90%	>90%	>90%	60% ... 90%
PFDAVG (Tproof 1 year)	1.5E-4	4.3E-4	4.3E-4	11E-4
Proof test interval (based on PFDAVG of 3.5E-03 for SIL2)	23 years	8 years	8 years	2.3 years

Table 12.3.2: Proof test intervals for different output options for the 2130 series vibrating fork switches

12.3.7 Rosemount 5300 series guided wave radar SIL2 suitable

The 5300 series has been evaluated by third party Exida per hardware assessment IEC 61508. The hardware assessment consists of a FMEDA report.

Rosemount 5300 series 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 (Tproof (1 year)): 6.13E-04
- MTBF: 64 years
- Proof test interval: 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)

12.3.8 Rosemount 5400 series non-contacting radar SIL2 suitable

The 5400 series has been evaluated by third party SP per hardware assessment IEC 61508. The hardware assessment consists of a FMEDA (Failure Mode, Effects and Diagnostic Analysis) report. Rosemount 5400 series is considered to be a type B device.

With Safe Failure Fraction (SFF) 60% ... 90%, it has shown prior-use SIL 1 suitable, and SIL 2 suitable for Hardware Fault Tolerance of 1. This option provides the safety instrumentation engineer with the required failure data as per IEC 61508 /IEC 61511 and with proof test recommendations.

- SFF: 60% ... 90%
- PFDAVG (Tproof 1 year):
  - 5401: 13E-04
  - 5402: 12E-04
- Proof test interval: 2.7 – 2.9 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)

12.3.9 Rosemount 3051S_L liquid level transmitter safety certified

The Rosemount 3051S_L liquid level transmitter is safety certified to IEC 61508. It is a Type B device that meets the requirements of providing a level integrity of HFT=0 for SIL2 and HFT =1 for SIL 3 applications. The safety certification is for the transmitter only. The attached seal system PFD data which is dependent upon the seal system must be added to the transmitter failure data to account for the total PFD of the system.

- SFF: 93.1%
- PFDAVG (Tproof (1 year)): 1.65E-04
- Proof test interval: 5 years
- Valid for 4-20 mA/HART output

NOTE!

For more information regarding safety, including certificates, FMEDA reports, and safety manuals, go to:

http://www2.emersonprocess.com/en-US/brands/rosemount/Safety-Products/Pages/index.aspx

12.4 Cyber security for power plants – FERC & NERC organizations

In July 2006, Federal Energy Regulatory Commission (FERC) designated the North American Electric Reliability Corp. (NERC) as the Electric Reliability Organization (ERO) under section 215 of the Federal Power Act (FPA). This provision was added by the Energy Policy Act of 2005 to establish a system of mandatory, enforceable reliability standards under the commission's oversight.

NERC is an international, independent, self-regulatory, not-for-profit organization, whose mission is to ensure the reliability of the bulk power system in North America. NERC coordinates efforts towards the critical infrastructure protection program to improve physical and cyber security for the bulk power system of North America as it relates to reliability.

These efforts include standards development, compliance enforcement, assessments of risk and preparedness, disseminating critical information via alerts to industry, and raising awareness of key issues. Additionally, the program is home to the electricity sector information sharing and analysis center (or ES-ISAC) and monitors the bulk power system to provide real time situation awareness leadership and coordination services to the electric industry.

12.5 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. This document outlines these best practices and can be used as a *guideline during radar installation and start-up.*

There are several ways transient energy can enter a level transmitter and cause damage to the electronics.

See figure 12.5.1.

IMPORTANT!

Always ground in accordance with hazardous locations certifications, national, and local electrical codes.

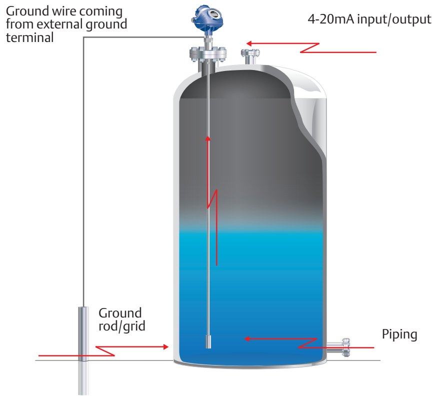


Figure 12.5.1: Example of transient or surge path

12.5.1 Proper grounding and transient protection - loop power requirements

Rosemount radar level transmitters are loop powered and require twisted shielded pair of wires in 18 - 22 American wire gauge (AWG) depending on the impedance and the voltage drop created. The table below outlines power requirements for Rosemount radar transmitters.

NOTE!

When wiring Rosemount radar with a Smart Wireless THUM™ Adapter, add 2.5 Vdc to power requirements. THUM adapters must be mounted in IS installation but can be remotely mounted if combined with Non-IS transmitter.

Loop power wiring must be grounded in accordance with national and local code, and it is important to ground only at one end in order to prevent ground loop currents.

NOTE!

Do not run the transient protection ground wire with signal wiring as the ground wire may carry excessive current if a lightning strike occurs.

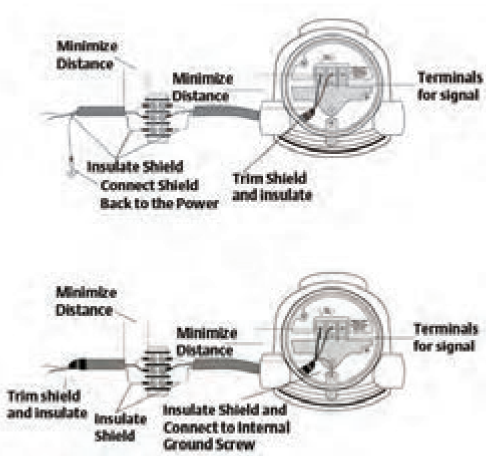


Figure 12.5.2: Possible field connections of Rosemount 3300, 5400, or 5300 series level transmitters

When directly mounting a Smart Wireless THUM™ Adapter to Rosemount Radar, the loop grounding principles remain the same. The ground wire should be grounded at the power supply and left floating at the THUM adapter/Radar.

12.5.2 Housing ground

In addition to grounding the signal wires, it is critical to ground the housing. In order to create a direct path to ground, the grounding terminal in the transmitters must be utilized. The housing should always be grounded in accordance with national and local electrical codes. Failure to do so may impair the protection provided by the equipment. The most effective grounding method is direct connection to earth ground with minimal impedance. There are two grounding screw connections provided. One is inside the field terminal side of the housing and the other is located on the housing. The internal ground screw is identified by a ground symbol: ⏚

See figure 12.5.3

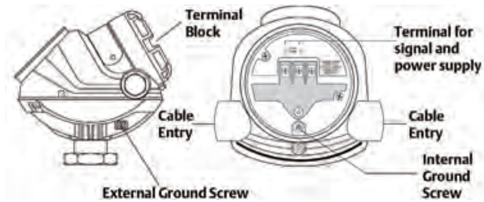


Figure 12.5.3: Location of ground terminals

When directly mounting a Smart Wireless THUM™ Adapter to Rosemount radar, the green wire of the THUM adapter should be connected to the internal ground screw. This prevents a shock hazard from occurring.

		Rosemount radar 5400	5300	3300
Power requirements: HART	Explosion/flame-proof	20-42.4 Vdc	20-42.4 Vdc	16-42 Vdc
	IS/standard	16-30 Vdc	16-30 Vdc	11-30 Vdc
Power requirements: Foundation Fieldbus	Explosion/flame-proof	16-32 Vdc	16-32 Vdc	NA
	IS/standard	9-30 Vdc	9-30 Vdc	NA
	FISCO	9-17.5Vdc	9-17.5 Vdc	NA
Power requirements: Modbus	Standard	8-30 Vdc[1]	8-30 Vdc[1]	8-30 Vdc[1]

Table 12.5.1: Power supply requirements for Rosemount Radar

(1) Requires separate power supply

> NOTE!
> In the explosion-proof/flameproof version, the electronics is grounded via the transmitter housing. After installation and commissioning make sure that minimal ground differences exist.

12.5.3 Transmitter transient protection design

To protect against transient energy, Rosemount radars utilize the transmitter housing as reference ground. The function of the transmitter transient protection is to lead any excessive surge energy directly to ground. To accomplish this, a separate chassis ground wire is required. This wire should go directly to a ground rod or other ground connection. The transmitter transient protection design is only as good as the grounding. Without proper grounding there is no place for the energy to be redirected.

When grounding the housing, the external ground connection can be a separate ground rod or grid at the tank. Alternatively, the piping to the tank can be used as ground if the piping is grounded. When using the piping as ground instead of a separate ground rod or grid, ensure that there is no galvanic isolation(1) in the piping system connected to the tank. This can be verified by checking the ground resistance. Additionally, if cathodic protection(2) is applied to the piping system, isolation and other special considerations may be necessary.

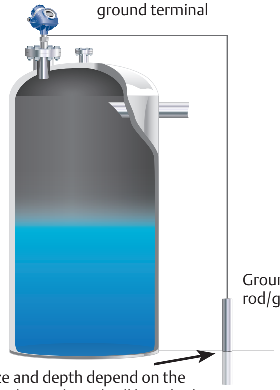


Figure 12.5.4: External ground connection

(1) *Galvanic isolation is the principle of isolating functional sections of electric systems so that charge-carrying particles cannot move from one section to another. Reference: www.wikipedia.org*

(2) *Cathodic Protection prevents corrosion by converting all of the anodic (active) sites on the metal surface to cathodic (passive) sites by supplying electrical curren (or free electrons) from an alternate source. Reference: www.cathodicprotection101.com*

NOTE!

For all the previously mentioned transient protection, if the grounding is not sufficient the transmitter chassis or ground will get a significantly different potential. This means that the current can go in the wrong direction and the 4-20 mA electronics can get damaged even though the surge entered the transmitter through the probe or vice versa.

12.5.4 Grounding wire

The dimension of the grounding wire is also important to proper grounding. The wire needs to efficiency lead the transients and energy to ground. The wire should be of sufficient diameter and be kept as short as possible. Larger diameter cable is always better than smaller diameter. *Table 12.5.2* below outlines the relationship between wire sizes, impedance, and maximum current..

12.5.5 Grounding resistance

Once all wiring and grounding recommendations have been followed, it is important to test the ground resistance at the grounding rod to assure a good ground. When grounding Rosemount radars, strive for impedance less than 5 Ohms and never allow more than 25 Ohms. Essentially, the goal in ground resistance is to achieve the lowest ground resistance value possible. There is no standard ground resistance threshold that is recognized by all agencies or users. The NFPA (National Fire Protection Association) and IEEE (Institute of Electrical and Electronics Engineers) have recommended a ground resistance value of 5.0 ohms or less. The NEC (National Electric Code) recommends that system impedance to ground is less than 25 ohms as specified in NEC 250.56. However, they suggest that the system impedance be 5.0 ohms or less for facilities with sensitive equipment.

AWG gauge	Metric wire size mm^2	Conductor diameter Inch	Conductor diameter mm.	Ohms per 1000 ft	Ohms per km	Maximum amps for chassis wiring
0	53.46	0.3249	8.25246	0.0983	0.322424	245
1	42.39	0.2893	7.34822	0.1239	0.406392	211
2	33.61	0.2576	6.54304	0.1563	0.512664	181
3	26.65	0.2294	5.82676	0.197	0.64616	158
4	**21.14**	**0.2043**	**5.18922**	**0.2485**	**0.81508**	**135**
5	**16.76**	**0.1819**	**4.62026**	**0.3133**	**1.027624**	**118**
6	**13.29**	**0.162**	**4.1148**	**0.3951**	**1.295928**	**101**
7	**10.55**	**0.1443**	**3.66522**	**0.4982**	**1.634096**	**89**
8	**8.36**	**0.1285**	**3.2639**	**0.6282**	**2.060496**	**73**
9	**6.63**	**0.1144**	**2.90576**	**0.7921**	**2.598088**	**64**
10	**5.26**	**0.1019**	**2.58826**	**0.9989**	**3.276392**	**55**
11	4.17	0.0907	2.30378	1.26	4.1328	47
12	3.31	0.0808	2.05232	1.588	5.20864	41
13	2.63	0.072	1.8288	2.003	6.56984	35
14	2.08	0.0641	1.62814	2.525	8.282	32

Table 12.5.2: AWG and metric wire gauge with current limit for ground wire consideration. Recommended sizes are AWG gauge 4-10 (metric wire size 21.14 - 5.26 mm^2)

12.5.6 Guided wave radar special considerations

When installing Rosemount guided wave radars in non-metal tanks or plastic pellets silos, the Rosemount 5300 is required for additional EMI performance. A ground plane between the electronics, microwave components, and housing results in a more stable microwave performance and minimizes unwanted disturbances. To enhance performance, the following grounding considerations should be practiced in order to ground the tank contents.

12.5.7 Non-metal tanks

On non-metal tanks, surges can enter the transmitter through the guided wave radar probe, so it is important to ground the fluid content in the tank. If the tank is filled from the bottom, the fluid is usually grounded through the piping. However, in situations where the tank is filled from the top, the fluid may not be properly grounded. In these cases, the grounding can be done by inserting a conductive rod or wire into the tank and connecting it to ground. This rod or wire should be more than 12-in (30 cm) away from the probe so that it does not contact the probe. Also, it should cover the entire height of the tank so that the fluid is grounded at all times.

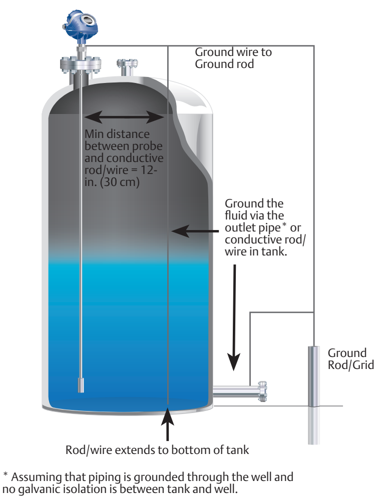


Figure 12.5.5: Non-metal tank with connection to ground

12.5.8 Plastic pellets

Plastic pellets are usually contained in metal silos, which are less susceptible to external transient damage. However, it is possible for transient energy to originate inside the tank and damage the electronics by passing up the probe. This transient energy is created by friction from the pellets. When the tank is filled or emptied, the static electricity will increase because the friction between pellets increases. Since the tank walls are grounded, the static electricity created by the pellets is typically only a concern for silo diameters greater than 10-ft. (3 m). Similar to a non-metal tank, the contents can be grounded by adding a conductive rod or wire inside the tank. It is common practice to add a conductive wire that strings from a flange at the top of the tank to a flange at the bottom of the tank. The bottom flange can then be grounded by wiring to a ground rod. In large diameter tank it may be necessary to add additional wires equally distributed in the tank. For example, a 15-ft. (4.5 m) diameter might have 3 wires equally distributed as backup in case one breaks. Plastic pellets are more susceptible to static charge than plastic powder.

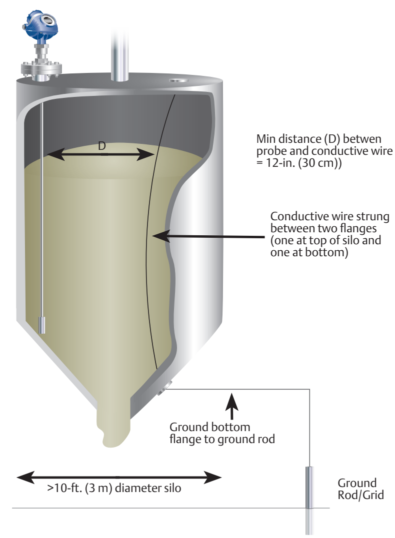


Figure 12.5.6: Metal storage silo with plastic pellets

12.5.9 Wiring best practices

The checklist below summarizes wiring best practices discussed in this section. It can be used to confirm that Rosemount radar transmitters are properly grounded.

- □ Check power loop:
  - √ Twisted shielded pair of wires in 18-22 AWG

Only grounded at one point in loop.

- □ Verify that transmitter has terminal block with transient protection.
- □ Check that transmitter housing is grounded:
  - √ Grounding terminal (either *internal or external ground screw) utilized for direct path to ground 3

**May be required by local regulations*

- □ Verify that the ground wire is a sufficient diameter and is kept as short as possible.
- □ Check resistance at ground.
  - √ Less than 5 Ohms and no greater than 25 Ohms
- □ Verify that probe is grounded by grounding the process fluid (non-metal tanks and plastic pellet silos only)

12.5.10 Troubleshooting

For troubleshooting see Table 12.5.1.

