www.able.co.uk

ABLE Instruments & Controls

Radar Level Gauges

1st POINT ASSESSMENT

LLOYD'S REGISTER QUALITY ASSURANCE · ISO9002

NATIONAL ACCREDITATION OF CERTIFICATION BODIES

Radar Level Gauge Measurement Guide

Index

page

RADAR LEVEL GAUGES

General Introduction

Initially it should be understood that there are multiple technologies available on the market to measure level. Each and every technology works, when applied appropriately and no technology represents the "Holy Grail" for level measurement.

The last decade however has seen the rise of microwave or radar technology for level measurement to the extent where capacitance, differential pressure and ultrasonic transmitters have been replaced as the preferred level solution by many users. Initially radar was only used in the high accuracy custody transfer and tank gauging markets, however the development of new variants and mass production has seen radar become affordable for more widespread level applications.

Part of the attraction of radar as a technology is the seemingly easy method of specification and deployment. However in many respects a number of parallels can be drawn with ultrasonic technology, especially now, given the number of installations and variety of applications encountered. Simply put in order to cover as many applications as possible, the actual technology and gauge configuration has had to develop a multitude of variants which require careful consideration before a successful application solution can be found. This brochure looks at some of the technical and application detail ABLE investigate before specifying a radar gauge. To obtain a detailed quotation, simply complete the application questionnaire on page 11, or call the factory direct.

History

ABLE Instruments & Controls Ltd are in a unique position having vast practical knowledge in providing solutions for some of the most taxing radar gauging applications plus an ability to offer radar variants of all known kinds. Moreover we have been providing measurement and control solutions for in excess of 18 years. Our comprehensive product portfolio encompasses virtually every measurement technology, it therefore allows us to make an informed choice as to the best possible solution to any measurement application. ABLE have a team of specialised application engineers who review each application individually selecting components and customising them where necessary to provide a cost effective solution which is uncompromising in terms of both performance, reliability and whole life cost.

Techniques

Essentially radar gauging can be broken down into two distinct areas, air firing radar, which is the more common of the two, and guided wave radar (GWR) both of which have numerous derivatives.

Contact Radar

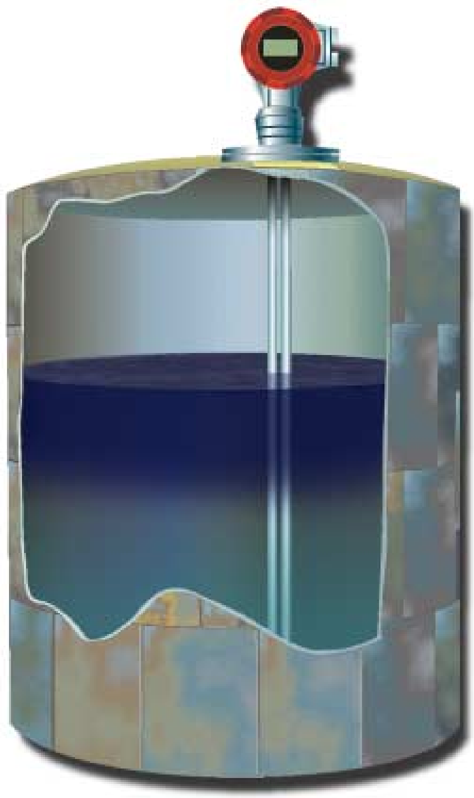
GWR

Unlike airbourne radar systems GWR is a contact technology and in appearance is not unlike RF Admittance although it does not have the same capability in terms of coping with extremes of pressure, temperature or product coating. Pulses of electromagnetic energy are emitted from the base of the transmitter down the wave guide. When the signal reaches a point down the wave guide where a change in dielectric constant occurs, usually the media surface, some of this signal is reflected back. The amount of signal reflection from the media is therefore proportional to the difference in dielectric constant between the wave-guide and the media. Fundamentally medias with a higher dielectric / conductivity, provide stronger return signals, this however is true for all types of radar.

