

Guided Wave Radar

TODAY'S VANGUARD IN LEVEL MEASUREMENT



Today's Vanguard in Level Measurement

Guided Wave Radar (GWR), the increasingly popular, industrial, loop-powered transmitters we know today burst on the scene in the late 1990s. Magnetrol's, Eclipse Model 705, like most devices, were based on the revolutionary Lawrence Livermore National Lab patent that in 1995 Popular Science magazine called "Radar on a Chip" for \$10.

Hard-fought early battles

At first the Eclipse GWR was almost shunned. Why would a customer use an "RF capacitance-looking device" with a probe? Non-contact devices had clear advantages over contact with ultrasonic and radar transmitters already carving out their own niche in the marketplace. Installing a probe seemed almost archaic.....but the probe WAS the secret.

What almost 15 years of experience has taught us is that the probe, the initial perceived weakness, is the real strength of the system. First, the probe offers a conductive path for the extremely low-energy signal to travel. This allows a maximum amount of energy to reach the surface where it is reflected and sent back to the transmitter for interpretation. Extremely low dielectric/low SG liquids like propane and butane can be measured with no problem. Non-contact radars can measure these liquids using a stillwell/standpipe; essentially becoming a guided wave device but at a far greater cost. DPs can measure these materials but are subject to SG variations that will greatly affect accuracy. Secondly, since the probe is a conductive path that maintains control of the signal, energy is not scattered within the tank (like non-contact radar) where it can encounter numerous objects that create false targets.

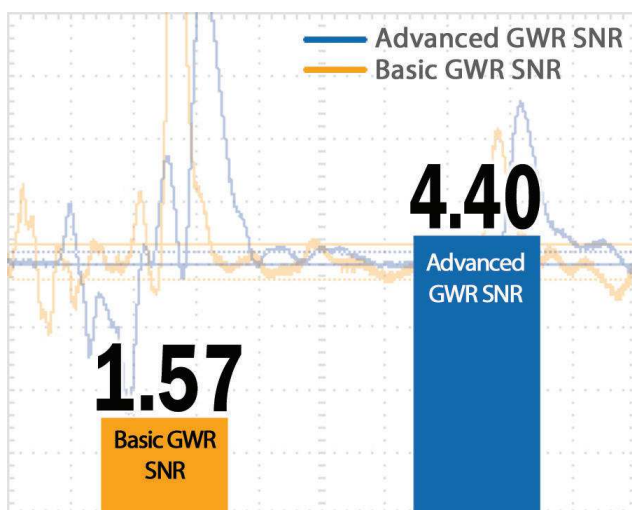
What have been revealed in the past 15 years are the special qualities of Eclipse GWR that has allowed it to seep into the bag of instrumentation tricks we have come to count on every day. Guided Wave Radar as a technology has slowly become the standard in process and storage tanks around the globe- first as a problem-solver then, as users gained confidence, as a daily staple on their level measurement menu.

This article will not explore the simple, generic applications we know can be solved with almost any level measurement technology including Guided Wave Radar. Rather, we intend to highlight a few of the special areas where users have found particular success in solving nagging measurement problems and the Eclipse GWR has become their go-to technology as application knowledge and product performance have evolved

Radar echo- is bigger always better?

Much has been said in the radar world about the need for a strong signal, i.e., a strong (high amplitude) transmitted signal to the medium you are measuring. It might seem heresy to say it is not the real issue, but is it? In some ways the radar signal is like the sound from a radio to which you are listening. If you want it louder you amplify the signal, an easy task. However, if there is a high noise level behind the desired signal what you get is garbage; similarly, in the radar world. This relationship between the wanted and unwanted signals is called Signal to Noise Ratio, abbreviated as SNR. Strong amplitude is a "brute force" approach and is much easier to achieve than overall SNR. In practical use the design with a greater SNR is more robust and far less likely to have issues with unwanted reflections than one that has an inferior value.