Symptoms	Corrective action
Transmitter milliamp reading is zero	Verify power is applied to signal terminals Option for 5300/5400: check LCD/LED Check power wires for reversed polarity Verify power source voltage is adequate at terminals: 5300/5400: 16-30 V dc for IS, 20-42.4 V dc in Explosion-proof 3300: 11-30 V dc for IS, 16-42 V dc in Explosion Proof For 3300, check for open diode across test terminal Verify that the transmitter and power supply are properly grounded
Transmitter not communicating with HART communicator	Verify clean DC Power to transmitter (Max AC noise 0.2 volts peak to peak) Check loop resistance, 250 Ω minimum (PS voltage -transmitter voltage/loop current) Check if unit is addressed properly Verify power source voltage is adequate at terminals. See specifications above
Transmitter milliamp reading is low or high	Verify level Verify 4 and 20 mA range points Verify output is not in alarm condition Verify if 4-20 mA output trim is required
Transmitter will not respond to changes in level	Verify that level is between the 4 and 20 mA set points Verify output is not in alarm condition Verify transmitter is not in simulation mode Check threshold settings Check radar echo curve
Milliamp reading is erratic	Verify power source voltage is adequate at terminals. See specifications above Check for external electrical interference Verify transmitter is properly grounded Verify shield for twisted pair is only grounded at one end
Milliamp reading is spiking or dropping out intermittently	If using Tri-loop, check that AC noise (RMS value) is less than 70 mV (using a Fluke) or less than 200 mV (using oscilloscope) Verify Tri-loop is installed in a shielded container Check echo curve threshold settings Verify transmitter is properly grounded

Table 12.5.1: Troubleshooting guide for potential power and grounding related issues

13

Reference material

Topic | Page

13. Reference material

13.1 Dielectric constants

COMPOUND	DK	°F	°C	STATE
ALUM (ALUMINIUM POTASSIUM SULPHATE)	4.2	140	60	S
ALUM (ALUMINIUM SULPHATE)	2.6	68	20	S
AMMONIA	1.0072	32.0	0.0	GA
AMMONIA	14.9	77.0	25.0	L
AMMONIA	15.5	68.0	20.0	L
AMMONIA	18.9	40.0	4.4	L
AMMONIA	22.0	-30.0	-34.4	L
AMMONIA	22.7	-58.0	-50.0	L
AMMONIA	25.0	-104.0	-75.6	L
AMMONIA	25.0	-74.0	-58.9	L
AMMONIA, AQUEOUS (25%)	31.6	68.0	20.0	L
ASBESTOS, BLUE	3.4	68.0	20.0	S
ASBESTOS, DRY	10.2	68.0	20.0	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
ASH, SODA (0.09% H2O)	1.7	75.0	23.9	S
BONE MEAL	1.7	68.0	20.0	S
BRINE	>80	68	20	L
CALCIUM SULFATE	2.3	75.0	23.9	S
CALCIUM SULFATE	5.6	75.0	23.9	S
CARBON DIOXIDE	1.000921	68.0	20.0	GA
CARBON DIOXIDE	1.5	71.6	22.0	L
CARBON DIOXIDE	1.6	32.0	0.0	L
CHLORINE	1.5	142.0	61.1	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	L
COAL 15% MOISTURE	4.0	68.0	20.0	S
COAL 65% MOISTURE	25.3	68.0	20.0	S
COAL BITUMINOUS 0% H2O	3.2	700.0	371.1	S
COAL BITUMINOUS 0% H2O	4.1	400.0	204.4	S

COMPOUND	DK	° F	° C	STATE
COAL BITUMINOUS 0% H2O	7.5	77.0	25.0	S
COAL DUST	2.49	68.0	20.0	S
COAL POWDER	4.6	68.0	20.0	S
COAL TAR	2.0-3.0			L
COAL, POWDER, FINE	2-4			S
COKE	3.0	68.0	20.0	S
COKE	8.0	68.0	20.0	S
COKE	1.1-2.2			S
COKE (FROM COAL)	1.6	75.0	23.9	S
COMMON SALT 0.9	22.0	230.0	110	S
COMMON SALT 0.9	23.0	68.0	20.0	S
CORN COBS	1.8	75.0	23.9	S
CORN COBS 2% H2O (CRUSHED)	2.0	75.0	23.9	S
DIESEL FUEL	2.1	68.0	20.0	L
ETHYLENE GLYCOL	37.0	68.0	20.0	L
ETHYLENE GLYCOL	38.7	68	20	L
ETHYLENE GLYCOL	46.7	59	15	L
FLY ASH	3.3	68.0	20.0	S
FLY ASH	1.9-2.6			S
GLYCOL	37.0	68	20	L
GYPSUM (3.5% H2O)	5.4	75.0	23.9	S
HEAVY OIL	3.0	482	250	L
HYDROCHLORIC ACID	2.6	68.0	20.0	L
HYDROCHLORIC ACID	4.6	68.0	20.0	L
HYDROCHLORIC ACID	4.6	81.9	27.7	L
HYDROCHLORIC ACID	6.3	5.0	-15.0	L
HYDROCHLORIC ACID	10.1	-121.0	-85.0	L
HYDROCHLORIC ACID	10.2	-162.4	-108.0	L
HYDROCHLORIC ACID	11.8	-171.8	-113.2	L
KEROSENE (COMMERCIAL)	1.8	70.0	21.1	L
LIME	2.6	75.0	23.9	S
LIME	10.9	75.0	23.9	S
LIME (REBURNED)	2.2	75.0	23.9	S
LIME 1% H2O	4.2	75.0	23.9	S
LIME 2% H2O	7.7	75.0	23.9	S
LIME GRANULATE	4.0	68.0	20.0	S
LIME POWDER	3.3	68.0	20.0	S
LIME, CARBON-DIOXIDE PROCESS	3.1	68.0	20.0	S
LIME, MUNSTER	1.8	RT	RT	S
LIME, PHOSPHORIC ACID	5.0	68.0	20.0	S

COMPOUND	DK	° F	° C	STATE
LIME, SLAKED, 4 WEEKS OLD	2.2	68.0	20.0	S
LIME, SLAKED, DOLOMITE	1.8	RT	RT	S
LIME, SLAKED, REFINED	4.0	68.0	20.0	S
LIMESTONE	9.0	75.0	23.9	S
LIMESTONE .6% H2O	2.8	75.0	23.9	S
LIMESTONE 2% H2O	2.3	75.0	23.9	S
METHANE (LIQ. NATURAL GAS)	1.7	-295.6	-182.0	L
METHANOL (WOOD ALCOHOL, METHYL ALCOHOL)	33.0	68.0	20.0	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
MINERAL OIL	2.1	80.0	26.7	L
NITRIC ACID	50.0	14.0	-10.0	L
NITRIC ACID 97% HNO3	33.6	68.0	20.0	L
NITRIC ACID 98% HNO3	19.0	68.0	20.0	L
NITROGEN	1.00058	68.0	20.0	GA
NITROGEN	1.5	-346.0	-210.0	L
NITROGEN	1.445	-352.1	-213.4	L
NITROGEN	1.454	-318.5	-194.7	L
NITROGEN (LIQUIFIED)	1.3	-310.0	-190.0	L
NITROGEN (LIQUIFIED)	1.5	336.0	168.9	L
OIL	2.0 - 3.0	68.0	20.0	L
OIL / WATER MIXTURE	24.2	68.0	20.0	L
OIL, FUEL (#2)	2.7	75.0	23.9	L
OIL, HEATING	2.1	68.0	20.0	L
OIL, LUBE	2.1-2.4	68.0	20.0	L
OIL, TRANSFORMER (LUBE OIL)	2.1	68.0	20.0	L
PALLMAN CHIPS (WOOD, MOIST)	2.3	68.0	20.0	S
PAPER, WOOD, DRY	2.0	75.0	23.9	S
PROPANE	1.6	32.0	0.0	L
PROPANE	1.7	68.0	20.0	L
REBURNED LIME	2.2			S
RESIN	1.5	68.0	20.0	S
RESIN, NATURAL	2.2	RT	RT	S
RESIN, POLYESTER "ATLAS", +C2480 PECHINEY	2.3	68.0	20.0	S
RESIN, TECHNICAL PURITY	24.5	68.0	20.0	S
ROCK SALT 0-25MM	4.3	68.0	20.0	S
SALT	3.0-15.0	212	100	S
SALT WATER	32.0	68.0	20.0	L
SAWDUST	1.3	RT	RT	S

COMPOUND	DK	° F	° C	STATE
SAWDUST, (DRY)	1.6	75.0	23.9	S
SHAVINGS-DUST, DRY	1.3	68.0	20.0	S
SHAVINGS-DUST, MOIST	2.0	68.0	20.0	S
SLAKED LIME, POWDER	2.0-3.5	158	70	S
SLATE	7.0	75.0	23.9	S
SODA (SODIUM CARBONATE)	4.6	RT	RT	S
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	68	20	S
SODIUM HYDROXIDE	25.8	68.0	20.0	
SODIUM HYPOCHLORITE	6.7	122	50	L
SODIUM PHOSPHATE	1.6-1.9			S
SODIUM SULFITE	5.0	90,14	32,3	S
SODIUM TRIPOLYPHOSPHATE	2.3	75.0	23.9	S
SULFURIC ACID	21.9	68.0	20.0	L
SULFURIC ACID, 15%	31.0	68.0	20.0	L
SULFURIC ACID, 95%	8.3	68.0	20.0	L
SULFURIC ACID, 96%	7.76	68.0	20.0	L
SULFURIC ACID, 97%	8.64	68.0	20.0	L
SULFURIC ACID, 98%	7.18	68.0	20.0	L
SULFURIC ACID, CONC.	3.5	69.8	21.0	L
UREA RESIN	5.0-8.0	248	120	S
UREA	2.9	RT	RT	S
UREA	3.5	71.6	22.0	L
UREA	3.5	75.0	23.9	S
WATER AT 580 PSI (40 BAR)	26.94	482	250	L
STEAM AT 580 PSI (40 BAR)	1.150	482	250	GA
WATER AT1305 PSI (90 BAR)	19.69	578	303	L
STEAM AT1305 PSI (90 BAR)	1.370	578	303	GA
WATER AT 2175 psi (150 bar)	14.30	649	343	L
STEAM AT 2175 psi (150 bar)	1.810	649	343	GA
WATER AT 2320 psi (160 bar)	13.57	658	348	L
STEAM AT 2320 psi (160 bar)	1.920	658	348	GA
WATER, DEIONIZED	30.0	68.0	20.0	L
WATER, DEMINERALISED	30.0	68.0	20.0	L
WATER, DISTILLED	34.0	77.0	25.0	L
WATER, FROZEN (ICE)	3.2	10.0	-12.0	S
WATER, HEAVY	78	77.0	25.0	L

COMPOUND	DK	° F	° C	STATE
WATER, HEAVY (DEUTERIUM OXIDE)	80.0	68.0	20.0	L
WOOD CHIPPINGS, WOOD MOIST	2.3	68.0	20.0	S
WOOD CHIPS	1.13	68.0	20.0	S
WOOD PULP DUST	1.53	68.0	20.0	S
WOOD SHAVINGS, COARSE AND COMPACT	1.4	RT	RT	S
WOOD SHAVINGS, COARSE AND LOOSE	1.1	RT	RT	S
WOOD SHAVINGS, DRY	1.23	68.0	20.0	S
WOOD SHAVINGS, FINE AND COMPACT	1.3	RT	RT	S
WOOD SHAVINGS, FINE AND LOOSE	1.1	RT	RT	S
WOOD SHAVINGS, MOIST	1.73	68.0	20.0	S
WOOD, DRY	2.6			S

13.2 Glossary

A

Acid rain: Also called acid precipitation or acid deposition, acid rain is precipitation containing harmful amounts of nitric and sulfuric acids formed primarily by nitrogen oxides and sulfur oxides released into the atmosphere when fossil fuels are burned. It can be wet precipitation (rain, snow, or fog) or dry precipitation (absorbed gaseous and particulate matter, aerosol particles or dust). Acid rain has a pH below 5.6. Normal rain has a pH of about 5.6, which is slightly acidic. The term pH is a measure of acidity or alkalinity and ranges from 0 to 14. A pH measurement of 7 is regarded as neutral. Measurements below 7 indicate increased acidity, while those above indicate increased alkalinity.

Adjustment bid: A bid that is used by the independent system operator to adjust supply or demand when congestion on the transmission system is anticipated.

Aggregator: Any marketer, broker, public agency, city, county, or special district that combines the loads of multiple end-use customers in facilitating the sale and purchase of electric energy, transmission, and other services on behalf of these customers.

Ampere: The unit of measurement of electrical current produced in a circuit by 1 volt acting through a resistance of 1 ohm.

Ancillary services: Necessary services that must be provided in the generation and delivery of electricity. As defined by the federal energy regulatory commission, they include: coordination and scheduling services (load following, energy imbalance service, control of transmission congestion); automatic generation control (load frequency control and the economic dispatch of plants); contractual agreements (loss compensation service); and support of system integrity and security (reactive power, or spinning and operating reserves).

Anthracite: The highest rank of coal; used primarily for residential and commercial space heating. It is hard, brittle, and black lustrous coal, often referred to as hard coal, containing a high percentage of fixed carbon and a low percentage of volatile matter. The moisture content of fresh-mined anthracite generally is less than 15 percent. The heat content of anthracite ranges from 22 to 28 million Btu per ton on a moist, mineral-matter-free basis. The heat content of anthracite coal consumed in the United States averages 25 million Btu per ton, on the as-received basis (i.e., containing both inherent moisture and mineral matter).

> **NOTE!**
>
> Since the 1980's, anthracite refuse or mine waste has been used for steam electric power generation. This fuel typically has a heat content of 15 million Btu per ton or less.

Apparent power: The product of the voltage (in volts) and the current (in amperes). It comprises both active and reactive power. It is measured in “volt-amperes” and often expressed in “kilovolt-amperes” (kVA) or “megavolt-amperes” (MVA).

Ash: Impurities consisting of silica, iron, alumina, and other noncombustible matter that are contained in coal. Ash increases the weight of coal, adds to the cost of handling, and can affect its burning characteristics. Ash content is measured as a percent by weight of coal on a "received" or a "dry" (moisture-free, usually part of a laboratory analysis) basis.

Available but not needed capability: Net capability of main generating units that are operable but not considered necessary to carry load, and cannot be connected to load within 30 minutes.

Average revenue per kilowatthour: The average revenue per kilowatthour of electricity sold by sector (residential, commercial, industrial, or other) and geographic area (state, census division, and national), is calculated by dividing the total monthly revenue by the corresponding total monthly sales for each sector and geographic area.

B

Barrel: A volumetric unit of measure for crude oil and petroleum products equivalent to 42 U.S. gallons.

Base bill: A charge calculated through multiplication of the rate from the appropriate electric rate schedule by the level of consumption.

Baseload: The minimum amount of electric power delivered or required over a given period of time at a steady rate.

Baseload capacity: The generating equipment normally operated to serve loads on an around-the-clock basis.

Baseload plant: A plant, usually housing high-efficiency steam-electric units, which is normally operated to take all or part of the minimum load of a system, and which consequently produces electricity at an essentially constant rate and runs continuously. These units are operated to maximize system mechanical and thermal efficiency and minimize system operating costs.

Bbl: The abbreviation for barrel.

Bcf: The abbreviation for 1 billion cubic feet.

Bilateral agreement: Written statement signed by a pair of communicating parties that specifies what data may be exchanged between them.

Bilateral contract: A direct contract between the power producer and user or broker outside of a centralized power pool or power exchange.

Bituminous coal: A dense coal, usually black, sometimes dark brown, often with well-defined bands of bright and dull material, used primarily as fuel in steam-electric power generation, with substantial quantities also used for heat and power applications in manufacturing and to make coke. Bituminous coal is the most abundant coal in active U.S. mining regions. Its moisture content usually is less than 20 percent. The heat content of bituminous coal ranges from 21 to 30 million Btu per ton on a moist, mineral-matter-free basis. The heat content of bituminous coal consumed in the United States averages 24 million Btu per ton, on the as-received basis (i.e., containing both inherent moisture and mineral matter).