The actual level measurement itself is a function of the time taken from when the electromagnetic signal is emitted to the time at which the resultant receive echo is received. As such this radar technology is often referred to as Time Domain Reflectometry or TDR radar. The propagation of the signal along a wave guide does eliminate false echoes and helps minimise signal loss due to vapours or dust, plus operation is possible in applications with changing vapour space humidity or fluctuating product dielectric constant. It should be noted though that like all radar gage types low dielectric materials, and low dielectric materials that stratify can be a cause for concern.

GWR has fewer restrictions than airbourne radar in terms of a dead zone at the upper end of the measuring range. Over short distances, however, specialised software maybe required as the delta T (time difference) between send and receive signals is so small that the accuracy of the gauges internal “stopwatch” has to be considered as a potentially large component of the overall accuracy.

Systems are available with both single and dual wave-guides depending upon application. Dual wave-guide systems in general provide slightly better flexibility and are suitable for; interface measurements, materials with a low dielectric or where foam is present. The position of a liquid interface is measured by utilizing the portion of the initial electromagnetic pulse, which is not reflected by the surface of the upper phase. This energy continues down the wave-guide until it meets the liquid / liquid interface and a percentage of it is reflected back toward the gauge. The dielectric constant of the upper phase must be known for accurate measurement as the gauge electronics have to compensate the resultant change in speed of electromagenetic pulse through the upper phase, as it will be different to that of its speed through the air space.



Techniques

Airbourne Radar

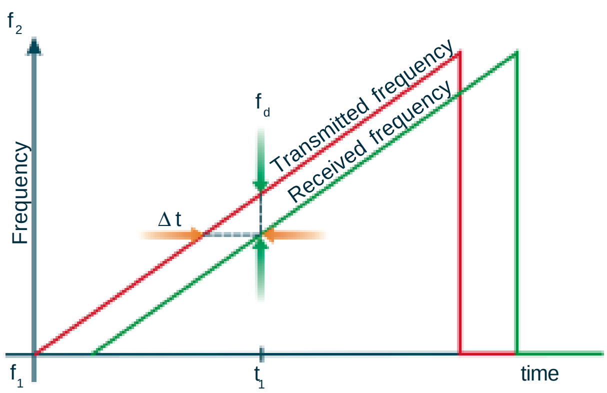
Airbourne radar can be broadly broken down into two distinct categories pulsed wave time of flight and frequency modulated continuous wave (FMCW). Whilst both use microwave signals fired into the vapour space above the media, the return signal processing, manipulation and resultant distance calculation vary significantly.

FMCW

FMCW systems, continuously emit a swept frequency signal and distance is inferred from the difference in frequency between the transmit and receive signals at any point in time. This technique whilst providing an inferential measurement can be highly accurate and is in fact the only method that is suitable for the high accuracy demanded for tank gauging and custody transfer. In such applications gauges are required to accept temperature and pressure inputs for compensation purposes.

The level of signal processing associated with FMCW radar gauges and the resultant power requirements means that two wire gauges of this type are suitable only for the simpler applications, with most applications being fulfilled by four wire devices. Essentially FMCW radar utilises a microwave frequency transmission sweep that changes within a specified time. This signal is transmitted toward the media, which produces an echo back toward the gauge. The return signal is then combined or subtracted from the outgoing signal at that instant resulting in a low frequency signal that is proportional to the distance between the gauge and the product surface.

In the case of hydrocarbons, an accurate water bottom measurement must be made for precise inventory control. Typically, another technology, such as RF Admittance is used to make the interface measurement between water and hydrocarbons.



The FM-CW radar technique is an indirect method of level measurement.
fd is proportional to Δt which is proportional to distance

$$\Delta t = \frac{2xR}{C}$$

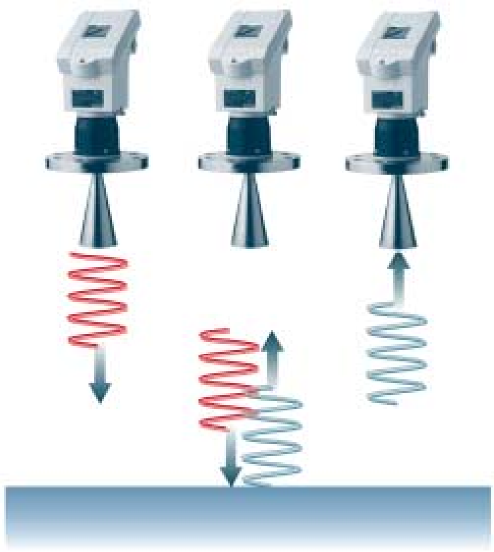
Where R is distance to media surface
C is the speed of light

Pulse Radar

These gauges work on a time-of-flight principle (transmission to reception) and in many respects are similar to ultrasonic level devices differing mainly in the use of a higher frequency electromagnetic signal.