Modern radar designs strive for increasing their SNR and users would be wise to keep this lesser-known trait in mind as they choose between the various designs offered in the market. Low dielectric, turbulence and other challenging conditions are made easier with a superior SNR- the new Eclipse Model 706 leads the industry in this area.

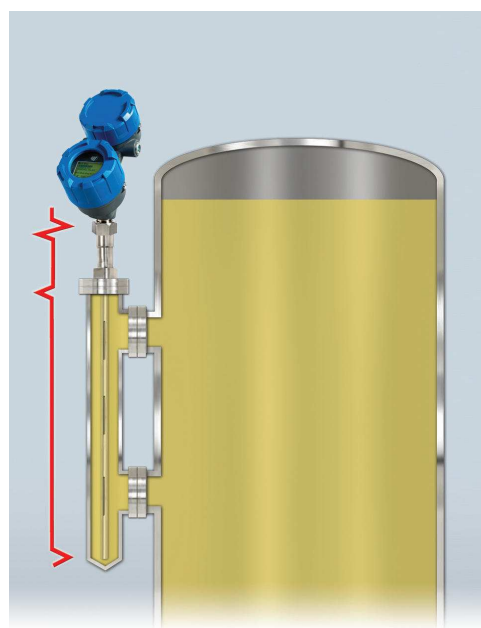


Overfill Capability

It is commonly understood that no level measurement technology is perfect in all applications. Many have issues measuring accurately to the very top of the tank. The more advanced of today's guided wave radar designs remove this weakness that plagues so many devices in the radar category. This can be critical with media that are highly corrosive, toxic or otherwise dangerous in a spill. The ability to read to the very top of the vessel is often called Overfill Capability.

European agencies like WHG or VLAREM certify Overfill proof protection, defined as the tested, reliable operation when the transmitter is used as an overfill alarm. Further, it is assumed in their analysis that the installation is designed in such a way that the vessel or side mounted cage cannot physically overfill. However, there are practical applications where a GWR probe can be completely flooded with level all the way up to the process connection (face of the flange). Although the affected areas are application dependent, typical GWR probes have a transition zone (or possibly dead zone) at the top of the probe where interacting signals can either affect the linearity of the measurement or, more dramatically, result in a complete loss of signal.

While some manufacturers of GWR transmitters may use special algorithms to "infer" level measurement when this undesirable signal interaction occurs and the actual level signal is lost, the advanced design of the Eclipse Models 705 and 706 offer unique solutions by utilizing a concept called Overfill Safe Operation. An Overfill safe probe is defined by the fact that it has predictable and uniform characteristic impedance all the way down the entire length of the waveguide (probe). This allows the probe to measure true level at all times.



This probe design has the ability to measure accurate levels up to the process flange without any non-measurable zone at the top of the GWR probe. Overfill safe GWR probes are a unique advancement; coaxial probes can be installed at any location on the vessel. Overfill safe probes are offered in a variety of Coaxial and Caged designs.

Guided Wave Radar in chambers/bridles and Magnetic Level Indicators

Bridles and chambers have become popular means of level measurement; first due to use with displacer transmitters but now accepted as they offer an efficient means of mounting external to a vessel allowing isolation via shut-off valves. Guided Wave Radar has often been used in this configuration utilizing coaxial probes. However, the recent popularity of single rod probes (primarily due to their cost and higher immunity to build-up) has raised a set of important performance issues.

Coaxial probes are the most efficient propagators of microwave energy; this is why everyone's television signal is transmitted over coaxial cable. Single rod probes are inefficient in two key aspects. First, launching the signal causes a large impedance mismatch at the top of the probe which creates noise that interferes with good target acquisition. Second, propagation of energy along the single rod probe is the least efficient of all GWR waveguides; not the best approach for optimal performance.