Boiler: A device for generating steam for power, processing, or heating purposes or for producing hot water for heating purposes or hot water supply. Heat from an external combustion source is transmitted to a fluid contained within the tubes in the boiler shell. This fluid is delivered to an end-use at a desired pressure, temperature, and quality.

Bottom ash: A byproduct of coal combustion. Bottom ash forms clinkers on the wall of the furnace, with the clinkers eventually falling to the bottom of the furnace.

Broker: An entity that arranges the sale and purchase of electric energy, transmission, and other services between buyers and sellers, but does not take title to any of the power sold.

BTU (British Thermal Unit): A standard unit for measuring the quantity of heat energy equal to the quantity of heat required to raise the temperature of 1 pound of water by 1 degree Fahrenheit.

Bundled utility service: All generation, transmission, and distribution services provided by one entity for a single charge. This would include ancillary services and retail services.

C

California power exchange: The California power exchange corporation, a state chartered, non-profit corporation charged with providing day-ahead and hour-ahead markets for energy and ancillary services, if it chooses to self-provide, in accordance with the power exchange tariff. The power exchange is a scheduling coordinator and is independent of both the independent system operator and all other market participants.

Capability: The maximum load that a generating unit, generating station, or other electrical apparatus can carry under specified conditions for a given period of time without exceeding approved limits of temperature and stress.

Capacity: The amount of electric power delivered or required for which a generator, turbine, transformer, transmission circuit, station, or system is rated by the manufacturer.

Capacity (purchased): The amount of energy and capacity available for purchase from outside the system.

Capacity charge: An element in a two-part pricing method used in capacity transactions (energy charge is the other element). The capacity charge, sometimes called demand charge, is assessed on the amount of capacity being purchased.

Census divisions: The nine geographic divisions of the United States established by the Bureau of the Census, U.S. Department of Commerce, for the purpose of statistical analysis. The boundaries of census divisions coincide with State boundaries. The pacific division is subdivided into the pacific contiguous and pacific noncontiguous areas.

Circuit: A conductor or a system of conductors through which electric current flows.

Coal: A readily combustible black or brownish-black rock whose composition, including inherent moisture, consists of more than 50 percent by weight and more than 70 percent by volume of carbonaceous material. It is formed from plant remains that have been compacted, hardened, chemically altered, and metamorphosed by heat and pressure over geologic time.

Cogenerator: A generating facility that produces electricity and another form of useful thermal energy (such as heat or steam), used for industrial, commercial, heating, or cooling purposes. To receive status as a qualifying facility (QF) under the Public Utility Regulatory Policies Act (PURPA), the facility must produce electric energy and "another form of useful thermal energy through the sequential use of energy," and meet certain ownership, operating, and efficiency criteria established by the Federal Energy Regulatory Commission (FERC). *(See the Code of Federal Regulations, Title 18, Part 292.)*

Coincidental demand: The sum of two or more demands that occur in the same time interval.

Coincidental peak Load: The sum of two or more peak loads that occur in the same time interval.

Coke (petroleum): A residue high in carbon content and low in hydrogen that is the final product of thermal decomposition in the condensation process in cracking. This product is reported as marketable coke or catalyst coke. The conversion is 5 barrels (of 42 U.S. gallons each) per short ton. Coke from petroleum has a heating value of 6.024 million Btu per barrel.

Combined cycle: An electric generating technology in which electricity is produced from otherwise lost waste heat exiting from one or more gas (combustion) turbines. The exiting heat is routed to a conventional boiler or to a heat recovery steam generator for utilization by a steam turbine in the production of electricity. This process increases the efficiency of the electric generating unit.

Combined cycle unit: An electric generating unit that consists of one or more combustion turbines and one or more boilers with a portion of the required energy input to the boiler(s) provided by the exhaust gas of the combustion turbine(s).

Combinedpumped-storage plant: A pumped-storage hydroelectric power plant that uses both pumped water and natural stream flow to produce electricity.

Commercial: The commercial sector is generally defined as nonmanufacturing business establishments, including hotels, motels, restaurants, wholesale businesses, retail stores, and health, social, and educational institutions. The utility may classify commercial service as all consumers whose demand or annual use exceeds some specified limit. The limit may be set by the utility based on the rate schedule of the utility.

Commercial operation: Commercial operation begins when control of the loading of the generator is turned over to the system dispatcher.

Competitive transition charge: A non-bypassable charge levied on each customer of a distribution utility, including those who are served under contracts with nonutility suppliers, for recovery of a utility's transition costs.

Congestion: A condition that occurs when insufficient transfer capacity is available to implement all of the preferred schedules for electricity transmission simultaneously.

Consumption (fuel): The amount of fuel used for gross generation, providing standby service, start-up and/or flame stabilization.

Contract price: Price of fuels marketed on a contract basis covering a period of 1 or more years. Contract prices reflect market conditions at the time the contract was negotiated and therefore remain constant throughout the life of the contract or are adjusted through escalation clauses. Generally, contract prices do not fluctuate widely.

Contract receipts: Purchases based on a negotiated agreement that generally covers a period of 1 or more years.

Cooperative electric utility: An electric utility legally established to be owned by and operated for the benefit of those using its service. The utility company will generate, transmit, and/or distribute supplies of electric energy to a specified area not being serviced by another utility. Such ventures are generally exempt from Federal income tax laws. Most electric cooperatives have been initially financed by the Rural Electrification Administration, U.S. Department of Agriculture.

Cost: The amount paid to acquire resources, such as plant and equipment, fuel, or labor services.

Cost-of-service regulation: Traditional electric utility regulation under which a utility is allowed to set rates based on the cost of providing service to customers and the right to earn a limited profit.

Current (electric): A flow of electrons in an electrical conductor. The strength or rate of movement of the electricity is measured in amperes.

Customer choice: Allowing all customers to purchase kilowatthours of electricity from any of a number of companies that compete with each other.

D

Day-ahead market: The forward market for energy and ancillary services to be supplied during the settlement period of a particular trading day that is conducted by the independent system operator, the power exchange, and other scheduling coordinators. This market closes with the independent system operator's acceptance of the final day-ahead schedule.

Day-ahead schedule: A schedule prepared by a scheduling coordinator or the independent system operator before the beginning of a trading day. This schedule indicates the levels of generation and demand scheduled for each settlement period that trading day.

Delivery only providers: Owners and/or operators of transmission and distribution system equipment who provide billing and related energy services for the transmission and delivery of electricity.

Demand: The rate at which energy is delivered to loads and scheduling points by generation, transmission, and distribution facilities.

Demand (electric): The rate at which electric energy is delivered to or by a system, part of a system, or piece of equipment, at a given instant or averaged over any designated period of time.

Demand bid: A bid into the power exchange indicating a quantity of energy or an ancillary service that an eligible customer is willing to purchase and, if relevant, the maximum price that the customer is willing to pay.

Demand-side management: The planning, implementation, and monitoring of utility activities designed to encourage consumers to modify patterns of electricity usage, including the timing and level of electricity demand. It refers only to energy and load-shape modifying activities that are undertaken in response to utility-administered programs. It does not refer to energy and load-shape changes arising from the normal operation of the marketplace or from government-mandated energy-efficiency standards. Demand-side management (DSM) covers the complete range of load-shape objectives, including strategic conservation and load management, as well as strategic load growth.

Deregulation: The elimination of regulation from a previously regulated industry or sector of an industry.

Direct access: The ability of a retail customer to purchase commodity electricity directly from the wholesale market rather than through a local distribution utility.

Distillate fuel oil: A general classification for one of the petroleum fractions produced in conventional distillation operations. It is used primarily for space heating, on-and-off-highway diesel engine fuel (including railroad engine fuel and fuel for agriculture machinery), and electric power generation. Included are fuel oils No. 1, No. 2, and No. 4; and diesel fuels No. 1, No. 2, and No. 4.

Distribution: The delivery of electricity to retail customers (including homes, businesses, etc.).

Distribution system: The portion of an electric system that is dedicated to delivering electric energy to an end user.

Divestiture: The stripping off of one utility function from the others by selling (spinning-off) or in some other way changing the ownership of the assets related to that function. Stripping off is most commonly associated with spinning-off generation assets so they are no longer owned by the shareholders that own the transmission and distribution assets.

E

Electric plant (physical): A facility containing prime movers, electric generators, and auxiliary equipment for converting mechanical, chemical, and/or fission energy into electric energy.

Electric rate schedule: A statement of the electric rate and the terms and conditions governing its application, including attendant contract terms and conditions that have been accepted by a regulatory body with appropriate oversight authority.

Electric service provider: An entity that provides electric service to a retail or end-use customer.

Electric utility: A corporation, person, agency, authority, or other legal entity or instrumentality that owns and/or operates facilities within the United States, its territories, or Puerto Rico for the generation, transmission, distribution, or sale of electric energy primarily for use by the public and files forms listed in the Code of Federal Regulations, Title 18, Part 141. Facilities that qualify as cogenerators or small power producers under the Public Utility Regulatory Policies Act (PURPA) are not considered electric utilities.

Energy: The capacity for doing work as measured by the capability of doing work (potential energy) or the conversion of this capability to motion (kinetic energy). Energy has several forms, some of which are easily convertible and can be changed to another form useful for work. Most of the world's convertible energy comes from fossil fuels that are burned to produce heat that is then used as a transfer medium to mechanical or other means in order to accomplish tasks. Electrical energy is usually measured in kilowatthours, while heat energy is usually measured in British thermal units.

Energy charge: That portion of the charge for electric service based upon the electric energy (kWh) consumed or billed.

Energy deliveries: Energy generated by one electric utility system and delivered to another system through one or more transmission lines.

Energy efficiency: Refers to programs that are aimed at reducing the energy used by specific end-use devices and systems, typically without affecting the services provided. These programs reduce overall electricity consumption (reported in megawatthours), often without explicit consideration for the timing of program-induced savings. Such savings are generally achieved by substituting technically more advanced equipment to produce the same level of end-use services (e.g. lighting, heating, motor drive) with less electricity. Examples include high-efficiency appliances, efficient lighting programs, high-efficiency heating, ventilating and air conditioning (HVAC) systems or control modifications, efficient building design, advanced electric motor drives, and heat recovery systems.

Energy only providers: Power marketers or other electricity vendors who provide an unbundled service and bill for only the energy component of the electricity consumed by the end-use customer.

Energy receipts: Energy generated by one electric utility system and received by another system through one or more transmission lines.

Energy source: The primary source that provides the power that is converted to electricity through chemical, mechanical, or other means. Energy sources include coal, petroleum and petroleum products, gas, water, uranium, wind, sunlight, geothermal, and other sources.

EPACT: The Energy Policy Act of 1992 addresses a wide variety of energy issues. The legislation creates a new class of power generators, exempt wholesale generators, that are exempt from the provisions of the Public Holding Company Act of 1935 and grants the authority to the Federal Energy Regulatory Commission to order and condition access by eligible parties to the interconnected transmission grid.

Exchange energy: A specific electricity transactions between electric utilities wherein a barter of energy for energy occurs and money is used merely to settle minor imbalances at the end of a stated period.

Exempt wholesale generator: Created under the 1992 Energy Policy Act, these wholesale generators are exempt from certain financial and legal restrictions stipulated in the Public Utilities Holding Company Act of 1935.

F

Facility: An existing or planned location or site at which prime movers, electric generators, and/or equipment for converting mechanical, chemical, and/or nuclear energy into electric energy are situated, or will be situated. A facility may contain more than one generator of either the same or different prime mover type. For a cogenerator, the facility includes the industrial or commercial process.

Federal Energy Regulatory Commission (FERC): A quasi-independent regulatory agency within the Department of Energy having jurisdiction over interstate electricity sales, wholesale electric rates, hydroelectric licensing, natural gas pricing, oil pipeline rates, and gas pipeline certification.

Federal power act: Enacted in 1920, and amended in 1935, the act consists of three parts. The first part incorporated the Federal Water Power Act administered by the former Federal Power Commission, whose activities were confined almost entirely to licensing non-Federal hydroelectric projects. Parts II and III were added with the passage of the Public Utility Act. These parts extended the Act's jurisdiction to include regulating the interstate transmission of electrical energy and rates for its sale as wholesale in interstate commerce. The Federal Energy Regulatory Commission is now charged with the administration of this law.

Federal power commission: The predecessor agency of the Federal Energy Regulatory Commission. The Federal Power Commission (FPC) was created by an Act of Congress under the Federal Water Power Act on June 10, 1920. It was charged originally with regulating the electric power and natural gas industries. The FPC was abolished on September 20, 1977, when the Department of Energy was created. The functions of the FPC were divided between the Department of Energy and the Federal Energy Regulatory Commission.

FERC: The Federal Energy Regulatory Commission.

Firm gas: Gas sold on a continuous and generally long-term contract.

Firm power: Power or power-producing capacity intended to be available at all times during the period covered by a guaranteed commitment to deliver, even under adverse conditions.

Flue gas desulfurization unit (Scrubber): Equipment used to remove sulfur oxides from the combustion gases of a boiler plant before discharge to the atmosphere. Chemicals, such as lime, are used as the scrubbing media.

Flue gas particulate collectors: Equipment used to remove fly ash from the combustion gases of a boiler plant before discharge to the atmosphere. Particulate collectors include electrostatic precipitators, mechanical collectors (cyclones), fabric filters (baghouses), and wet scrubbers.

Fly ash: Particulate matter from coal ash in which the particle diameter is less than 1 x 10-4 meter. This is removed from the flue gas using flue gas particulate collectors such as fabric filters and electrostatic precipitators.

Forced outage: The shutdown of a generating unit, transmission line or other facility, for emergency reasons or a condition in which the generating equipment is unavailable for load due to unanticipated breakdown.

Fossil fuel: Any naturally occurring organic fuel, such as petroleum, coal, and natural gas.

Fossil-fuel plant: A plant using coal, petroleum, or gas as its source of energy.

Fuel: Any substance that can be burned to produce heat; also, materials that can be fissioned in a chain reaction to produce heat.

Fuel expenses: These costs include the fuel used in the production of steam or driving another prime mover for the generation of electricity. Other associated expenses include unloading the shipped fuel and all handling of the fuel up to the point where it enters the first bunker, hopper, bucket, tank, or holder in the boiler-house structure.

Full-forced outage: The net capability of main generating units that is unavailable for load for emergency reasons.

Full service providers: Utilities, municipalities, cooperatives and others who provide both electricity and the transmission services necessary to deliver it to end use customers.

Futures market: Arrangement through a contract for the delivery of a commodity at a future time and at a price specified at the time of purchase. The price is based on an auction or market basis. This is a standardized, exchange-traded, and government regulated hedging mechanism.

G

Gas: A fuel burned under boilers and by internal combustion engines for electric generation. These include natural, manufactured and waste gas.

Gas turbine plant: A plant in which the prime mover is a gas turbine. A gas turbine consists typically of an axial-flow air compressor, one or more combustion chambers, where liquid or gaseous fuel is burned and the hot gases are passed to the turbine and where the hot gases expand to drive the generator and are then used to run the compressor.

Generating unit: Any combination of physically connected generator(s), reactor(s), boiler(s), combustion turbine(s), or other prime mover(s) operated together to produce electric power.

Generation (electricity): The process of producing electric energy by transforming other forms of energy; also, the amount of electric energy produced, expressed in watthours (Wh).

Generation company: A regulated or non-regulated entity (depending upon the industry structure) that operates and maintains existing generating plants. The generation company may own the generation plants or interact with the short-term market on behalf of plant owners. In the context of restructuring the market for electricity, the generation company is sometimes used to describe a specialized "marketer" for the generating plants formerly owned by a vertically-integrated utility.

Gross generation: The total amount of electric energy produced by the generating units at a generating station or stations, measured at the generator terminals.

Net generation: Gross generation less the electric energy consumed at the generating station for station use.

Generator: A machine that converts mechanical energy into electrical energy.

Generator nameplate capacity: The full-load continuous rating of a generator, prime mover, or other electric power production equipment under specific conditions as designated by the manufacturer. Installed generator nameplate rating is usually indicated on a nameplate physically attached to the generator.

Geothermal plant: A plant in which the prime mover is a steam turbine. The turbine is driven either by steam produced from hot water or by natural steam that derives its energy from heat found in rocks or fluids at various depths beneath the surface of the earth. The energy is extracted by drilling and/or pumping.

Gigawatt (GW): One billion watts.

Gigawatthour (GWh): One billion watthours.