Level measurement is based on the time taken for a non-continuous pulse to be transmitted to and reflected from the media surface with signals being evaluated by sampling and building up a historical profile of the echoes. As microwaves travel at the speed of light, the time taken for a signal to travel the distances involved in most applications is measured in nanoseconds. Due to the difficulties associated with making accurate measurements over these short time periods various methods exist and are combined to provide successful measurement. These include regimented progressive sampling, which effectively provides a slow motion expanded snap shot of the actual echo, and the use of a reference signal for cross correlation when sampling the send and return signals.

Pulse radar in particular can encounter difficulties when the media is in close proximity to the antenna because the time difference between send and return signals is too fast to measure accurately. ABLE can provide a number of alternatives for these type of applications including gauges with differing frequencies or antenna types, whilst for really small spans close to the gauge, technology such as RF Admittance should be considered.



Pulse radar operated purely within the time domain. Millions of pulses are transmitted every second and a special sampling technique is used to produce a "time expanded" output signal

Frequency

Frequency

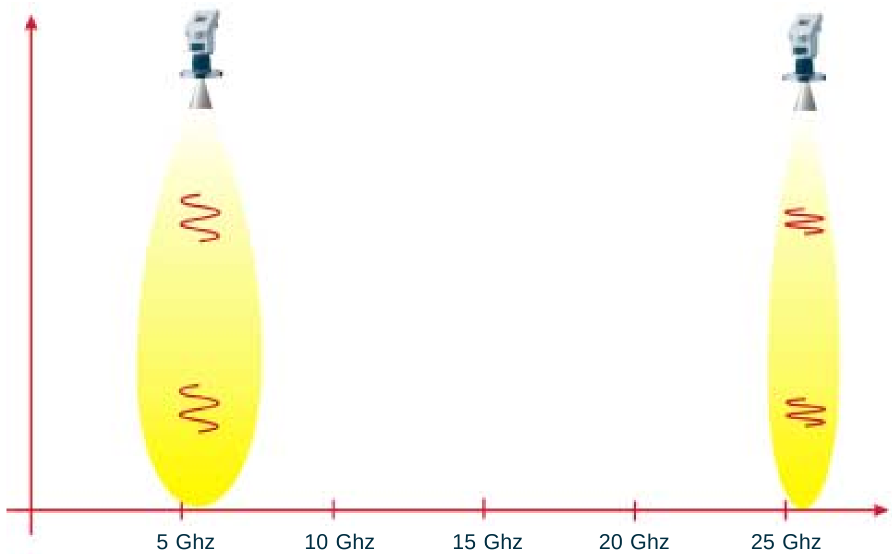
ABLE can supply gauges which utilise a number of frequencies between 5.8 and 26Ghz. Selection of a gauge that operates at the optimum frequency for a particular application can have an enormous impact on the functionality, accuracy, and reliability of any installation. Despite claims to the contrary, when you look at the properties of microwaves at differing frequencies it is obvious that no single operating frequency will provide the consummate solution. The frequency of the signal utilised has an effect on the radar beam shape, potential distance measured, and the ability to resist the effects of vapours, condensation, steam and dust.

Generally a higher frequency provides a more focused beam which can be useful in applications where there are objects such as manways, ladders, baffles and heating coils, as the narrow beam angle allows an uninterrupted path to be sought between the gauge and the media.

However higher frequency radar is adversely effected by product build up on the antenna such as condensation, plus turbulent media surfaces, as a result of fast filling or an agitator, can be to detrimental performance. Lower frequencies, which have a longer wavelength and widerbeam angle, by contrast tend to cope with steam, dust and low density far more successfully than higher frequency gauges.