Both of these issues are resolved in the Eclipse Model 706 when its single rod probe is carefully impedance-matched to the typical chambers/bridles seen in the process industries. In this way there is no top-of-probe mismatch and, when done very carefully, the single rod probe/cage combination effectively becomes a coaxial arrangement creating excellent propagation efficiency.

The most recent Eclipse Model 706 developments have included this probe/chamber matching design which yields excellent performance at the lower cost of a single rod probe.

Saturated Steam applications

Saturated steam applications (i.e. high temperature/high pressure water used in power generation) touches on one of the theoretical weaknesses radar. Radar technology has proven to be a successful level measurement technology because it can measure liquids that have drastically changing characteristics like dielectric, specific gravity- conditions that cause accuracy headaches conventional technologies like pressure cells and torque-tube transmitters. This is true because the speed of microwave propagation is based on the equation $velocity = speed\ of\ light / \sqrt{dielectric}$ (of vapor space). Typical process conditions have little effect on this equation until you enter the realm of high temperature/high pressure water (steam) applications encountered in power generation.

As the temperature of a saturated steam increases in these boiler and feedwater heater applications, the dielectric constant of the polar gas steam vapor space also increases. This increase in vapor space dielectric causes a delay in the GWR signal propagation as it travels down the probe, causing the liquid level to appear lower than actual.

NOTE: The measurement error associated with this propagation delay does depend on temperature and is a function of the square root of the vapor space dielectric constant. For example, with no compensation, a 450° F application would show a level error of about 5.5%, while a 600° F application would show an error approaching 20%!

The Eclipse GWR advanced measurement techniques provide a unique solution to this application. The effects of the changing steam conditions can be compensated for by utilizing a mechanical steam target placed 10-20" (250-500mm) down on a single rod probe. (Some advanced designs have shortened this distance to 5 inches [125 mm] by utilizing a coaxial probe, which allows measurement closer to the very top). Knowing exactly where the target is located at room temperature, then continuously monitoring its apparent location, the vapor space dielectric can be back-calculated. By knowing the vapor space dielectric, accurate compensation of the actual liquid level reading is accomplished.



Saturated Steam applications

Remote site/solar power applications

One application that has been gaining in popularity is generically called a "solar application". By this it means a remote, often un-manned site, with a solar powered system with battery backup. The demand on transmitter performance may not be obvious at first glance. These systems by their very design have three key criteria that must be met; low power, fast turn-on time, and a fast response time.

Low power has evolved to mean the ability to operate at 12VDC minimum (240 mW @20mA). This can be accomplished straight away or with the use of a digital signal like HART or MODBUS with a fixed output current to some low value, say 8-10mA. In this way power usage can be controlled to a tolerable level particularly if using a multi-drop configuration.

Fast turn-on is the key to successful solar power applications. Since these are remote sites, continuous reporting of information is usually not a requirement. Updating once per hour or even once per day is not unusual. This allows for a highly efficient installation with minimal power usage. The real challenge for transmitters is the ability to come back from being turned off ("sleep" mode), power up and take a reliable reading within 15-30 seconds before being put back to sleep awaiting the next measurement cycle. The latest GWR designs can accomplish this power up cycle in <15 seconds making for an extremely nice fit in these installations.

Non-standard measurement techniques

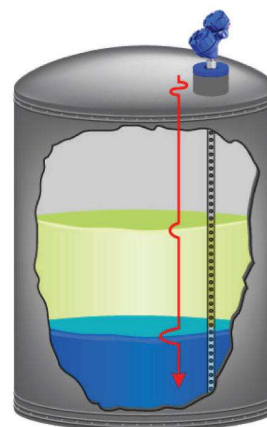
Guided Wave Radar is a time-of-flight technology whose microwave echo yields a reliable level reading even in changing process conditions. This direct-measurement of true product level is key to accurate performance. However, there are times when a calculated (inferred) measurement may be necessary. Again, the probe becomes a critical component. Knowing the exact probe length (a standard parameter) allows the transmitter to look for the end of probe signal to be in a precise location. In applications of extremely low dielectric (<1.4) due to inherent media characteristics or process conditions (e.g. flashing) detecting the "apparent location" of the end of probe can be used to calculate the amount (level) of the medium.