Greenhouse effect: The increasing mean global surface temperature of the earth caused by gases in the atmosphere (including carbon dioxide, methane, nitrous oxide, ozone, and chlorofluorocarbon). The greenhouse effect allows solar radiation to penetrate but absorbs the infrared radiation returning to space.

Grid: The layout of an electrical distribution system.

Gross generation: The total amount of electric energy produced by a generating facility, as measured at the generator terminals.

H

Heavy oil: The fuel oils remaining after the lighter oils have been distilled off during the refining process. Except for start-up and flame stabilization, virtually all petroleum used in steam plants is heavy oil.

Heavy water: Heavy water, D2O, is water in which both hydrogen atoms have been replaced with deuterium, the isotope of hydrogen containing one proton and one neutron. It is present naturally in water, but in only small amounts, less than 1 part in 5,000. Heavy water is one of the two principal moderators which allow a nuclear reactor to operate with natural uranium as its fuel.

Hedging contracts: Contracts which establish future prices and quantities of electricity independent of the short-term market. Derivatives may be used for this purpose.

Hydroelectric plant: A plant in which the turbine generators are driven by falling water.

I

Independent power producers: Entities that are also considered nonutility power producers in the United States. These facilities are wholesale electricity producers that operate within the franchised service territories of host utilities and are usually authorized to sell at market-based rates. Unlike traditional electric utilities, independent power producers do not possess transmission facilities or sell electricity in the retail market.

Independent system operators: An independent, Federally-regulated entity that coordinates regional transmission in a non-discriminatory manner and ensures the safety and reliability of the electric system.

Industrial: The industrial sector is generally defined as manufacturing, construction, mining agriculture, fishing and forestry establishments Standard industrial classification (SIC) codes 01-39. The utility may classify industrial service using the SIC codes, or based on demand or annual usage exceeding some specified limit. The limit may be set by the utility based on the rate schedule of the utility.

Intermediate load (electric system): The range from base load to a point between base load and peak. This point may be the midpoint, a percent of the peak load, or the load over a specified time period.

Internal combustion plant: A plant in which the prime mover is an internal combustion engine. An internal combustion engine has one or more cylinders in which the process of combustion takes place, converting energy released from the rapid burning of a fuel-air mixture into mechanical energy. Diesel or gas-fired engines are the principal types used in electric plants. The plant is usually operated during periods of high demand for electricity.

Interruptible gas: Gas sold to customers with a provision that permits curtailment or cessation of service at the discretion of the distributing company under certain circumstances, as specified in the service contract.

Interruptible load: Refers to program activities that, in accordance with contractual arrangements, can interrupt consumer load at times of seasonal peak load by direct control of the utility system operator or by action of the consumer at the direct request of the system operator. It usually involves commercial and industrial consumers. In some instances the load reduction may be affected by direct action of the system operator (remote tripping) after notice to the consumer in accordance with contractual provisions. For example, loads that can be interrupted to fulfill planning or operation reserve requirements should be reported as Interruptible Load. Interruptible Load as defined here excludes Direct Load Control and Other Load Management. (Interruptible Load, as reported here, is synonymous with Interruptible Demand reported to the North American Electric Reliability Council on the voluntary Form EIA-411, "Coordinated Regional Bulk Power Supply Program Report," with the exception that annual peak load effects are reported on the form EIA-861 and seasonal (i.e., summer and winter) peak load effects are reported on the EIA-411).

Investor-owned utility: A class of utility whose stock is publicly traded and which is organized as a tax-paying business, usually financed by the sale of securities in the capital market. It is regulated and authorized to achieve an allowed rate of return.

K

Kilowatt (kW): One thousand watts.

Kilowatthour (kWh): One thousand watthours.

L

Light oil: Lighter fuel oils distilled off during the refining process. Virtually all petroleum used in internal combustion and gas-turbine engines is light oil.

Lignite: The lowest rank of coal, often referred to as brown coal, used almost exclusively as fuel for steam-electric power generation. It is brownish-black and has a high inherent moisture content, sometimes as high as 45 percent. The heat content of lignite ranges from 9 to 17 million Btu per ton on a moist, mineral-matter-free basis. The heat content of lignite consumed in the United States averages 13 million Btu per ton, on the as-received basis (i.e., containing both inherent moisture and mineral matter).

Load (electric): The amount of electric power delivered or required at any specific point or points on a system. The requirement originates at the energy-consuming equipment of the consumers.

M

Market-based pricing: Electric service prices determined in an open market system of supply and demand under which the price is set solely by agreement as to what a buyer will pay and a seller will accept. Such prices could recover less or more than full costs, depending upon what the buyer and seller see as their relevant opportunities and risks.

Market clearing price: The price at which supply equals demand for the dayahead and/or hour ahead markets.

Maximum demand: The greatest of all demands of the load that has occurred within a specified period of time.

Mcf: One thousand cubic feet.

Megawatt (MW): One million watts.

Megawatthour (MWh): One million watthours.

MMcf: One million cubic feet.

Monopoly: One seller of electricity with control over market sales.

N

Natural gas: A naturally occurring mixture of hydrocarbon and non-hydrocarbon gases found in porous geological formations beneath the earth's surface, often in association with petroleum. The principal constituent is methane.

NERC: North American Electric Reliability Corp.

Net capability: The maximum load-carrying ability of the equipment, exclusive of station use, under specified conditions for a given time interval, independent of the characteristics of the load. (Capability is determined by design characteristics, physical conditions, adequacy of prime mover, energy supply, and operating limitations such as cooling and circulating water supply and temperature, headwater and tailwater elevations, and electrical use.)

Net generation: Gross generation minus plant use from all electric utility owned plants. The energy required for pumping at a pumped-storage plant is regarded as plant use and must be deducted from the gross generation.

Net summer capability: The steady hourly output, which generating equipment is expected to supply to system load exclusive of auxiliary power, as demonstrated by tests at the time of summer peak demand.

Net winter capability: The steady hourly output which generating equipment is expected to supply to system load exclusive of auxiliary power, as demonstrated by tests at the time of winter peak demand.

Non-coincidental peak load: The sum of two or more peak loads on individual systems that do not occur in the same time interval. Meaningful only when considering loads within a limited period of time, such as a day, week, month, a heating or cooling season, and usually for not more than 1 year.

Non-firm power: Power or power-producing capacity supplied or available under a commitment having limited or no assured availability.

North American Electric Reliability Corp. (NERC): An international, independent, self-regulatory, not-for-profit organization, whose mission is to ensure the reliability of the bulk power system in North America.

Non-utility power producer: A corporation, person, agency, authority, or other legal entity or instrumentality that owns electric generating capacity and is not an electric utility. Nonutility power producers include qualifying cogenerators, qualifying small power producers, and other nonutility generators (including independent power producers) without a designated franchised service area, and which do not file forms listed in the Code of Federal Regulations, Title 18, Part 141.

Nuclear fuel: Fissionable materials that have been enriched to such a composition that, when placed in a nuclear reactor, will support a self-sustaining fission chain reaction, producing heat in a controlled manner for process use.

Nuclear power plant: A facility in which heat produced in a reactor by the fissioning of nuclear fuel is used to drive a steam turbine.

O

Off-Peak gas: Gas that is to be delivered and taken on demand when demand is not at its peak.

Ohm: The unit of measurement of electrical resistance. The resistance of a circuit in which a potential difference of 1 volt produces a current of 1 ampere.

Open access: A regulatory mandate to allow others to use a utility's transmission and distribution facilities to move bulk power from one point to another on a nondiscriminatory basis for a cost-based fee.

Operable nuclear unit: A nuclear unit is "operable" after it completes low-power testing and is granted authorization to operate at full power. This occurs when it receives its full power amendment to its operating license from the Nuclear Regulatory Commission.

Outage: The period during which a generating unit, transmission line, or other facility is out of service.

P

Peak demand: The maximum load during a specified period of time.

Peak load plant: A plant usually housing old, low-efficiency steam units; gas turbines; diesels; or pumped-storage hydroelectric equipment normally used during the peak-load periods.

Peaking capacity: Capacity of generating equipment normally reserved for operation during the hours of highest daily, weekly, or seasonal loads. Some generating equipment may be operated at certain times as peaking capacity and at other times to serve loads on an around-the-clock basis.

Percent difference: The relative change in a quantity over a specified time period. It is calculated as follows: the current value has the previous value subtracted from it; this new number is divided by the absolute value of the previous value; then this new number is multiplied by 100.

Petroleum: A mixture of hydrocarbons existing in the liquid state found in natural underground reservoirs, often associated with gas. Petroleum includes fuel oil No. 2, No. 4, No. 5, No. 6; topped crude; kerosene; and jet fuel.

Petroleum coke: See coke (petroleum).

Petroleum (crude oil): A naturally occurring, oily, flammable liquid composed principally of hydrocarbons. Crude oil is occasionally found in springs or pools but usually is drilled from wells beneath the earth's surface.

Planned generator: A proposal by a company to install electric generating equipment at an existing or planned facility or site. The proposal is based on the owner having obtained (1) all environmental and regulatory approvals, (2) a signed contract for the electric energy, or (3) financial closure for the facility.

Plant: A facility at which are located prime movers, electric generators, and auxiliary equipment for converting mechanical, chemical, and/or nuclear energy into electric energy. A plant may contain more than one type of prime mover. Electric utility plants exclude facilities that satisfy the definition of a qualifying facility under the Public Utility Regulatory Policies Act of 1978.

Plant use: The electric energy used in the operation of a plant. Included in this definition is the energy required for pumping at pumped-storage plants.

Plant-use electricity: The electric energy used in the operation of a plant. This energy total is subtracted from the gross energy production of the plant; for reporting purposes the plant energy production is then reported as a net figure. The energy required for pumping at pumped-storage plants is, by definition, subtracted, and the energy production for these plants is then reported as a net figure.

Power: The rate at which energy is transferred. Electrical energy is usually measured in watts. Also, used for a measurement of capacity

Power exchange: The entity that will establish a competitive spot market for electric power through day- and/or hour-ahead auction of generation and demand bids.

Power exchange generation: Generation being scheduled by the power exchange.

Power exchange load: Load that has been scheduled by the power exchange and which is received through the use of transmission or distribution facilities owned by participating transmission owners.

Power marketers: Business entities engaged in buying, selling, and marketing electricity. Power marketers do not usually own generating or transmission facilities. Power marketers, as opposed to brokers, take ownership of the electricity and are involved in interstate trade. These entities file with the Federal Energy Regulatory Commission for status as a power marketer.

Power pool: An association of two or more interconnected electric systems having an agreement to coordinate operations and planning for improved reliability and efficiencies.

Price: The amount of money or consideration-in-kind for which a service is bought, sold, or offered for sale.

Prime mover: The engine, turbine, water wheel, or similar machine that drives an electric generator; or, for reporting purposes, a device that converts energy to electricity directly (e.g., photovoltaic solar and fuel cell(s)).

Profit: The income remaining after all business expenses are paid.

Providers of bundled retail energy: Similar to full service providers, except for their operation in deregulated markets, as in Texas (retail electricity providers).

Public authority service to public authorities: Public authority service includes electricity supplied and services rendered to municipalities or divisions or agencies of State or Federal governments, under special contracts or agreements or service classifications applicable only to public authorities.

Public street and highway lighting: Public street and highway lighting includes electricity supplied and services rendered for the purposes of lighting streets, highways, parks, and other public places; or for traffic or other signal system service, for municipalities, or other divisions or agencies of State or Federal governments.

Pumped-storage hydroelectric plant: A plant that usually generates electric energy during peak-load periods by using water previously pumped into an elevated storage reservoir during off-peak periods when excess generating capacity is available to do so. When additional generating capacity is needed, the water can be released from the reservoir through a conduit to turbine generators located in a power plant at a lower level.

Purchased power adjustment: A clause in a rate schedule that provides for adjustments to the bill when energy from another electric system is acquired and it varies from a specified unit base amount.

Pure pumped-storage hydroelectric plant: A plant that produces power only from water that has previously been pumped to an upper reservoir.

PURPA: The Public Utility Regulatory Policies Act of 1978, passed by the U.S. Congress. This statute requires States to implement utility conservation programs and create special markets for co-generators and small producers who meet certain standards, including the requirement that States set the prices and quantities of power the utilities must buy from such facilities.

Q

Qualifying Facility (QF): A cogeneration or small power production facility that meets certain ownership, operating, and efficiency criteria established by the Federal Energy Regulatory Commission (FERC) pursuant to the Public Utility Regulatory Policies Act (PURPA).

R

Railroad and railway services: Railroad and railway services include electricity supplied and services rendered to railroads and interurban and street railways, for general railroad use, including the propulsion of cars or locomotives, where such electricity is supplied under separate and distinct rate schedules.

Rate base: The value of property upon which a utility is permitted to earn a specified rate of return as established by a regulatory authority. The rate base generally represents the value of property used by the utility in providing service and may be calculated by any one or a combination of the following accounting methods: fair value, prudent investment, reproduction cost, or original cost. Depending on which method is used, the rate base includes cash, working capital, materials and supplies, and deductions for accumulated provisions for depreciation, contributions in aid of construction, customer advances for construction, accumulated deferred income taxes, and accumulated deferred investment tax credits.

Reactive power: The portion of electricity that establishes and sustains the electric and magnetic fields of alternating-current equipment. Reactive power must be supplied to most types of magnetic equipment, such as motors and transformers. Reactive power is provided by generators, synchronous condensers, or electrostatic equipment such as capacitors and directly influences electric system voltage. It is a derived value equal to the vector difference between the apparent power and the real power. It is usually expressed as kilovolt-amperes reactive (kVAR) or megavolt-ampere reactive (MVAR). See apparent power, power, real Power.

Real power: The component of electric power that performs work, typically measured in kilowatts (kW) or megawatts (MW)--sometimes referred to as Active Power. The terms "real" or "active" are often used to modify the base term "power" to differentiate it from Reactive Power and Apparent Power. See Apparent Power, Power, Reactive Power.

Ratemaking authority: A utility commission's legal authority to fix, modify, approve, or disapprove rates, as determined by the powers given the commission by a State or Federal legislature.

Receipts: Purchases of fuel.

Regional transmission group: A utility industry concept that the Federal Energy Regulatory Commission embraced for the certification of voluntary groups that would be responsible for transmission planning and use on a regional basis.

Regulation: The governmental function of controlling or directing economic entities through the process of rulemaking and adjudication.

Reliability: Electric system reliability has two components--adequacy and security. Adequacy is the ability of the electric system to supply to aggregate electrical demand and energy requirements of the customers at all times, taking into account scheduled and unscheduled outages of system facilities. Security is the ability of the electric system to withstand sudden disturbances, such as electric short circuits or unanticipated loss of system facilities. The degree of reliability may be measured by the frequency, duration, and magnitude of adverse effects on consumer services.

Renewable resources: Naturally, but flow-limited resources that can be replenished. They are virtually inexhaustible in duration but limited in the amount of energy that is available per unit of time. Some (such as geothermal and biomass) may be stock-limited in that stocks are depleted by use, but on a time scale of decades, or perhaps centuries, they can probably be replenished. Renewable energy resources include: biomass, hydro, geothermal, solar and wind. In the future, they could also include the use of ocean thermal, wave, and tidal action technologies. Utility renewable resource applications include bulk electricity generation, on-site electricity generation, distributed electricity generation, non-grid-connected generation, and demand-reduction (energy efficiency) technologies.

Reregulation: The design and implementation of regulatory practices to be applied to the remaining regulated entities after restructuring of the vertically-integrated electric utility. The remaining regulated entities would be those that continue to exhibit characteristics of a natural monopoly, where imperfections in the market prevent the realization of more competitive results, and where, in light of other policy considerations, competitive results are unsatisfactory in one or more respects. Regulation could employ the same or different regulatory practices as those used before restructuring.

Reserve margin (operating): The amount of unused available capability of an electric power system at peak load for a utility system as a percentage of total capability.

Residential: The residential sector is defined as private household establishments which consume energy primarily for space heating, water heating, air conditioning, lighting, refrigeration, cooking and clothes drying. The classification of an individual consumer's account, where the use is both residential and commercial, is based on principal use. For the residential class, do not duplicate consumer accounts due to multiple metering for special services (water, heating, etc.). Apartment houses are also included.