It should also be noted that selection of the appropriate antenna type and size is also an integral factor in providing a focused beam and suitable return echo. ABLE therefore closely examine each application individually before recommending an operating frequency and antenna combination.

Focusing at Different Frequencies



For a given size of antenna, a higher frequency gives a more focused beam

Antenna Types

Antennas are available in a multitude of different configurations and sizes, and correct selection plays an important role in ensuring that the maximum amount of signal is launched at, and echoed from the media surface. In general terms it can be stated that a larger antenna results in a larger return echo being received at the gauge. Antenna types can be broken down into five main categories; the parabolic antenna, the cone or horn, the rod, isolation windowed or flush mount and the planar. Each antenna type emits microwave energy in a characteristic 'footprint' which must also be considered during gauge specification.

Cone Antenna

Window Antenna

Rod Antenna

Cone Antennas

Cone antennas are the most commonly deployed of all radar gauge antennas due to their modest size (when compared to parabolic gauges), ability to fit on flanges as small as 2", reasonable signal propagation and reception capabilities. Whilst cone antennas are widespread and suitable for a large cross section of applications this is partly because of the variety of configurations that have been developed to meet the demands of the individual applications. Common examples include extended wave guides for high temperature applications or where entry to the vessel is available from the side only. For dirty and dusty environments such as reactor vessels variants are available with purging connections to allow the antenna to be periodically cleaned without necessitating gauge removal. In addition cone antennas are often used in conjunction with still pipes (wave guides), particularly for floating roof tank applications such as LPG and LNG. Here a number of reference pins may be added to the still pipe design to allow verification of the gauge without removal.

Rod Antenna

Rod antennas tend to be used in the simplest of applications or where vessel entry is restricted. Unlike the other antenna types, rod antennas are available on a screw thread and in a number of differing designs to suit the individual requirements of an application. In general rod antennas offer the least focused microwave beam of all the antennas, this limits their applicability. When specifying this type of antenna ABLE consider the associated signal dispersion in conjunction with frequency to be used and the vessel conditions, before making a recommendation.

Parabolic and Planar

The parabolic and planar type antennas are used predominantly in high accuracy applications for instance where fiscal accuracies are required and as such are a common feature on tank farms. These antennas are relatively bulky and as standard are supplied on flanges of 6" or above, although specials are available. Due to their physical size these gauges often require installation via a manway. The parabolic antenna results in a highly focused signal that is characterized by the large return signal present where installed successfully. This in part also contributes to their high sensitivity which is perfect for the slow moving tanks associated with fiscal gauging, but not always suitable for smaller process vessels.

Window Antenna

Another antenna style available is the windowed antenna, which although basically a horn antenna with a low dielectric process window separating the gauge and the process, has become recognised as an antenna in its own right due to its wide spread use. Windowed gauges are predominantly utilised in applications where the gauge needs to be protected from the conditions within the vessel or where coating of the antenna may be a problem. These are available with an angled surface to help disperse any condensation on the window, again this is application dependant. Like wave guides or still pipes these should only ever be considered as a potential solution where the product to be measured has a high enough dielectric constant.

Four Wire vs. Two Wire

The primary advantage of two wire radar is that of reduced cabling costs as both the power for the gauge and its output can be transmitted simultaneously along a standard twisted pair. Moreover the use of an appropriate two wire device with a suitable communication protocol such as HART will allow a number of gauges, and other compatible instruments to be multi-dropped on to a single loop.

The processing involved with FMCW gauges means that two wire devices of this type are limited, as they are required to operate on a low power consumption basis. It should be noted, however that two wire FMCW devices can operate without problem provided they are correctly and carefully applied, as such ABLE application engineers carefully scrutinise every potential installation before recommending deployment of two wire FMCW gauges, particularly in multi-drop installations. Pulse radar involves less signal processing and can be used in two wire loops more readily, although obviously not for the high accuracy applications such as fiscal tank gauging.