Why? The speed of propagation of the microwave signal is constant when passing through the typical vapor space (air) of liquids normally measured. However, when the signal passes into a low dielectric liquid the speed of the electromagnetic signal slows based on the equation **velocity = speed of light / square root of dielectric**. By knowing the medium dielectric and the expected end of probe location (based on probe length), the level of the medium can be calculated based on the apparent (delayed) end of probe location.

As the delayed position of the end of probe will vary as the dielectric of the process medium varies, this technique will not provide the same accuracy as measuring the true product level. For that reason, this is not a commonly used technique but can come in quite handy when using today's more sophisticated GWR transmitters in troublesome applications. The goal of dedicated GWR manufacturers is to always detect the true level signal, so this feature should only be used when conventional gain/threshold troubleshooting techniques are exhausted.

Guided Wave Radar measurement bonus- Interface

Many industries encounter interface applications- two, immiscible liquids of different specific gravities. The Oil & Gas industry is rife with these oil/water vessels where separation is critical. Water can be a major liquid that accompanies hydrocarbons from within their original rock formations or a minor liquid that condenses out after long periods. In many cases it is advantageous to measure both the hydrocarbon that rises to the top and the water that settles to the bottom.



The Eclipse GWR transmitters are capable of effectively measuring both an upper liquid level and an interface liquid level. As only a portion of the pulse is reflected from a low dielectric upper surface, some of the transmitted energy continues down the GWR probe through the upper liquid. The remaining initial pulse is again reflected when it reaches the higher dielectric lower liquid. It is typically required that the upper liquid have a dielectric constant less than 10, and the lower liquid has a dielectric constant greater than 15. A typical interface application would be oil over water, with the upper layer of oil being non-conductive ($\epsilon_r \approx 2.0$), and the lower layer of water being very conductive ($\epsilon_r \approx 80$). The Eclipse GWR transmitter can accurately detect upper layer thicknesses as small as 2" (50 mm) while the maximum upper layer is limited to the length of the GWR probe.

One consideration with interface applications is emulsion layers. For those applications containing an emulsion layer (also called a "rag layer"), of 4 inches or less, the Eclipse will detect the emulsion/ water interface level. For applications with an emulsion layer greater than approximately 4 inches, the Eclipse will tend to read the top of the emulsion (the oil/emulsion interface).

ANSI/ISA 12.27.01 process seals

Measurement of flammable media has always taken on a higher level of criticality. In search of ultimate safety, the issue has been raised as to what makes an appropriate seal between flammable media inside a vessel and the outside world. The intent is to eliminate the possibility of process fluids (gas or liquid) migrating under pressure through conduit/cable/wiring systems back to the control room in the event of a primary seal failure. Poured, conduit seals are NOT considered a deterrent to pressurized fluids.

This issue has evolved to a discussion of "single seal" vs. "dual seal". Does a single seal have enough integrity to be considered safe in these applications? Is dual seal a better solution?

Stainless steel thermowells come to mind which, by their very design, have the kind of robust characteristics that meet the ANSI/ISA 12.27.01 specifications as an acceptable single seal. However, remove the stainless steel well and create an O-ring compression seal and the design no longer has those same robust

characteristics. This design would demand a secondary seal as a back-up, the double seal approach.

But what are the key characteristics of these seals?

Single seals must pass the following testing:

- Leakage and burst: must show visible signs of leakage when subjected to overpressure.
- Temperature cycling: must not fail when subjected to repeated changes in temperature near the manufacturer's rated maximum.
- Fatigue cycling: must not fail when subjected to changes in pressure over 100,000 cycles which includes cycling from atmospheric pressure to the manufacturer's rated maximum.