Residual fuel oil: The topped crude of refinery operation, includes No. 5 and No. 6 fuel oils as defined in ASTM specification D396 and federal specification VV-F-815C; navy special fuel oil as defined in military specification MIL-F-859E including Amendment 2 (NATO Symbol F-77); and bunker C fuel oil. Residual fuel oil is used for the production of electric power, space heating, vessel bunkering, and various industrial purposes. Imports of residual fuel oil include imported crude oil burned as fuel.

Restricted-universe census: This is the complete enumeration of data from a specifically defined subset of entities including, for example, those that exceed a given level of sales or generator nameplate capacity.

Restructuring: The process of replacing a monopoly system of electric utilities with competing sellers, allowing individual retail customers to choose their electricity supplier but still receive delivery over the power lines of the local utility. It includes the reconfiguration of the vertically-integrated electric utility.

Retail: Sales covering electrical energy supplied for residential, commercial, and industrial end-use purposes. Other small classes, such as agriculture and street lighting, also are included in this category.

Retail competition: The concept under which multiple sellers of electric power can sell directly to end-use customers and the process and responsibilities necessary to make it occur.

Retail market: A market in which electricity and other energy services are sold directly to the end-use customer.

Retail wheeling: The process of moving electric power from a point of generation across one or more utility-owned transmission and distribution systems to a retail customer.

Revenue: The total amount of money received by a firm from sales of its products and/or services, gains from the sales or exchange of assets, interest and dividends earned on investments, and other increases in the owner's equity except those arising from capital adjustments.

Running and quick-start capability: The net capability of generating units that carry load or have quick-start capability. In general, quick-start capability refers to generating units that can be available for load within a 30-minute period.

S

Safety integrity level (SIL): A relative level of risk-reduction provided by a safety function, or to specify a target level of risk reduction. In simple terms, SIL is a measurement of performance required for a Safety Instrumented Function (SIF).

The requirements for a given SIL are not consistent among all of the functional safety standards. Within the european functional safety standards four SILs are defined, with SIL 4 being the most dependable and SIL 1 being the least. A SIL is determined based on a number of quantitative factors in combination with qualitative factors such as development process and safety life cycle management.

Sales: The amount of kilowatthours sold in a given period of time; usually grouped by classes of service, such as residential, commercial, industrial, and other. Other sales include public street and highway lighting, other sales to public authorities and railways, and interdepartmental sales.

Sales for resale: Energy supplied to other electric utilities, cooperatives, municipalities, and Federal and State electric agencies for resale to ultimate consumers.

Scheduling coordinators: Entities certified by the Federal Energy Regulatory Commission that act as a go-between with the Independent System Operator on behalf of generators, supply aggregators (wholesale marketers), retailers, and customers to schedule the distribution of electricity.

Scheduled outage: The shutdown of a generating unit, transmission line, or other facility, for inspection or maintenance, in accordance with an advance schedule.

Securitization: A proposal for issuing bonds that would be used to buy down existing power contracts or other obligations. The bonds would be repaid by designating a portion of future customer bill payments. Customer bills would be lowered, since the cost of bond payments would be less than the power contract costs that would be avoided.

Securitize: The aggregation of contracts for the purchase of the power output from various energy projects into one pool which then offers shares for sale in the investment market. This strategy diversifies project risks from what they would be if each project were financed individually, thereby reducing the cost of financing. Fannie mae performs such a function in the home mortgage market.

Short ton: A unit of weight equal to 2,000 pounds.

SIL: Safety Integrity Level

Small Power Producer (SPP): Under the Public Utility Regulatory Policies Act (PURPA), a small power production facility (or small power producer) generates electricity using waste, renewable (water, wind and solar), or geothermal energy as a primary energy source. Fossil fuels can be used, but renewable resource must provide at least 75 percent of the total energy input. *(See Code of Federal Regulations, Title 18, Part 292.)*

Spinning reserve: That reserve generating capacity running at a zero load and synchronized to the electric system.

Spot purchases: A single shipment of fuel or volumes of fuel, purchased for delivery within 1 year. Spot purchases are often made by a user to fulfill a certain portion of energy requirements, to meet unanticipated energy needs, or to take advantage of low-fuel prices.

Stability: The property of a system or element by virtue of which its output will ultimately attain a steady state. The amount of power that can be transferred from one machine to another following a disturbance. The stability of a power system is its ability to develop restoring forces equal to or greater than the disturbing forces so as to maintain a state of equilibrium.

Standard industrial classification (SIC): A set of codes developed by the Office of Management and Budget, which categorizes business into groups with similar economic activities.

Standbyfacility: A facility that supports a utility system and is generally running under no-load. It is available to replace or supplement a facility normally in service.

Standby service: Support service that is available, as needed, to supplement a consumer, a utility system, or to another utility if a schedule or an agreement authorizes the transaction. The service is not regularly used.

Steam-electric plant (conventional): A plant in which the prime mover is a steam turbine. The steam used to drive the turbine is produced in a boiler where fossil fuels are burned.

Stocks: A supply of fuel accumulated for future use. This includes coal and fuel oil stocks at the plant site, in coal cars, tanks, or barges at the plant site, or at separate storage sites.

Stranded benefits: Benefits associated with regulated retail electric service which may be at risk under open market retail competition. Examples are conservation programs, fuel diversity, reliability of supply, and tax revenues based on utility revenues.

Stranded costs: Prudent costs incurred by a utility which may not be recoverable under market-based retail competition. Examples are undepreciated generating facilities, deferred costs, and long-term contract costs.

Subbituminous coal: A coal whose properties range from those of lignite to those of bituminous coal and are used primarily as fuel for steam-electric power generation. It may be dull, dark brown to black, soft and crumbly at the lower end of the range, to bright, jet black, hard, and relatively strong at the upper end. Subbituminous coal contains 20 to 30 percent inherent moisture by weight. The heat content of subbituminous coal ranges from 17 to 24 million Btu per ton on a moist, mineral-matter-free basis. The heat content of subbituminous coal consumed in the United States averages 17 to 18 million Btu per ton, on the as-received basis (i.e., containing both inherent moisture and mineral matter).

Substation: Facility equipment that switches, changes, or regulates electric voltage.

Sulfur: One of the elements present in varying quantities in coal which contributes to environmental degradation when coal is burned. In terms of sulfur content by weight, coal is generally classified as low (less than or equal to 1 percent), medium (greater than 1 percent and less than or equal to 3 percent), and high (greater than 3 percent). Sulfur content is measured as a percent by weight of coal on an "as received" or a "dry" (moisture-free, usually part of a laboratory analysis) basis.

Switching station: Facility equipment used to tie together two or more electric circuits through switches. The switches are selectively arranged to permit a circuit to be disconnected, or to change the electric connection between the circuits.

System (electric): Physically connected generation, transmission, and distribution facilities operated as an integrated unit under one central management, or operating supervision.

T

Transformer: An electrical device for changing the voltage of alternating current.

Transmission: The movement or transfer of electric energy over an interconnected group of lines and associated equipment between points of supply and points at which it is transformed for delivery to consumers, or is delivered to other electric systems. Transmission is considered to end when the energy is transformed for distribution to the consumer.

Transmission system (eectric): An interconnected group of electric transmission lines and associated equipment for moving or transferring electric energy in bulk between points of supply and points at which it is transformed for delivery over the distribution system lines to consumers, or is delivered to other electric systems.

Transmitting utility: This is a regulated entity which owns, and may construct and maintain, wires used to transmit wholesale power. It may or may not handle the power dispatch and coordination functions. It is regulated to provide non-discriminatory connections, comparable service, and cost recovery. According to EPACT, this includes any electric utility, qualifying cogeneration facility, qualifying small power production facility, or Federal power marketing agency which owns or operates electric power transmission facilities which are used for the sale of electric energy at wholesale.

Turbine: A machine for generating rotary mechanical power from the energy of a stream of fluid (such as water, steam, or hot gas). Turbines convert the kinetic energy of fluids to mechanical energy through the principles of impulse and reaction, or a mixture of the two.

U

Unbundling: The separating of the total process of electric power service from generation to metering into its component parts for the purpose of separate pricing or service offerings.

Uniform system of accounts: Prescribed financial rules and regulations established by the Federal Energy Regulatory Commission for utilities subject to its jurisdiction under the authority granted by the Federal Power Act.

Useful thermal output: The thermal energy made available for use in any industrial or commercial process, or used in any heating or cooling application, i.e., total thermal energy made available for processes and applications other than electrical generation.

Utility distribution companies: The entities that will continue to provide regulated services for the distribution of electricity to customers and serve customers who do not choose direct access. Regardless of where a consumer chooses to purchase power, the customer's current utility, also known as the utility distribution company, will deliver the power to the consumer's home, business, or farm.

V

Vertical integration: An arrangement whereby the same company owns all the different aspects of making, selling, and delivering a product or service. In the electric industry, it refers to the historically common arrangement whereby a utility would own its own generating plants, transmission system, and distribution lines to provide all aspects of electric service.

Voltage reduction: Any intentional reduction of system voltage by 3 percent or greater for reasons of maintaining the continuity of service of the bulk electric power supply system.

Volumetric wires charge: A type of charge for using the transmission and/or distribution system that is based on the volume of electricity that is transmitted.

W

Watt: The electrical unit of power. The rate of energy transfer equivalent to 1 ampere flowing under a pressure of 1 volt at unity power factor.

Watthour (Wh): An electrical energy unit of measure equal to 1 watt of power supplied to, or taken from, an electric circuit steadily for 1 hour.

Wheeling service: The movement of electricity from one system to another over transmission facilities of intervening systems. Wheeling service contracts can be established between two or more systems.

Wholesale competition: A system whereby a distributor of power would have the option to buy its power from a variety of power producers, and the power producers would be able to compete to sell their power to a variety of distribution companies.

Wholesale cales: Energy supplied to other electric utilities, cooperatives, municipals, and Federal and State electric agencies for resale to ultimate consumers.

Wholesale power market: The purchase and sale of electricity from generators to resellers (who sell to retail customers), along with the ancillary services needed to maintain reliability and power quality at the transmission level.

Wholesale transmission services: The transmission of electric energy sold, or to be sold, at wholesale in interstate commerce (from EPACT).

Wires charge: A broad term which refers to charges levied on power suppliers or their customers for the use of the transmission or distribution wires.

Source: U.S. Energy Information Administration (April 2010).

13.3 Saturated steam table (Metric units) (page 1 of 2)

Gage pressure (bar)	Absolute pressure (bar)	Temperature (°C)	Specific volume (m^3/kg)	Sat. liquid	Specific enthalpy (kJ/kg) 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	1918	2796
19,0	20	212,37	0,09958	908,6	1890	2799
21,5	22,5	218,4	0,0887	936,3	1865	2801

13.3 Saturated steam table (Metric units) (page 2 of 2)

Gage pressure (bar)	Absolute pressure (bar)	Temperature (°C)	Specific volume (m^3/kg)	Sat. liquid	Specific enthalpy (kJ/kg) Evap.	Sat. vapor
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
69,0	70	285,5	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

13.3 Saturated steam table (English units) (page 1 of 3)

Gage pressure (lbs./Sq. In.)	Absolute pressure (lbs./Sq. In.)	Temperature (°F)	Specific volume (Cu. ft./lb.)	Sat. liquid	Specific enthalpy (B.T.U./Lb.) 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

13.3 Saturated steam table (English units) (page 2 of 3)

Gage pressure (lbs./Sq. In.)	Absolute pressure (lbs./Sq. In.)	Temperature (°F)	Specific volume (Cu. ft./lb.)	Sat. liquid	Specific enthalpy (B.T.U./lb.) evap.	Sat. vapor
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
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
785.3	800	518	0.565	511.8	684.9	1196.7

13.3 Saturated steam table (English units) (page 3 of 3)

Gage pressure (lbs./Sq. In.)	Absolute pressure (lbs./Sq. In.)	Temperature (°F)	Specific volume (Cu. ft./lb.)	Sat. liquid	Specific enthalpy (B.T.U./Lb.) evap.	Sat. vapor
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

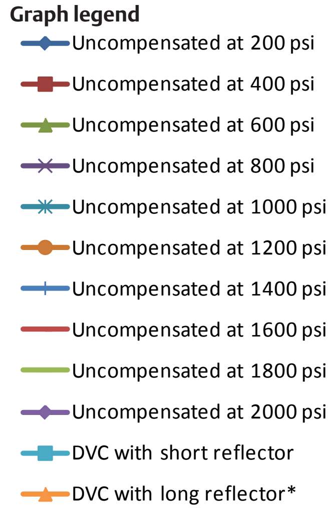
13.4 Uncompensated error tables

13.4.1 Error in measurement due to changing vapor dielectric

Water vapor under high pressure and varying temperature will have different dielectric constants and these changes can influence the radar level measurement. An increase in the dielectric constant slows propagation down, causing the signal for the liquid level to appear beyond the actual level point.

Dynamic vapor compensation (DVC) is a function of the 5300 guided wave radar that compensates for the change in dielectric. DVC becomes more important for the higher pressure applications that may have more variations in the operating conditions.

Below is a graph showing the error in measurement as a function of the distance to surface if left uncompensated, as well as the error if compensated using DVC. The graph shows these errors at different operating pressures. On the following pages, there are tables showing the numbers in more detail.



for total probe length > 78 in (2000 mm)