Areas of Concern

In addition to understanding fundamental gauge properties from a technical and theoretical perspective, knowledge and experience of the impact of physical conditions is an important contributing factor to providing a successful installation. A selection of the areas which ABLE application engineers review for each new application are listed below:-

Vapours and Dust:-

In general careful gauge selection virtually eliminates the effects of vapours or fumes. Some vapours do however have a catastrophic effect on gauge performance. For instance in the case of ammonia, the microwave energy causes a polarization of the ammonia molecules resulting in the energy being used up and sending the gauge into fault.

Dust is altogether more unpredictable especially when trying to measure powder level; in these instances a successful installation requires ABLE application engineers to thoroughly examine the process cycle before recommending airborne radar. In fact it is likely that RF Admittance or even GWR would prove to be more reliable in powder or granular level measurement.

Dielectric Constant

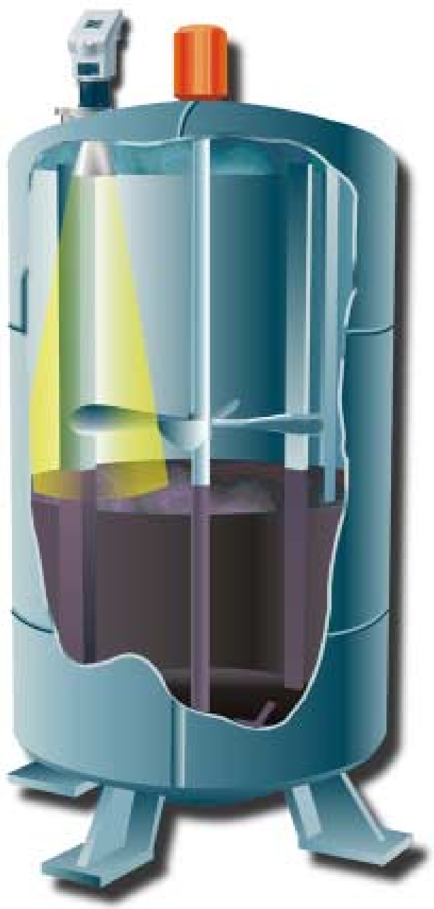
The higher the dielectric constant, or more simply put the greater the conductivity, of a media the greater the signal reflected back toward the gauge. Materials with a low dielectric constant of less than 1.4 will allow microwaves to pass either completely through them or may result in a reflection form a point below the surface. This explains the ability of radar to predominantly ignore vapours.

When looking to measure the total level of a mixture of media, it is often important to have knowledge of whether the mixture will stratify. Consider a condensate glycol mix which during a mixed state provides sufficient return echo for accurate total level measurement. As the medias begin to separate the low dielectric condensate becomes an upper phase and an error is introduced.

Internal Structures

Objects such as agitators and mixers provide a source for false echos. Whilst the selection of the best fit radar frequency and antennas may help in the focusing of the microwave beam to avoid a disturbing echo the presence of an unwanted return signal is often unavoidable.

ABLE have a number of sophisticated software options available for disturbance echo handling which may be applied during commissioning and throughout gauge operation. Initially software will be used to determine the best possible orientation and, where possible, location for the gauge. Strong false echoes can thus be minimised. Once physical installation is completed, software can be programmed to ignore unwanted echoes from any internal structures whether fixed, or mobile as is the case with mixers.



Areas of Concern (cont.)

Foam:-

Like dust the effects of foam on a radar gauge can be quite difficult to predict. In some instances the microwave signal may be lost whilst in other applications the foam will be completely ignored. The thickness, density and the dielectric constant of the foam are all factors that need to be considered. Selecting a radar gauge, which operates at a frequency sympathetic to the application, is also significant (usually this is a lower frequency).

In addition to the gauge itself ABLE application engineers have often overcome the problems associated with foaming by reviewing customer process to ensure that it reduces foaming. For applications where foaming is present as a result of tank filling rather than a chemical reaction, ABLE often recommend a still pipe installation.