Dual seal designs must pass these tests:

- Leakage and burst: same as single seal.
- Venting: must account for pressure and flow capacity of the worst-case primary seal failure. Pressure is applied until the needed annunciation has indicated failure.
- Annunciation must be verified by further testing.

It should be clear that the goal is to use, where possible, a single-seal device given its more robust design and rigorous testing. There are premium guided wave radar probes on the market that have been approved to the ANSI/ISA 12.27.01 specification. These designs offer the kind of safety via robust designs that users need and the specification demands- Eclipse Model 705 and 706 GWR probe designs meet this challenge.

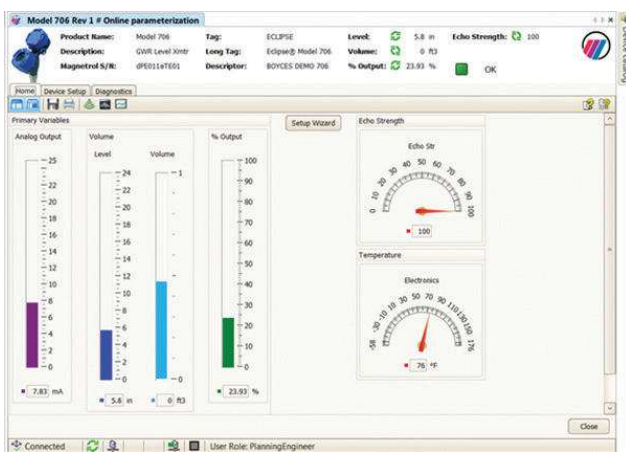
Improvements in user interface and software tools

The use of personal computers (PCs) has been a boon for instrument people. The ability to do sophisticated calibration and remote diagnostic troubleshooting means optimized performance and less downtime. PACTware is one program in the FDT (Field Device Tool) family that has become popular with many customers. Manufacturers design DTMs that work within the PACTware frame. These DTMs present transmitter information in the way each manufacturer feels best represents their device. This is important when involved with the more sophisticated aspects of PC software use.

Of course as transmitters and their accompanying PC programs have become more sophisticated, the cry from users is “keep it simple and intuitive”. Magnetrol’s Eclipse Model 706 DTM is a logical approach that is centered on how the customer uses the information NOT how the transmitter develops it.

The new Eclipse 706 approach is to break the information down into useable sections:

- HOME SCREEN (dashboard) showing a snapshot in time of all key information
- DEVICE SETUP yielding all necessary configuration parameters
 - SETUP WIZARD- a minimum subset of configuration parameters to quickly get up and running
- DIAGNOSTICS making available all diagnostic and troubleshooting

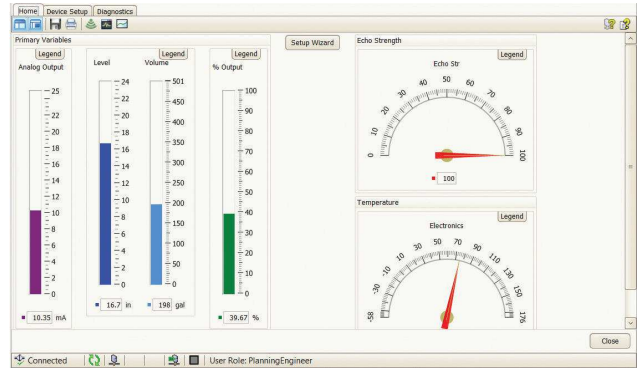


The above screen shows such a layout (HOME screen showing). Key aspects are:

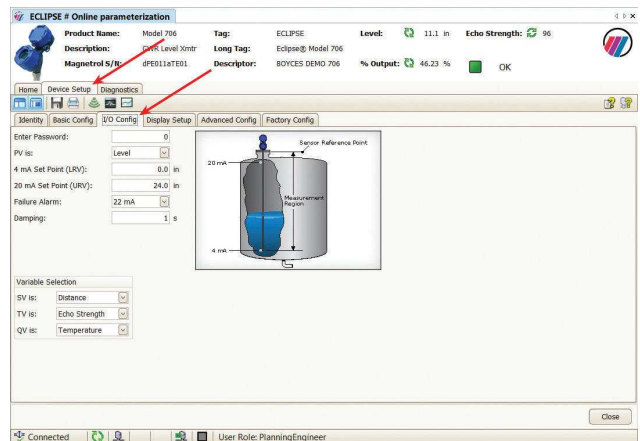
- HEADER yielding all key information and is viewable regardless where you navigate in the program.