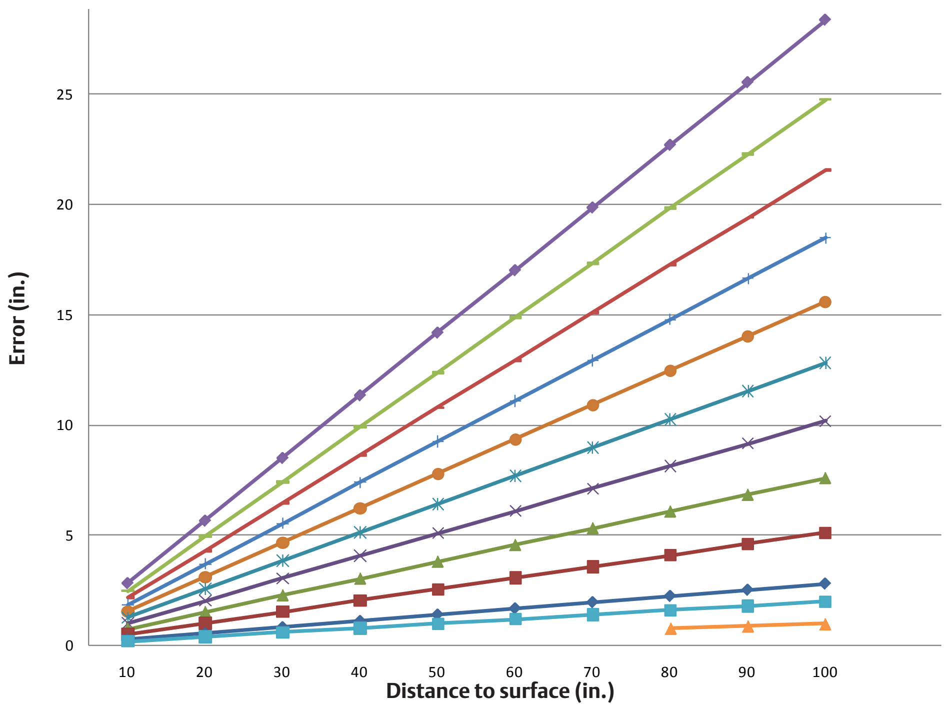


Table 13.4.1: Error in measurement due to changing vapor dielectric

13.4.2 Error in measurement due to changing vapor dielectric (in bars and mm)

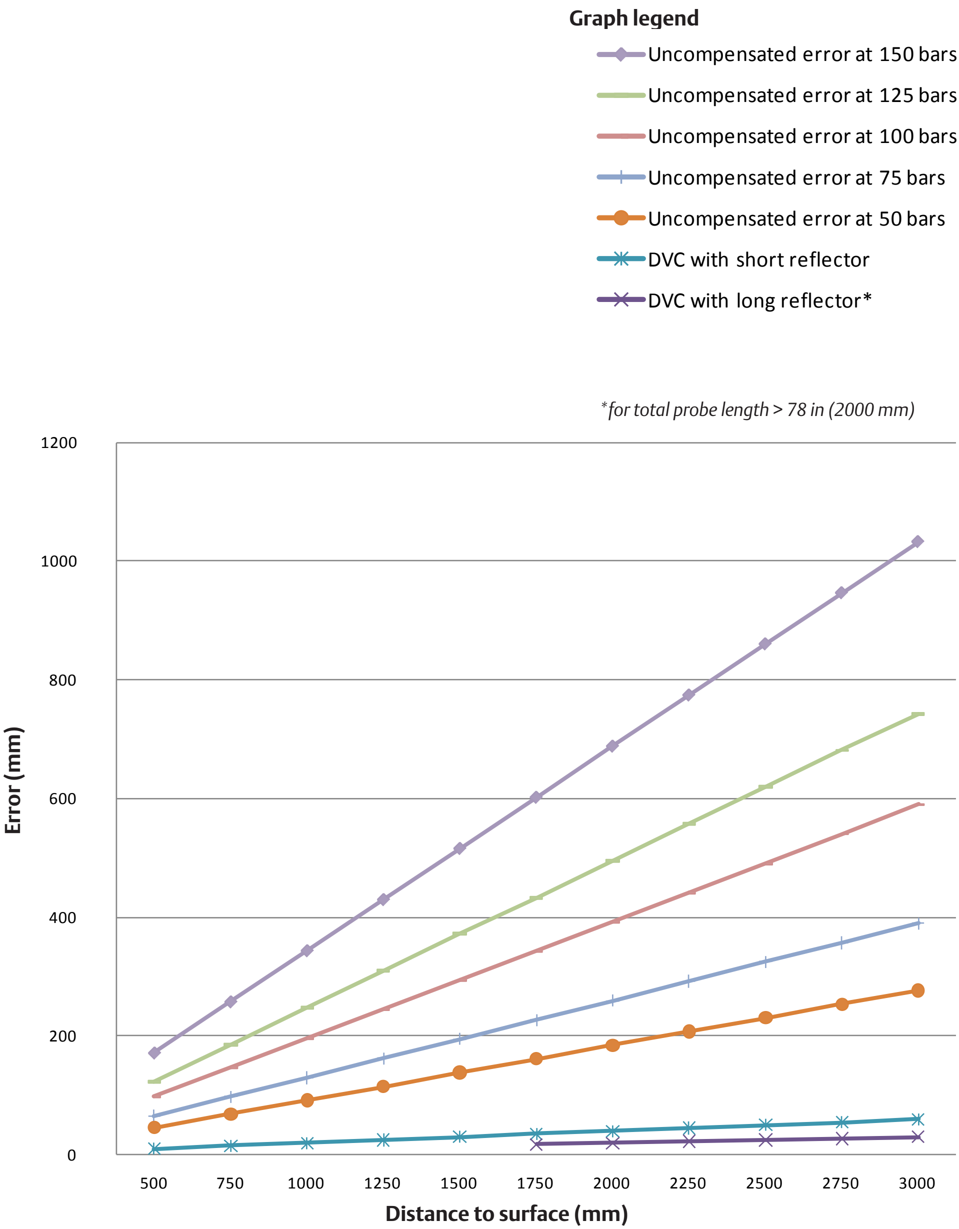


Table 13.4.2: Error in measurement due to changing vapor dielectric (in bars and mm)

14

Proven results

14. Proven results

14.1 Guided wave radar

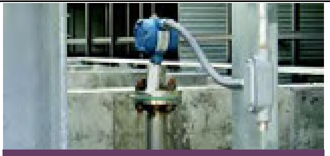
14.1.1 Improve lifetime cost savings by $31,800 per power plant by using guided wave radar

POWER ROSEMOUNT 3300

Improve Lifetime Cost Savings by $31,800 per Power Plant by Using Guided Wave Radar

RESULTS

- Lifetime cost savings total $31,800 per power plant
- Installation integrity was enhanced by eliminating multiple components
- Maintenance is eliminated by the use of Guided Wave Radar
- Save $3961 per unit



The return on investment and the total cost of ownership was improved with an estimated lifetime savings of over $31,800 per plant.

APPLICATION

Bubbler System Replacement in Cooling Tower Basins, Blow-Down Sumps and Waste Water Sumps

APPLICATION CHARACTERISTIC

Bubbler systems are top-down level measurement devices. They use a constant air source to create a back pressure to the transmitter that is proportional to the level. If the measured liquids contain mud, fiber particles, or other debris, they tend to plug lines and create an artificially high pressure, resulting in erroneous level readings.

CUSTOMER

Fluor®, an Engineering and Construction Company

CHALLENGE

Flour® is an Engineering and Construction Company that has built many standard design, turnkey, lump sum power plants in the United States. During a project's engineering and design, both Flour® and their clients place an emphasis on reduction of overall cost without affecting the integrity and functionality of the plant design.

One area that was ripe for improvement was level measurement using bubbler systems. Bubbler systems consist of differential pressure transmitter, pressure regulator, an indicating rotameter, various tubing and fittings, and a constant source of instrument air. These systems have a long proven history of use in many plants and are an accepted way to provide top-down level measurements in low pressure applications.

With the many components involved, a bubbler system can be costly to install. While the most costly item is the transmitter, the other system components and lines for instrument can easily double the basic hardware cost. In addition, over the life of the system, consideration needs to be given towards the supply of instrument air and general maintenance to

Guided Wave Radar Installed

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keep the bubbler line clear and open. In many of these applications the pipe goes through water which has mud, fibers and other plant debris which can cause the pipe to plug. Plugged pipes can cause false level readings which can have significant consequences.

In one installation in a power plant, a bubbler was used in a fire water storage pond containing a mixture of mud and carpet fiber sediment. The bubbler pipe was often caked in mud and carpet fibers. This plugged the end of the tube and caused erroneous level measurements.

In another case, a cooling water sump basin caused a shutdown of a steam turbine and eventually tripped the entire plant. The cause of the shutdown was traced back to a faulty connection to the supply air tubing in the bubbler system. Back pressure caused it to blow off and send the transmitter output to zero.

The overall cost to install a Rosemount GWR was 64% of the bubbler's installed cost.

SOLUTION

In keeping their desire to reduce overall cost without compromising the integrity and functionality o the plant design, the engineers at Flour® decided to evaluate alternatives to bubbler systems. A proposal was made during the P&ID review on a new power plant project to reduce the initial investment and material costs of using a bubbler system.

The Rosemount 3300 GWR installation only requires the loop connection and process mounting.

In addition to the necessary control loop connections and process mounting, a bubbler system also includes an air supply with filter regulator, tubing and fittings to the transmitter, a rotometer for regulation of the air supply and a mounting support for the transmitter.

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In addition to the necessary control loop connections and the process mounting, a bubbler system installation also includes an air supply system with a filter regulator, tubing and fittings to the transmitter, a rotameter for the regulation of the air supply and a mounting support for the transmitter.

In contrast the Rosemount Guided Wave Radar (GWR) only requires the loop connection and process mounting. When considering the elimination of the extra pieces and the labor to install them, the total cost of the GWR was determined to be 64% of the total cost of the bubbler system. Based on a total cost of ownership analysis, a decision was made to try a guided wave radar level transmitter.

Once installed, the GWR is able to make direct level measurement with a minimal amount of configuration support. No adjustments are needed for an air supply, no continual maintenance is needed to keep the lines clear.

In operating the bubbler system it was found it was estimated to be about $US 106 per year of instrument air. Many of the power plants designed by Flour® typically have 8 units consuming $848 per year in instrument air. Over a 20 year plant life this totals $17,000.

The applications using these level instruments are often installed in areas that have little instrumentation, so the instrument air lines are more difficult to route to bubbler air system.

By switching to the Rosemount 3300, Flour® was able to fulfill their goal of reducing overall costs to the plant without affecting the integrity and functionality of the plant design. The return on investment and total cost of ownership was improved with an estimated lifetime savings of over $31,800 for the 8 units typically found in a power plant.

TABLE 1. Per Unit Lifetime Cost Savings

	Savings
Installation Savings Per Unit	$1,841
20 Year Supply of Air for Each Unit	$2,120
Total Per Savings Unit	**$3,961**

RESOURCES

Rosemount 3300

http://www.emersonprocess.com/rosemount/products/level/m3300.html

Emerson Process Management
Rosemount Division
8200 Market Boulevard
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14.1.2 Sunbury generation increased heat rate efficiency and decreased risk of equipment damage with guided wave radar

COAL FIRED POWER | ROSEMOUNT 3300

Sunbury Generation Increased Heat Rate Efficiency and Decreased Risk of Equipment Damage with Guided Wave Radar

RESULTS

- Increased heat rate efficiency
- Decreased risk of equipment damage
- Reduced labor and maintenance costs

Labor and repair costs were reduced by eliminating the maintenance intensive technologies previously used.

APPLICATION

High temperature feedwater heaters

Application Characteristics: Water with saturated steam, 450 psig, 382 °F (195 °C), changing fluid density

CUSTOMER

Sunbury Generation, Shamokin Dam, PA

CHALLENGE

Sunbury Generation was concerned about the efficiency of their high pressure feedwater heaters. Water level control in the heaters affects heater efficiency, and thus plant efficiency. It also protects downstream turbines from water carryover.

The high pressure feedwater heaters were using displacer technology for level control, magnetic level gauges for visual indication, and floats for alarms. The unreliable indication of water level negatively impacted the water level in the heater due to the demanding conditions.

The previous technologies negatively impacted heat rate efficiency, increased labor and maintenance costs, and risked damage to the turbines downstream from the heater.

SOLUTION

The Rosemount 3301 Guided Wave Radar with the high temperature high pressure (HTHP) process seal replaced the three previous technologies and was installed in the displacer chambers. The design of the process seal of Rosemount 3301 made it ideally suited for this demanding application.

The Rosemount 3301 was able to control the level in the heater, as it is not susceptible to changing densities like the displacer technology.

The Rosemount 3301 has no moving parts and is virtually maintenance free. Also, the design of the HTHP probe provided multiple layers of protection for the demanding conditions.

The Rosemount 3301 Guided Wave Radar Installed at the Sunbury Generation power plant.

EMERSON

COAL FIRED POWER

The Rosemount 3301 positively impacted this power plant. Through better level control, heat rate efficiency increased with known water levels inside the feedwater heater. Labor and repair costs were also reduced by eliminating the maintenance intensive technologies previously used. Finally, risk of equipment damage was reduced by protecting the downstream turbine from potential water damage.

RESOURCES

Rosemount 3300 Series

http://www.emersonprocess.com/rosemount/products/level/m3300.html

Rosemount 3300 Series Product Data Sheet

http://www.emersonprocess.com/rosemount/document/pds/4811b00n.pdf

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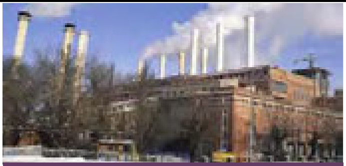
00830-4500-4811, Rev AA

14.1.3 Power station improved bulk sulfuric acid tank storage measurement reliability

POWER ROSEMOUNT 3300 SERIES

Power Station Improved Bulk Sulfuric Acid Tank Storage Measurement Reliability



RESULTS

- Improved accuracy and reliability of tank level readings
- Improved safety by eliminating manual reading of tank level
- Prevented equipment damage caused by inadequate water treatment
- Decreased acid spillage and associated costs

APPLICATION

Bulk sulfuric acid tank storage

APPLICATION CHARACTERISTICS:

9.0 ft. (2.7 m) tall tank; heavy vapors and fumes

CHALLENGE

A power station requires a sufficient supply of sulfuric acid as part of the water treatment regimen for the cooling towers. If the sulfuric acid supply is inadequate, fouling of the cooling system is possible. They had previously tried to measure the level with ultrasonic technology, but the fumes created by the acid caused errors in the reading. The ultrasonic device gave accurate readings at startup, but the readings would change as the sun warmed the sulfuric acid tank, increasing the amount of fumes. Because the ultrasonic readings were unreliable, they would sometimes schedule delivery of acid while the tank was partially filled. This created a potential for acid spills. To avoid this, they often manually checked on the level with a wooden dipstick, exposing personnel to the acid and creating a safety risk. To add to the challenge, they wanted to maximize the storage capacity of the tank, so they needed a technology that would have a minimum amount of dead space.

Rosemount Guided Wave Radar was chosen since it can handle heavy fumes, fits in a small connection, is able to measure close to the top of the probe, and is simple and quick to set up.

SOLUTION

The plant chose the Rosemount 3301 Guided Wave Radar (GWR) Level transmitter for a number of reasons. The overall height of the tank was only 9.0 ft. (2.7 m) and they wanted to take the measurement close to the top of the tank. Since this vessel only had a small connection, the choice of antennas for non-contacting radar was limited. GWR was chosen because it can handle heavy fumes, fits in a small connection, is able to measure close to the top of the probe, and is simple and quick to set up.

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The 3300 GWR provided more reliable and accurate level readings despite any changes in the vapor space which eliminated the need to do manual checks. This maximized the capacity of the tank, and increased the safety of personnel. Because the level of the acid was more reliable, the cooling equipment could be treated more effectively reducing its risk of damage. This also eliminated the threat of overfilling the tank due to the delivery of too much acid.

Rosemount 3300 Guided Wave Radar Installed

Rosemount 3300 Series Product Data Sheet
http://www.emersonprocess.com/rosemount/document/pds/4811b00n.pdf

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14.1.4 Paper mill reduces operations and maintenance costs with advanced guided wave radar technology

PULP & PAPER ROSEMOUNT 5300

Paper Mill Reduces Operations and Maintenance Costs with Advanced Guided Wave Radar Technology

RESULTS

- Reduced operations & maintenance costs
- Increased boiler system efficiency
- Minimized unplanned shutdown

APPLICATION

Bark Boiler Drum Level Control

CUSTOMER

Major Paper Mill in United States

CHALLENGE

A paper mill had problems with boiler trips during routine start-ups and sought to improve the system's reliability and accuracy. The bark boiler creates steam by burning waste bark from the trees being processed into paper. For safe operation of the bark boiler and for maximum heat transfer, the boiler drum levels must be kept within a control range of 8-in (20 cm). If the drum water levels get too low, the water tubes risk being uncovered and exposed to heat stress and damage. High drum levels risk water carryover into the steam header and exposing steam turbines to corrosion and damage.

This paper mill used DP transmitters with impulse piping to monitor the levels in the boiler drum. In this application, the DP transmitter is calibrated for full boiler operating pressure and temperature. During startup when the boiler is cold, both water and steam density are different than at operating temperature and pressure. If the level of the condensate in the legs is not equal, this density difference can cause an error in the level reading. If the difference in impulse leg condensate level is large enough, the boilers could trip during start-up which takes 30 minutes or more to recover.

They experienced many negative business results due to inadequate drum level control during routine start-ups. Unreliable drum levels risked high operations and maintenance costs to replace damaged water tubes and risked carryover into turbines. Unstable level measurements reduced efficiency of the boiler and increased utility costs. Lastly, unplanned process shutdowns directly translated to lost production.

Figure 1: Rosemount 5301 with Dynamic Vapor Compensation measures reliably on boiler drum

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PULP & PAPER

SOLUTION

To supplement the DP measurement, the paper mill installed a Rosemount 5301 Guided Wave Radar and High Pressure, High Temperature (HTHP) single lead probe with Dynamic Vapor Compensation (DVC). This device was mounted on a chamber. Since the flange temperatures were too hot for the transmitter electronics, the housing was mounted remotely. Guided Wave Radar technology is not impacted by density changes in the process and has no moving parts. Dynamic Vapor Compensation utilizes a unique probe design and firmware functionality to dynamically compensate for changes in the vapor space dielectric. This feature allows it to give accurate level readings during all process conditions from ambient to full output.

The paper mill experienced many positive business results by addressing boiler drum start-up problems. The Rosemount 5300 Guided Wave Radar with DVC reliably measured boiler drum levels at all times, thereby reducing operations and maintenance costs. The stable output increased boiler efficiency. Finally, the risk of the boiler tripping was reduced, thereby minimizing unplanned process shutdowns and increasing production.