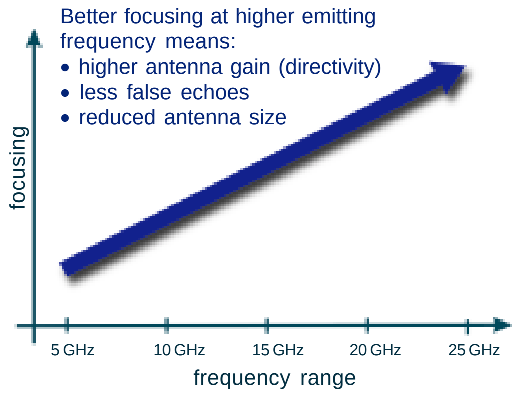
Agitated Media Surface:-

Turbulent surfaces have a tendency to scatter the microwave beam, essentially this is because of the varying angle at which the microwave hits the media. As a result less echo reaches the gauge than in an application where the media surface is 'still'. The use of a lower frequency radar with a larger 'footprint' can help but for the optimum installation lower frequency should be combined with sophisticated echo management software.

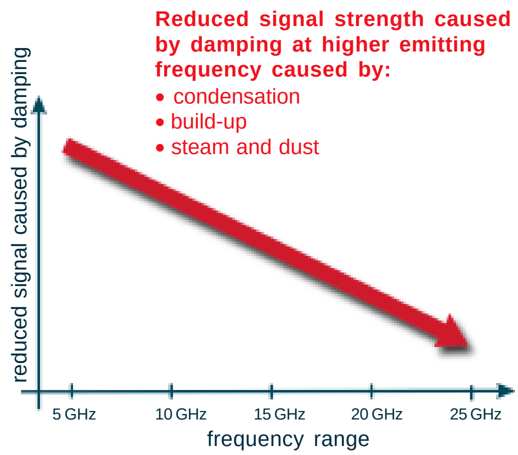
Still Pipes:-

Some installations, such as floating roof tanks, require the addition of a stillpipe. It should be noted that inconsistencies on the internal surface of the stillpipe can cause serious operational problems. To overcome these potential problems ABLE supply gauges and stillpipes as one complete factory tested unit where possible.

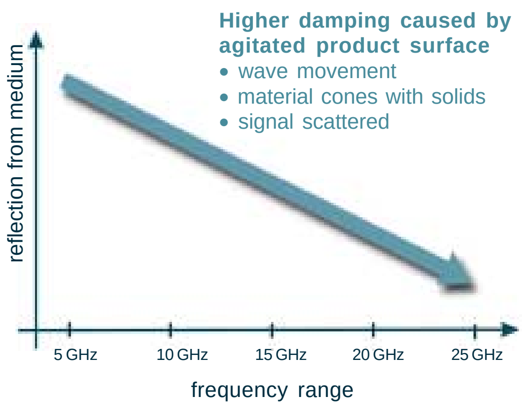
Summary of the Effects of Radar Frequency



Focusing and Radar Frequency



Signal Damping and Radar Frequency



Undulating Surfaces and Radar Frequency

ABLE Radar as part of a complete tank control strategy:-

To compliment our level solution portfolio ABLE have devised a complete scaleable turnkey solution for vessel content and tank farm control T.I.C.S. (Tank Indicating Control System). The concept behind T.I.C.S. is unique in that ABLE provide a solution customised to meet your requirements. Control panel designs are modular, ensuring that you get only those features required, whilst simultaneously ensuring systems maybe easily upgraded to fulfil future requirements. Essentially ABLE review, design and build each system on an individual basis, closely liaising with you on control requirement and strategy, to provide a cost effective uncompromising solution.

The flexibility of T.I.C.S. means that it maybe incorporated into an existing measurement and control architecture, or a green field site. The ability to incorporate inputs from any physical measurement device, not just radar, and communicate with, where necessary, any master control system such as a SCADA or DCS allows for easy system integration and cannot be understated.

For new build or new control applications, the flexibility associated with T.I.C.S. provides an enormous contribution to safety and reliability whilst simultaneously keeping costs low.

Please consult factory for further information relating to ABLE's TIC's systems.

Obtaining an Installation License:-

UK regulations dictate that a license is required for installation of a radar gauge. The application is fairly straight forward however ABLE qualified personnel are available to assist in the process of both obtaining a license and or renewing it. Our vast experience and wide installed base means we can ensure the process of obtaining a license is trouble free.