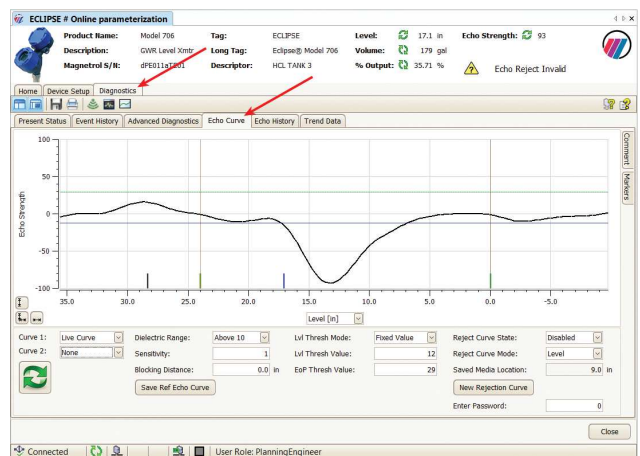
- Three tabs are visible showing HOME, DEVICE SETUP and DIAGNOSTICS
 - HOME, or dashboard, shows key variables and diagnostic information in an easy-to-read graphical format



- DEVICE SETUP opens up a set up tabs instrumental for configuration



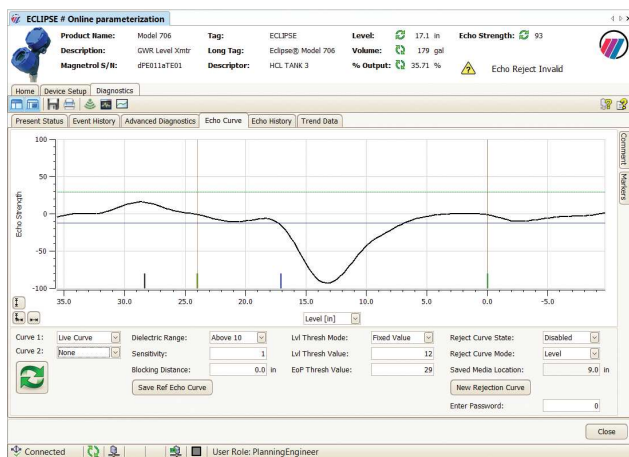
- DIAGNOSTICS opens up a different set of tabs for troubleshooting



Two clicks of the mouse will navigate you to any piece of transmitter information. Further, “flyover” HELP is available by positioning the cursor over whatever piece of key information is needed.

Unattended Echo Capture

It would be a wonderful world where transmitters never experienced a process upset or other problem throughout their entire lifecycle.of course, this utopia has never been found. The practical matter becomes how fast a user can turn around a problem and get his device back on line minimizing down time. One of the most important tools used to troubleshoot a Radar/GWR application is the Echo Curve.



This graphical representation of a GWR's echo speaks volumes to those trained in interpreting them. It is like a snapshot in time of the health of the transmitter; it is an EKG in the hands of a cardiologist. It is actually like seeing inside of the tank.

The problem with Echo Curves is acquiring them in a timely fashion. We all know the story. The tank farm, blending tanks, etc., have been working fine for months.then a problem develops. Does it happen at 10:00a so you don't miss break and can have it repaired by lunch.NO! The alarm goes off at 2:30 in the morning when there is a skeleton crew and no one watching this tank. By the time an instrument tech can investigate the alarm has cleared and no one understands why it occurred or, more importantly, when it will happen again.