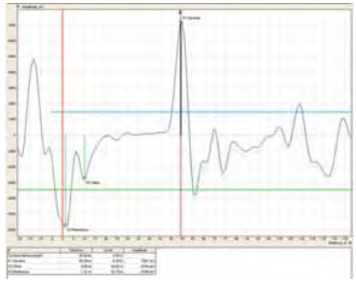

Figure 2: Echo plots shows a strong, reliable surface signal during all process conditions

RESOURCES

Emerson Process Management Pulp & Paper Industry
http://www.emersonprocess.com/solutions/paper/

Rosemount 5300 Series Guided Wave Radar
http://www.emersonprocess.com/rosemount/products/level/m5300b.html

Technical Note: Using Guided Wave Radar for Level in High Pressure Steam Applications
http://www2.emersonprocess.com/siteadmincen-
ter/PM%20Rosemount%20Documents/00840-0100-4530.pdf

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00830-1800-4530, Rev AA

14.1.5 Power plant reduces risk of incurring higher maintenance costs with reliable guided wave radar

POWER ROSEMOUNT 5300

Power Plant Reduces Risk of Incurring Higher Maintenance Costs with Reliable Guided Wave Radar

RESULTS

- Reduced risk of higher operations and maintenance costs
- Lowered risk of reductions in facility throughput
- Minimized risk of outages

APPLICATION

Condenser

APPLICATION CHARACTERISTICS

Presence of steam and turbulence. Temperatures between 50 to 105 °C (122 - 221 °F), pressure between 0.3 to 1.2 bar-a (4 - 17 psia), and measuring range of 803 mm (32-in.)

CUSTOMER

E. ON in Örebro, Sweden

CHALLENGE

A Maintenance Engineer at E. ON Power Plant was tasked with improving the reliability of facility equipment. Due to aging equipment on two large condensers, he saw an opportunity to improve the system's reliability and accuracy. If the water levels get too low in the condenser, pumps risk being damaged. If the water levels get too high, there is risk of water backing up into the turbine which risks turbine damage and halts electricity generation and heating water production.

Previously E. ON used a pneumatic displacer for level control of the condensers. Their displacer technology was over 30 years old, and it had become increasingly difficult to find suppliers of spare parts or new instruments of this type. They needed to find a reliable level technology for its replacement. The level measurement controls the outlet valve for the condensate by sending a pneumatic signal to a control valve downstream from the pumps. They needed a level transmitter that was not affected by steam or turbulence and could follow very rapid changes in the water level. Reliability of the level measurement is critical for efficient control of the condensate levels.

"The Guided Wave Radar surpassed our expectations and demonstrated that it is both reliable and accurate in this application."

Per Lundmark
Maintenance Engineer

Figure 1. Rosemount 5301 replaces a displacer on chamber for condenser level control.

EMERSON

POWER

If this customer did not replace the old technology with a compatible continuous level measurement, they risked high operations and maintenance costs associated with obsolete displacer parts. Without a reliable level measurement, the plant risked process instability, potential equipment damage, and potential outages.

Figure 2. A second Rosemount 5301 replaces the electronic displacer.

SOLUTION

As a solution to this problem, E.ON installed a Rosemount 5301 Guided Wave Radar (GWR) with rigid single lead probe. The Rosemount 5300 was installed in a chamber and tested against a new electronic displacer. During testing, the GWR outperformed the displacer as it was unaffected by temperature changes and had a faster response time to the rapid level changes. Furthermore, the strong signal enabled by direct switch technology allowed the Rosemount 5300 to accurately measure in turbulent conditions.

E. ON was pleased with the performance of the Rosemount 5301 and eventually replaced the electronic displacer with another Rosemount 5301 transmitter. Business results included a reduction in maintenance costs for both labor and parts. Since the Guided Wave Radar does not need calibration and provides a reliable measurement, they were able to maintain process stability thereby minimizing the risk of reduced power generation, outages, and equipment damage.

RESOURCES

Emerson Process Management Power Industry

http://www.emersonprocess.com/solutions/power/

Rosemount 5300 Series Guided Wave Radar

http://www.emersonprocess.com/rosemount/products/level/m5300b.html

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14.1.6 Power plant reduces risk of outage and minimizes safety risks with SIL2 suitable guided wave radar

POWER | ROSEMOUNT 5300

Power Plant Reduces Risk of Outage and Minimizes Safety Risks with SIL2 Suitable Guided Wave Radar

RESULTS

- Reduced risk of higher operations & maintenance costs
- Decreased safety risks
- Minimized risk of outages

APPLICATION

Steam/Water levels in condenser and water pre-heaters for supercritical circulating fluid bed (CFB) boilers

CUSTOMER

PKE Elektrownia Lagisza (PKE Lagisza Power Plant) in Bedzin, PL

CHALLENGE

During construction of the world's largest supercritical fluid boiler at PKE, engineers needed to design superior safety shutdown systems, stability, and reliability into the steam generation system. Consistent and efficient steam generation relies on fine-tuned operation of the condenser and pre-heaters. If the levels in these tanks get too low, they risk damage to pumps. If the levels get too high, efficiency decreases.

Historically, DP level transmitters and/or displacers are used in these applications. Excursions in the high vacuum/low pressure condenser make it challenging for DP technology to reliably monitor the levels in the tank. Wet-legs and fill heights in the legs can vary widely making it difficult to get a reading during start-up. Both Displacer and DP technology are dependent on density changes which impacts the reliability in pre-heater applications. Displacers are also affected by vibration and turbulence. The mechanical parts can give false readings, and maintenance costs can be expensive. These vessels require reliability at all times and measurement equipment needs to be easy to test and maintain. The extreme temperatures and pressures can also be a challenge on some of the applications.

This customer could experience many negative business results from unreliable level measurements in the steam generation system. The plant risks process instability and potential equipment damage which leads to increased operations costs, maintenance costs, and safety risks. Additionally, they risk unplanned outages.

Figure 1. Three Rosemount 5301 Guided Wave Radars used for condenser level control.

EMERSON

POWER

SOLUTION

To address these challenges, PKE installed triple redundant Rosemount 5301 Guided Wave Radars (GWR) with single lead probes on two condensers, eight pre-heaters, and the feed-water tank. The devices on the pre-heaters and feed-water tank were installed with High Temperature, High Pressure (HTHP) probes which are designed to prevent leakage and perform reliably when exposed to extreme process conditions for extended periods of time. GWR technology is not dependent on density changes and manages heavy vibration without impacting measurement reliability. These devices were mounted on chambers directly attached to the vessels thereby giving them access to reliable readings at all times. Additionally, the Rosemount 5300 transmitters were purchased with the QS option which supplied PKE with documentation to help support their use in a Safety Instrumented System.

PKE experience many positive business results with the performance of the Rosemount 5300 transmitters. Since the Guided Wave Radar does not need calibration and provides a reliable measurement throughout commissioning, they are able to maintain process stability thereby minimizing the risk of reduced unplanned outages and equipment damage. These reduced risks lead to decreased operations and maintenance costs and reduced safety risks.

Figure 2. Rosemount 5301 GWR with HTHP probe

Figure 3. Reliable level measurement on this pre-heater tank provides improved process stability.

RESOURCES

Emerson Process Management Power Industry

http://www.emersonprocess.com/solutions/power/

Rosemount 5300 Series Guided Wave Radar

http://www.emersonprocess.com/rosemount/products/level/m5300b.html

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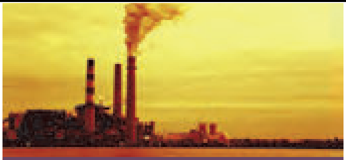
14.1.7 Power plant increases efficiency and reduces risk of equipment damage with innovative guided wave radar

POWER | ROSEMOUNT 5300 AND 9901

Power Plant Increases Efficiency and Reduces Risk of Equipment Damage with Innovative Guided Wave Radar

RESULTS

- Reduced risk of equipment damage
- Improved heat rate
- Reduced risk of outages
- Decreased operations and maintenance costs



Feedwater heater level control is critical for heat rate efficiency and to prevent costly equipment damage.

APPLICATION

Feedwater Heater Level Control

CUSTOMER

Large Power Plant in United States

CHALLENGE

The Instrumentation and Control Fleet Team at a large U.S. power plant sought to improve the efficiency of heat transfer in their feedwater heaters. Controlling the level of the condensate is critical for efficiency and reliability of the steam generation system. If the level is too high, the feedwater tubes are submerged which reduces the heat transfer efficiency. However, if levels are too low, the steam can blow through without effectively heating the tubes which also reduces heat transfer efficiency. In addition, it is essential to monitor levels to prevent water induction (water carryover into the turbine).

A recent ASME standard recommends triple redundancy for the level measurement of feedwater heaters. Previous installations at this plant achieved triple or just dual redundancy using multiple measurement technologies: DP level, displacers, and electronic magnetic level indicators. The output often varied between the different technologies due to accuracy, density variations, and installation differences. This made it challenging for the control scheme to discern which level measurement was accurate. Often maintenance groups were called out to explain the variation.

High variability in feedwater level output leads to several negative business impacts. This plant had previous history of water damage in the turbine resulting in expensive replacement costs. In addition, MW generation was reduced and more outages were experienced. Instable level measurements prevented operation at optimal heat transfer levels. To compensate for instability in feedwater level control, levels were kept higher than desired to prevent risk of steam blow through. The feedwater tubes are therefore submerged leading to reduced heat transfer efficiency and higher operations costs. Lastly, maintenance costs are high because the instrument and control team was called out to work on equipment and explain the variation.

Figure 1. Feedwater heater level achieves triple redundancy with Rosemount 5300 Guided Wave Radar

EMERSON

POWER

SOLUTION

The challenges faced by the power plant were solved with the Rosemount 5301 Guided Wave Radar (GWR) combined with the Rosemount 9901 Chamber. The Instrument and Control Fleet Team installed three GWR in duplicate external mounting assemblies on each of the eleven feedwater heaters. The ordering transaction was minimized by obtaining both the GWR and chambers from a single supplier. True triple redundancy was achieved with high accuracy and consistency of the GWR measurements which are unaffected by density changes. Additionally, they utilized the SIL2 suitable transmitters to fulfill SIS requirements.

By improving the stability and accuracy of feedwater level measurements, this plant operated at feedwater heater levels that increased heat transfer efficiency and reduced risk of equipment damage. This reduced the plant heat rate and decreased the risk of unscheduled outages. The variability between the outputs decreased thereby improving the controllability of the system and reducing operations and maintenance costs.

RESOURCES

Emerson Process Management Power Industry

http://www.emersonprocess.com/solutions/power/

Rosemount 5300 Series Guided Wave Radar

http://www.emersonprocess.com/rosemount/products/level/m5300b.html

Rosemount 9901 Chamber for Process Level Instrumentation

http://www2.emersonprocess.com/en-US/brands/rosemount/Level/Guided-Wave-Radar/9901-Chambers/Pages/index.aspx

Technical Notes

Guidelines for Choosing and Installing Radar in Stilling Wells and Bypass Chambers

http://www2.emersonprocess.com/siteadmincenter/PM%20Rosemount%20Documents/00840-0300-4024.pdf

Replacing Displacers with Guided Wave Radar

http://www2.emersonprocess.com/siteadmincenter/PM%20Rosemount%20Documents/00840-2200-4811.pdf

Using Guided Wave Radar for Level in High Pressure Steam Applications

http://www2.emersonprocess.com/siteadmincenter/PM%20Rosemount%20Documents/00840-0100-4530.pdf

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00830-1900-4530, Rev BA

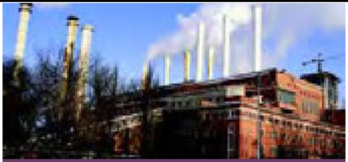
14.1.8 Power plant reduces safety risks with direct switch technology

COAL FIRED POWER | ROSEMOUNT 5300

Power Plant Reduces Safety Risks with Direct Switch Technology

RESULTS

- Reduced safety risks
- Lowered operations and maintenance costs
- Minimized the risk of overfill



The Rosemount 5300 provided a convenient and reliable means to directly monitor fly ash level from the control room.

APPLICATION

Fly ash level measurement

Application Characteristics: 44-ft. (13 m) high dusty silo, heavy, and has low dielectric

CUSTOMER

Coal fired power plant in the United States

CHALLENGE

This coal fired power plant had a problem monitoring the levels of fly ash in their storage silo. The monitoring is used to prevent overfill of their fly ash silo and the rail cars that distribute this by-product to users.

This customer used a mechanical drop weight level indicator to get the measurement three times a day. This mechanical measurement required frequent repair work due to malfunctioning moving parts. When the mechanical measurement failed, operators had to take manual measurements.

This measurement method exposed the operator to fly ash inhalation and safety risks related to climbing the silo. It required valuable operations time while only providing a measurement two to three times daily. Additionally, this customer experienced increased risk associated with overfilling and the clean-up costs.

The customer also tried a non-contacting radar transmitter. This measurement did not provide a sufficient signal return due to the slope of the fly ash surface.

SOLUTION

The Rosemount 5303 Guided Wave Radar with a single flex probe was installed. The measurement quality of the Rosemount 5300 series is not affected by dusty environments, long distances, and low dielectric because it has Direct Switch Technology. Also, the long stud option on the flexible probe helped minimize the influence of the nozzle at the top of the tank.

The Rosemount 5300 Guided Wave Radar with a Flexible Lead Probe.

EMERSON

COAL FIRED POWER

Operators can now monitor the fly ash level from the control room without having to climb the silo, which eliminated the safety risks associated with manual measurements and reduced operations and maintenance costs. Continuous and reliable measurement from the Rosemount 5300 also minimized the risk of overfill and clean up costs.

RESOURCES

Rosemount 5300
http://www.emersonprocess.com/rosemount/products/level/m5300b.html

Rosemount 5300 Technical Note
http://www.emersonprocess.com/rosemount/document/notes/00830-2300-4811.pdf

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00830-0500-4530, Rev AA

14.1.9 Garbage incineration plant reduces operations and maintenance costs with advanced guided wave radar

POWER | **ROSEMOUNT 5300**

Garbage Incineration Plant Reduces Operations and Maintenance Costs with Advanced Guided Wave Radar

RESULTS

- Decreased operations costs
- Reduced maintenance costs
- Eliminated risk of unplanned shutdown

This garbage incineration plant eliminated silo overfills and minimized the risk of unplanned shutdown.

APPLICATION

Level measurement of a combustion salt silo

CUSTOMER

Garbage Incineration Plant in Europe

CHALLENGE

A garbage incineration plant had difficulty monitoring their combustion salt silo. The plant trash incineration process produces a contaminated salt that gets stored in a large silo. When the silo is completely full, it is transported to another storage plant by truck. In order to optimize truck schedules, the silo should only be emptied if it is completely filled. Additionally, it must never be overfilled.

Previously, this customer had tried a non-Emerson guided wave radar, but the low reflectivity of combustion salts (DC less than 2) did not return a strong enough surface to measure reliably. In fact, the transmitter did not return any signal in the bottom half of the silo.

Without a reliable method to monitor the level of the combustion salt silo, this plant risked overfilling the silo which would result in an unplanned shutdown and high maintenance costs. In addition, waste costs were increased due to scheduling waste removal before it was needed.

Figure 1. 60-ft (18.5 m) tall combustion salt silo at garbage incineration plant.

SOLUTION

To solve this measurement problem, the customer installed a Rosemount 5303 Guided Wave Radar with flexible single lead probe (Figure 2). The transmitter electronics utilize a unique Probe End Projection (PEP) function that tracks the surface even when the surface signal is too weak to detect using traditional measurement methods. Since the signal was noisy, they decided to use the PEP function for the entire measuring range (Figure 3). Direct Switch Technology provides a stronger signal that enabled the PEP function to work for long distances.

EMERSON

POWER

This garbage incineration plant achieved many positive business results from the use of the Rosemount 5303 Guided Wave Radar level measurement. Overfills were prevented thus eliminating costly clean-up operations. In addition, the reliable level measurement reduced waste disposal costs by allowing for optimal scheduling of combustion salt removal trucks. Finally, reliable level measurement minimized the risk of unplanned shutdown.

RESOURCES

Emerson Process Management Power Industry

http://www.emersonprocess.com/solutions/power/

Rosemount 5300 Series Guided Wave Radar

http://www.emersonprocess.com/rosemount/products/level/m5300b.html

Figure 2. Installation of Rosemount 5303 Guided Wave Radar.

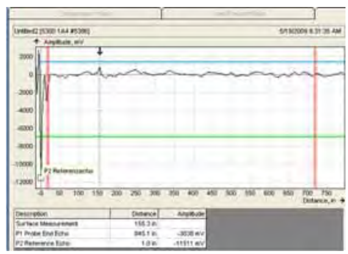

Figure 3. In cases of weak surface signal, Probe End Projection uses the probe length and the dielectric of the material to determine the product surface.