Level Measurement Quotation Request Form

FAXBACK +44 (0)118 931 2161 • EMAILBACK info@able.co.uk

For an IMMEDIATE quotation, PHOTOCOPY THIS PAGE, fill in the appropriate details below and FAXBACK to us on +44 (0)118 931 2161

Name: ____________________ Postcode: ____________________

Company: ____________________ Telephone: ____________________

Address: ____________________ Fax: ____________________

____________________ Email: ____________________

Number of units required ☐

I have the following application:-

Please show the preferred mounting location and any internal obstruction, such as agitators, heating coils, etc together with product feed and discharge points.

MEDIA:-

Upper Liquid __________ Lower Liquid __________

Upper SG __________ Lower SG __________

PRESSURE:-

BAR max. ______ normal ______ min. ______

TEMPERATURE:-

⁰C max. ______ normal ______ min. ______

cycling Yes ☐ No ☐

PHYSICAL VALUES:- (if known)

Conductivity (G) ____________________

Dielectric (K) ____________________

Viscosity (cS) ____________________

AGITATION:-

Yes ☐ No ☐

power __________ Kw

TANK CONSTRUCTION:-

C.S. ☐ S.S. ☐ Concrete ☐ Fibreglass ☐

Other ____________________

SYSTEM REQUIREMENTS:-

Total level ☐ Interface ☐ on/off ☐ 4-20mA output ☐

COATING:-

How much material build-upon antenna ______ mm

Metal wetted parts: ____________________ Area classification: ____________________

Power Input: to electronics) 24vdc __________ 110vac __________ 240vac __________

MOUNTING:-

thread size __________ flange size __________ flange spec. __________

ABLE Instruments & Controls Ltd.
Cutbush Park, Danehill, Lower Earley, Reading, Berks., RG6 4UT UK
Tel: **+44 (0)118 931 1188** Fax: **+44 (0)118 931 2161**
Email: **sales@able.co.uk** Website: **www.able.co.uk**

FAXBACK RESPONSE FORM

FAXBACK +44 (0)118 931 2161 • EMAILBACK info@able.co.uk

ABLE's product portfolio is listed below, to receive information on any of these products please indicate your interest and return this form to us:-

LEVEL

- ☐ Float Switches
- ☐ Ultrasonic Switches & Transmitters
- ☐ Magnetic Level Indicators
- ☐ Nucleonic Gauges
- ☐ R.F. Admittance
- ☐ Capacitance
- ☐ Radar

FLOW

- ☐ Open Channel Flow
- ☐ Clamp-on Ultrasonic
- ☐ Pitot Tubes
- ☐ Turbines
- ☐ Coriolis
- ☐ Mag meters

TEMPERATURE & PRESSURE

- ☐ Temperature & Pressure Transmitters
- ☐ Differential Pressure Gauges
- ☐ Temperature & Pressure Switches
- ☐ Pressure Regulators

PROCESS CONTROLLERS

- ☐ Hybrid Control Systems
- ☐ Signal Loop Controllers

HUMIDITY & MOISTURE

- ☐ RH & Dew Point
- ☐ Moisture in Solids Analysers
- ☐ Trace Moisture

RADIOMETRY

- ☐ Ultraviolet
- ☐ Visible
- ☐ Infra-red

COMPOSITION

- ☐ Liquid Analysis
- ☐ Gas Analysis

Mr/Ms/Other ________ Initials ________

Surname: ____________________

Job Title: ____________________

Company: ____________________

Address: ____________________

____

County: ____________________

Country: ____________ P/c.: ________

Tel: ____________________

Fax: ____________________

Email: ____________________

Website: ____________________

What industry is your Company associated with?

____

____

Do you have access to the internet?
◯ Yes ◯ No

Where did you learn of our Company?

____

www.able.co.uk

ABLE Instruments & Controls

ABLE Instruments & Controls Ltd.
Cutbush Park, Danehill, Lower Earley, Reading, Berks., RG6 4UT UK
Tel: **+44 (0)118 931 1188** Fax: **+44 (0)118 931 2161**
Email: **sales@able.co.uk** Website: **www.able.co.uk**