Since an Echo Curve is so important in troubleshooting the device, it is critical to capture the curve at the instant a problem occurs. Too often this means connecting a laptop and gathering information AFTER the first signs of the problem, obviously not ideal. The advanced Eclipse Model 706 GWR design have now made this much less painful. These advanced designs are shipped from the factory so an echo curve is






captured based on Time (using an on-board clock) or captured based on a key Event such as Loss of Echo or Low Echo Strength. The transmitter has the ability to store a number of echo curves in its on-board memory. These Echo Curves can then be downloaded to a laptop running software such as PACTware. The user can then email the information to the factory for expert assistance in troubleshooting. No more waiting for the problem to occur a second or third time, the problem can be resolved much more quickly minimizing possible downtime.

NE107

For many years transmitters could yield only 4-20mA information related to a change in its primary variable. Smart (microprocessor-based) devices raised that bar offering the ability to do self-diagnosis and transmit its information over digital networks such as HART, Profibus and Fieldbus. Many manufacturers evolved their diagnostics into three basic categories- Fault (most critical), Warning (less critical), Informational.

NAMUR, an international association dedicated to automation in the process industries, has been influential in improving various areas of this industry for many years. Its NE43 recommendation, modifying the original 4-20mA loops to a 3.8-20.5mA working range with low alarm below 3.8mA and high alarm above 21mA, has now been widely accepted as a de facto standard by many manufacturers.

NAMUR has raised that bar again with release of its NE107 recommendation for diagnostic information (Self-monitoring and Diagnosis of Field Devices). The NE107 recommendation offers the following categories in order of importance:

1. Failure  Output invalid due to a malfunction.
2. Function Check  Output is temporarily invalid due to other activity (e.g. maintenance)
3. Out of Specification  Operating out of specified measurement range
4. Maintenance Required  Output valid but in need of some attention
5. OK  No diagnostic issues

This relatively new standard allows the user to categorize diagnostic indicators in a way that suits their specific needs. The more advanced GWR transmitters are already incorporating this approach into their transmitter's diagnostic scheme allow much greater flexibility for the sophisticated user. All transmitters are shipped with default values for these diagnostic categories so the casual "non-NE107" user will still have them at their disposal with no added effort.

Summary

Guided Wave Radar has emerged as a level measurement staple in instrument shops around the world and the new Magnetrol Eclipse Model 706 GWR transmitter has shown to be in its own category.

It can measure effectively and reliably up to the very process seal of the probe. With specially bent probes GWR can measure to almost the last drop of liquid in a tank which makes them particularly attractive for industries like pharmaceuticals with their extremely high-value product.

From the first drop to the last, Eclipse has shown the ability to tackle some of the toughest industry challenges thrown its way. With its ease of installation and stellar performance in changing process conditions it is no wonder the Eclipse GWR transmitter has become a go-to product for problem applications yet is seen worthy of even the most generic plant applications.