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00830-1200-4530, Rev BA

14.2 Ultrasonic

14.2.1 Power station chooses ultrasonic technology for reliable level control

POWER ROSEMOUNT 3100

Power Station Chooses Ultrasonic Technology For Reliable Level Control

RESULTS

- Significantly reduced maintenance
- Potentially dangerous incidents are avoided

"The instruments have given no problems since installation - they operate perfectly"

Instrument Technician

APPLICATION

Acid and caustic measurement in boiler feed water treatment plant at a coal fired power station

CUSTOMER

A UK power station

CHALLENGE

In any large steam generating system, the quality of the water used to feed the steam generation boilers is critical to the efficient operation of the plant. All impurities must be removed to minimise problems such as corrosion, scaling and sludge formation. At the 4,000MW Power Generation site – Western Europe's largest coal-fired power station – water is drawn from a local borehole and subjected to a three-stage de-ionisation process to remove dissolved minerals. The process requires regular regeneration using concentrated solutions of sulphuric acid and caustic soda.

The 98% acid and 47% caustic solutions are held in five bulk storage tanks: four hold approximately 50t and the fifth is capable of storing 148t of acid; the tanks are replenished as necessary from 25t road tankers. The level in each tank is constantly monitored to ensure that it is never completely drained - if sludge from the bottom of the tank reached the ion-exchange beds a costly decontamination operation would have to be carried out. When a tank is refilled it must have sufficient capacity to accept a full 25t load: part loads are uneconomical and spillage unacceptable.

Figure 1 Transmitter installation

SOLUTION

Refurbishment of the water treatment plant provided the opportunity to replace the existing level measurement systems. These were based on hydrostatic pressure sensors immersed in the liquid and were causing concern because the seals were prone to attack by the aggressive concentrations of acid and caustic soda. In addition, the high and low alarm level switches had become corroded beyond use.

EMERSON

POWER

SOLUTION (continued)

Rosemount® model 3102 ultrasonic liquid level transmitters were selected as a replacement for continuous level measurement. PVDF faced sensors were selected for their resistance to chemical corrosion and the sensors are mounted at the top of each tank, eliminating any direct contact with the tank's contents.

The output from the 3102 is connected directly to a local display at the filling point showing the contents of each tank (in tonnes) and this is also relayed to the water treatment control room. The 3102's integral relay outputs are programmed to trigger an audible alarm if a pre-set level in the tank is exceeded, eliminating the possibility of overfill and spillage. This is a particular requirement at the tank filling point where the safety of the operators is paramount.

Tests have shown that the level measurement is well within the accuracy required for the application.

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00830-0200-4840, Rev AB

14.3 Switches

14.3.1 Power station manages high and low level control in aggressive chemicals with level switch

POWER | ROSEMOUNT 2120

Power Station Manages High and Low Level Control in Aggressive Chemicals with Level Switch

RESULTS

- Reliable high and low level protection in the most aggressive fluids
- Eliminated false switching

The Rosemount 2120 Vibrating Fork Level Switch provided reliable high and low level control under very challenging conditions.

APPLICATION

Regenerative fuel cells

Application Characteristics: High and low-level alarm and pump control of various aggressive fluids in storage process vessels, sumps and bund walls. Process fluids include solutions of sodium bromide, sodium hypochlorite, sodium polysulphide, and water.

CUSTOMER

Power station in Europe

CHALLENGE

The aggressive nature of certain fluids and product vapors means that the material selection is critical. Lower quality solutions using reconstituted coating material are often attacked and blister because of the impurities and porous structure. Some of the product vapors, particularly free bromide, tend to blister other coatings.

This application frequently has high electrical potential where no metal parts can come in contact with the process fluid. These installations also frequently have a mixture of safe and intrinsically safe hazardous area requirements that must be met

SOLUTION

The Rosemount 2120 Vibrating Fork Level Switch with the Halar ECTFE/PFA coating option was an ideal solution for providing high and low level control with aggressive chemicals, high electrical potential, and where hazardous area approvals may be required.

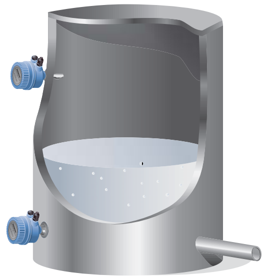
The Halar coating option was compatible with all of the aggressive fluids and vapors that might be present in the process. The high electrical potential in the process fluid is well suited to the Halar coated vibrating fork product where other level technologies may not have been acceptable.

To achieve the safe area requirements, the 2-wire direct loading switching output option can be selected. In intrinsically safe environments, standard NAMUR switching barriers make it possible to achieve the suitable hazardous area approvals using standard off the shelf barriers.

EMERSON

POWER

Upon commissioning, the Rosemount 2120 managed all high and low level switch controls by connection to the plant monitoring system. There it supported a level control strategy that included batch processes, control valves, and pumps.



Maximum and minimum detection in vessels containing many types of liquid is measured reliably using the Rosemount 2120.

RESOURCES

Rosemount 2120

http://www.emersonprocess.com/rosemount/products/level/m2120.html

Emerson Process Management's Power Industry Page

http://www.emersonprocess.com/solutions/power/

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00830-0200-4030, Rev BA

14.3.2 Cedar falls utilities reduces maintenance costs with vibrating fork technology

COAL FIRED PRODUCTION | ROSEMOUNT 2120

Cedar Falls Utilities Reduced Maintenance Costs With Vibrating Fork Technology

RESULTS

- Reduced maintenance costs
- Decreased utility costs
- Lowered risk of safety incidents

Cedar Falls Utilities utilized the heartbeat LED to quickly diagnose status and health of the 2120 which lead to simpler operations.

APPLICATION

Tank level and pump control on steam condensate return tanks and reverse osmosis tanks

CUSTOMER

Cedar Falls Utility (CFU)

CHALLENGE

Cedar Falls Utility had difficulty controlling the level on their steam condensate return tanks. Low levels risked pump cavitation and high levels risked overfilling.

CFU previously used differential pressure technology in a pneumatic control system. The pneumatic system was maintenance intensive and was unable to keep the pump control sequenced properly. Low levels required pumps to be shut off. High levels turned on the pumps and triggered a timing relay so that an alarm would signal if the level didn't go down.

Undependable level control lead to several negative business impacts for CFU. The previous pneumatic technology was unreliable and lead to increased maintenance costs for routine checks and repair. At times, CFU did not use the condensate tanks which risked plant efficiency and higher utility costs. Lastly, overfilling return tanks with boiling water increased personnel safety risks.

SOLUTION

Cedar Falls Utilities installed two Rosemount 2120 Vibrating Level Switches to solve their control challenges on the steam condensate return tanks. Unlike the previous technology, the 2120 provided reliable level detection for condensate return tank control with no moving parts for reduced maintenance. Also, CFU utilized the heartbeat LED to quickly diagnose status and health of the 2120 which lead to simpler operations and faster troubleshooting.

EMERSON

COAL FIRED PRODUCTION

The Rosemount 2120 helped Cedar Falls Utilities reduce maintenance costs by eliminating the previous pneumatic technology. CFU also decreased utility costs and lowered safety risk by accurately preventing return tank overfills.

RESOURCES

Emerson Process Management
http://www.emersonprocess.com/rosemount/industry/power/index.html

Rosemount 2120 Vibrating Fork Liquid Level Switch
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14.4 Hydrastep

14.4.1 Hydrastep solves safety problems at Lindsay oil refinery

OIL & GAS

Hydrastep solves safety problems at Lindsay oil refinery

RESULTS

- Reduced maintenance costs
- Concerns regarding safety issues solved
- No loss of indication or control

APPLICATION

Boiler drum water level monitoring

The fault tolerant design of the Hydrastep continues to operate even if the circuit fails

CUSTOMER

Lindsay oil refinery, Humber Estuary, UK

CHALLENGE

Lindsey Oil Refinery is a large petroleum refinery on the shores of the Humber Estuary.
The site has many pipework processes involved in the refining of crude oil into lighter fractions. Many of the lower fraction products are extremely viscose and therefore in order for them to remain in a fluid state they must be pumped along steam jacketed pipes, and/or be held in steam jacketed vessels.
The raising of this steam is carried out by a number of oil fired and waste heatboilers on site, the main one being a 60 tonne/hr boiler situated in the catalytic cracking area of the plant. This firetube boiler uses waste heat from the FCCU (Fluid Catalytic Cracking Unit) to raise steam.

The method of measuring the boiler drum water level had always been a front and back end gauge glass system giving a local visual indication of water level. Because of the purity of the water used to raise steam, the gauge glasses would etch badly giving poor - or in some instances zero - visibility along the column.
In addition to this problem, the water level in the drum would frequently drop down lower than the gauge glass window giving the impression of an empty drum. (not something one wants on a hot boiler drum).
Lastly, costly maintenance was a key issue as often the seals would leak.

Figure 1 Hydrastep installation

OIL & GAS

SOLUTION

It was essential to replace the gauge glass with a more reliable, fault redundant system which did not present safety issues to the site.

A 2468 Hydrastep system was fitted to the boiler, consequently removing the concerns regarding safety. A full 24 electrode column was fitted to both ends of the boiler drum – connected to two separate electronic gauge systems . Full Lloyds and Sole gauge /ASME approvals cover the system which incorporates the split circuit design providing superior dependability over other redundant circuits; this means that no single fault can result in a loss of indication or control.

Lindsey Oil Refinery are very happy with the new system, the fault tolerant design of the Hydrastep continues to operate even if the circuit fails. The 'On line' diagnostic circuits make a test switch unnecessary - indeed testing the Hydrastep itself is unnecessary, it does this itself.

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Applications overview

Topic Page

15. Applications overview

Area	Unit	Process	Fossil (coal)	Fossil (natural gas or fuel oil)	Heat recovery steam generation (combined cycle)	Nuclear power (BOP)	Water (hydro power)	Geo-thermal power	Solar-thermal power	Bio-mass (waste incineration)	Application in section:
Steam generation	Boiler	Boiler blowdown tank	●	●	●				●	●	4.6
Steam generation	Boiler	Boiler drum control	●	●	●				●	●	4.1
Steam generation	Boiler	Boiler drum indication (local and remote)	●	●	●				●	●	4.2
Steam generation	Boiler	Flash tanks/surge tanks	●	●		●			●	●	4.7
Steam generation	Boiler	Steam separators (once through systems)		●				●	●	●	4.5
Steam generation	Condensate system	Condensate storage	●	●	●				●		4.9
Steam generation	Condensate system	Deaerators	●	●	●	●			●	●	4.10
Steam generation	Condensate system	HP feedwater heaters	●	●	●	●			●	●	4.3
Steam generation	Condensate system	LP feedwater heaters	●	●	●	●			●	●	4.4
Steam generation	Condensate system	Boiler feedwater pump	●	●	●	●			●	●	4.42
Steam generation	Condensate system	Condenser/hot well	●	●	●			●	●	●	4.8
Electricity generation	Turbine auxillaries	Closed cooling water tanks	●	●	●	●		●	●	●	4.20
Electricity generation	Turbine auxillaries	Hydraulic oil tanks for control valves, actuation	●	●	●	●	●	●	●	●	4.13
Electricity generation	Turbine auxillaries	Lube oil pump protection	●	●	●	●	●	●	●	●	4.42
Electricity generation	Turbine auxillaries	Lubrication oil tanks (rotary equipment)	●	●	●	●	●	●	●	●	4.12
Electricity generation	Turbine auxillaries	Seal oil tanks (hydrogen systems)	●	●	●	●		●	●	●	4.42
Electricity generation	Turbine steam	Condensate extraction pumps	●	●	●	●		●	●	●	4.42
Electricity generation	Turbine steam	Steam bleed/extraction lines (TWIP)	●	●	●	●		●	●	●	4.14
Electricity generation	Turbine auxillaries	Water wash tanks	●	●	●			●	●	●	4.44
Electricity generation	Turbines	Gland steam condenser	●	●	●	●		●	●	●	4.11
Electricity generation	Turbines	Head and tail race level					●				4.39
Electricity generation	Turbines	Sump, drain pit for waste oil/water mix	●	●	●	●		●	●	●	4.43
Electricity generation	Turbines	Transformer oil	●	●	●	●		●	●	●	4.42
Fuel, air and flue gas process	Ash handling	Ash hopper	●							●	4.33
Fuel, air and flue gas process	Ash handling	Ash slurry	●								4.30

Area	Unit	Process	Fossil (coal)	Fossil (natural gas or fuel oil)	Heat recovery steam generation (combined cycle)	Nuclear power (BOP)	Water (hydro power)	Geo-thermal power	Solar-thermal power	Bio-mass (waste incineration)	Application in section:
Fuel, air and flue gas process	Ash handling	Bottom ash (unburned coal)	●								4.33
Fuel, air and flue gas process	Ash handling	Fly ash storage	●								4.33
Fuel, air and flue gas process	Carbon silos	Powder activated carbon	●							●	4.35
Fuel, air and flue gas process	Flue gas	Combustion salts	●							●	4.35
Fuel, air and flue gas process	Flue gas scrubbing/ desulfurization	Ammonia, anhydrous	●	●							4.28
Fuel, air and flue gas process	Flue gas scrubbing/ desulfurization	Ammonia, aqueous	●	●							4.29
Fuel, air and flue gas process	Flue gas scrubbing/ desulfurization	Lime silo	●								4.34
Fuel, air and flue gas process	Flue gas scrubbing/ desulfurization	Lime slurry	●								4.30
Fuel, air and flue gas process	Flue gas scrubbing/ desulfurization	Liquid gypsum /calcium sulfate)	●								4.30
Fuel, air and flue gas process	Flue gas scrubbing/ desulfurization	Scrubbers	●								4.32
Fuel, air and flue gas process	Flue gas scrubbing/ desulfurization	Sulfur solution tank	●								4.31
Fuel, air and flue gas process	Fuel additives	Bone meal or dried sludge	●							●	4.35
Fuel, air and flue gas process	Fuel supply	Coal bunker/hoppers	●								4.25
Fuel, air and flue gas process	Fuel supply	Coal pile	●								4.27
Fuel, air and flue gas process	Fuel supply	Coal silos	●								4.26
Fuel, air and flue gas process	Fuel supply	Fuel oil storage - overall level	●	●		●		●	●	●	4.23
Fuel, air and flue gas process	Fuel supply	Natural gas separator	●	●	●						4.24
Fuel, air and flue gas process	Fuel supply	Other fuel sources (bark, garbage)	●							●	4.27
Offsite & auxilary	Cooling system	Cooling tower basin	●	●	●	●		●	●	●	4.21
Offsite & auxilary	Cooling system - chillers	Refrigerants			●						4.22
Offsite & auxilary	Effluent/waste water	Clarifiers	●	●	●	●		●		●	4.38
Offsite & auxilary	Effluent/waste water	Effluent flow (open channel flow)	●	●	●	●		●		●	4.36
Offsite & auxilary	Effluent/waste water	Open atmosphere sumps	●	●	●			●		●	4.37
Offsite & auxilary	Fire protection	Fire water tanks (fire protection)	●	●	●	●		●	●	●	4.45

Area	Unit	Process	Fossil (coal)	Fossil (natural gas or fuel oil)	Heat recovery steam generation (combined cycle)	Nuclear power (BOP)	Water (hydro power)	Geo-thermal power	Solar-thermal power	Bio-mass (waste incineration)	Application in section:
Offsite & auxilary	Water supply and pre-treatment	Boric acid				●					4.19
Offsite & auxilary	Water supply and pre-treatment	Demineralization system tanks: chemical storage tanks: sodium hypochlorite, antifoam, caustic, acid (HCl or HNO3), hydrazine, phosphate solution, and other	●	●	●	●		●	●	●	4.15
Offsite & auxilary	Water supply and pre-treatment	Brine tank	●	●	●	●		●	●	●	4.18
Offsite & auxilary	Water supply and pre-treatment	Intake water screens	●	●	●	●	●	●	●	●	4.16
Offsite & auxilary	Water supply and pre-treatment	Lake or pond levels	●	●	●	●		●	●	●	4.46
Offsite & auxilary	Water supply and pre-treatment	Leaky wier at bottom of dam					●				4.40
Offsite & auxilary	Water supply and pre-treatment	Make-up water	●	●		●			●	●	4.19
Offsite & auxilary	Water supply and pre-treatment	Heavy water				●					4.19
Offsite & auxilary	Water supply and pre-treatment	Rock salt	●	●					●	●	4.17
Offsite & auxilary	Water supply and pre-treatment	Water catchment					●				4.41

Global capabilities

Recommended retail price $29.99

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