	Magnetrol Eclipse	Other Brands	Benefit
PROBES			
Overfill probes – A broad range of Coaxial and Caged probes which offer accurate readings to the very top of the prob	✓	Typical single rod probes may have non-measurable areas at the top, resulting in signal loss.	No dead zones equates to Overfill Capability and improved safety.
Probe seals that are fired and bonded for true hermetic performance. The glass ceramic alloy means no concerns about O-ring material compatibility. An upgrade to previous borosilicate designs	✓	Most offer "soft", non bonded seals only	Greatly reduced risk of process fluid leak, and material compatibility issues. Operation up to 850F and 2500# service.
Steam probe with patented compensation technique. Steam target only 5 inches down the probe. Offered in lengths up to 20 feet long.	✓	Large unusable range on probe. Some offer no compensation at all.	Maintains accuracy in saturated steam applications, and increases usable range.
ISA 12.27.01 / single and dual seal approved.	✓	May charge extra, or not offer	Increased safety. Compliance with NEC / CEC
Patented offering containing GWR transmitter integrated and matched to a Magnetic Level Indicator.	✓	Not Available	Provides redundant local indication, with independent technology.
Optional segmented probe configuration	✓	Available from some	Assemble segments on site where limited overhead clearance may be an issue.
NACE and B31 construction codes are standard options	✓	May do as a special	Required for critical applications in power plants and refineries
ELECTRONICS			
Full graphic local user interface, that is easily added or removed. Displays echo curves, trends etc. Configurable to show only the info you want to see, along with context sensitive help screens	✓	Non graphic indicator, with no local interface, is all that is available from some	No need for expensive hand held terminal, or external software.
Fully encapsulated electronics	✓	May have exposed circuitry	Reliable even under extreme moisture.
Can operate down to 11V supply voltage, even in hazardous areas	✓	May require 16VDC or higher, particularly in cold climates, and hazardous areas	Ideal for solar power installations

	Magnetrol Eclipse	Other Brands	Benefit
Highest Signal to noise ratio up to 3 times better than some competitors. Patent pending "Diode Switched Front End" circuit completely isolates the transmitted and received signals for more robust operation.	✓	Some offer similar, but less effective techniques.	Robust, reliable operation even in challenging applications. Continues to work where others would fail.
Built in "virtual technician" automatically saves echo curves during upsets and other events. Real time clock calendar on board to time stamp events. Supply voltage to device is continuously monitored.	✓	You may need a technician and / or external software to try and catch the issue when it happens	You don't have to be there for that erratic problem that occurs at 2:00 AM. Information is saved automatically in the transmitter to minimize troubleshooting and downtime.
"Fast Boot" fully functional level measurement in under 15 seconds from the application of power.	✓	Other are slow to get running and update level, taking up to 5 times longer just to get started	Fast start up, and short on-time in polled applications. Can start up, read the level, transmit data and shutdown in under 15 seconds.
One transmitter model handles all probe and application types	✓	Different models required for different applications	Reduced spares and more flexibility. Electronics do not need to be replaced if application is different than originally expected.
Published specifications are achieved with true direct level measurement.	✓	Others may use inferred level measurement when signals are lost, which can be less accurate, and risky in some applications	Always reading true level results in accurate performance even with dielectric changes, water bottoms etc.
Best in class interface performance, can resolve down to 2 inches of upper medium. Top tracking of large emulsions.	✓	May require 4 to 6 inches of upper medium before the interface signal can be detected. Can also be limited to small emulsions	Handles more challenging interface applications.
Patented "Split Barrier" design provides full safety compliance in explosion proof applications, without reductions in loop loading performance	✓	Limited loop loading and high supply voltage requirements	Can drive over 630 Ohms with a 24VDC supply in XP applications
SIL 2 Hardware with a Safe Failure Fraction (SFF) = 93%.	✓	Some may not offer.	Suitable for use in critical safety systems
NE 107 Compliant	✓	Some may not offer.	Compatible with the latest diagnostic standards
Dual Compartment, quick disconnect, factory sealed enclosure	✓	Some offer single compartment, screwed directly on the probe.	Full separation of wiring compartment from electronics. No need to pour an external seal in XP applications.
Multivariable device. In addition to level, easy configuration of interface, volume, or flow with extensive internal library of vessel and flow element shapes and types	✓	May require use of custom strapping tables developed and configured by user	Simply choose the Measurement type, enter a few configuration parameter, and the Eclipse does the rest.
Probe build up monitoring	✓		Alerts you to needed maintenance.
SOFTWARE			
Industry standard FDT / DTM, is free, and offers easy wizard based setup, advanced troubleshooting and documentation tools.	✓	Others may use proprietary software, or expensive asset management systems to work with the instrument.	Nothing else to buy. Universal operation across many brands