SENSOR
NETWORKS, INC

smartPIMS^{TM}

Corrosion/Erosion Monitoring System
Product Operation Manual

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February 2016

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Sensor Networks, Inc., 171-500 Technology Drive, Boalsburg, PA 16827 USA

The information in this document is subject to change without notice.

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TABLE OF CONTENTS

1   IMPORTANT – READ BEFORE USE

This chapter covers general pre-use information related to the product offering.

Specific topics include:

- Intended use of the equipment
- About this manual
- Repair and modification
- Technical specifications and ratings
- Warranty: (Hardware and Software)
- Company Information

1.1   INTENDED USE OF THE EQUIPMENT

The smartPIMS system, including hardware, software, and probes is designed to measure and monitor the wall thickness of industrial components such a pipes and pressure vessels. Rate of change (i.e. corrosion rate) is also derived from successive wall thickness readings.

WARNING: Operating the smartPIMS instrument outside of its intended use and/or specifications may impair certain protective features that are required for safe operation.

1.2   ABOUT THIS MANUAL

This manual is designed to be a comprehensive, and general reference for the operation, installation and basic maintenance of the smartPIMS system. As the smartPIMS system is flexible and modular, certain sections of this manual may reference hardware and software that is optional and/or not included with your system configuration. Please read the manual thoroughly prior to use and store it in an accessible location. For additional technical support, please contact your local sales or service representative.

1.3   REPAIR AND MODIFICATION

With the exception of the batteries, the smartPIMS system includes no operator serviceable parts. Contact your local sales or service representative for repair. To avoid injury and/or equipment damage, do not attempt repair / disassemble / and or modify the equipment.

Support can also be obtained from the factory at:

Sensor Networks Corporation
151-500 Technology Drive
Boalsburg, PA 16827
(814) 466 7207
www.installedsensors.com

1.4 Technical specifications and ratings:

EQUIPMENT RATINGS	
Inputs	
Supply voltage/current[1,2]	10<VDC<30 VDC, P<2W
Outputs	
Probe outputs (1-16)	+/- 5V, <1W
Resistance Temperature Detector	+2.06V, 5.75mA
Field wiring	
N/A	
Environmental	
Indoor/Outdoor Use	Outdoor
Temperature	$-20\,^{\circ}\text{C} \leq T_{amb} \leq 60\,^{\circ}\text{C}$
Humidity	99%, non-condensing
Ingress protection	IP66

Notes:

1. Product is not intended to be attached to mains power and shall only be powered through an appropriately rated and approved DC power supply with the following characteristics: 10-30 VDC output that is power limited to below 100 VA or 8 A per UL 60950-1.
2. For battery powered models, use only the manufacturer's specified battery type and capacity.

1.5 Product certifications

1.5.1 HAZARDOUS AREA:

The equipment is suitable for use and is marked for the following classified locations:

- Class 1, Division 2, Groups A-D, T4
- Class 1, Zone 2, IIC, T4

1.5.2 Product warnings / conditions for safe use.

WARNING – EXPLOSION HAZARD – DO NOT DISCONNECT WHILE CIRCUIT IS LIVE OR UNLESS THE AREA IS FREE OF IGNITABLE CONCENTRATIONS.

AVERTISSEMENT – RISQUE D'EXPLOSION – NE PAS DÉBRANCHER PENDANT QUE LE CIRCUIT EST SOUS TENSION OU À MOINS QUE L'EMPLACEMENT NE SOIT EXEMPT DE CONCENTRATIONS INFLAMMABLES.

WARNING – EXPLOSION HAZARD – BATTERIES MUST ONLY BE CHANGED IN AN AREA FREE OF IGNITABLE CONCENTRATIONS

AVERTISSEMENT – RISQUE D'EXPLOSION – LES BATTERIES NE DOIVENT ÊTRE REMLACÉES QUE DANS UN EMPLACEMENT EXEMPT DE CONCENTRATIONS INFLAMMABLES.

1.6 WARRANTY

1.6.1 Hardware:

Seller warrants that the Products sold to Buyer hereunder will be free from defects in material and workmanship furnished by Seller and will conform, within normal commercial tolerances, to applicable specifications. This warranty shall apply only where Buyer has given Seller written notice of such defect or nonconformity within one year (365) days after delivery of the Products by Seller. This warranty does not extend to any Product which has been subjected to abuse, misuse, neglect or accident, or to any Product which has been repaired or altered by other than Seller. THE FOREGOING WARRANTY IS BUYER'S SOLE AND EXCLUSIVE REMEDY AND IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING, WITHOUT LIMITATION, MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, DESCRIPTION, QUALITY, PRODUCTIVENESS, OR OTHERWISE.

1.6.2 Software:

The Software is being delivered to you "AS IS" and the Company makes no warranty as to its use or performance. SENSOR NETWORKS, INC. AND ITS SUPPLIERS DO NOT AND CANNOT WARRANT THE PERFORMANCE OR RESULTS YOU MAY OBTAIN BY USING THE SOFTWARE. EXCEPT FOR ANY WARRANTY, CONDITION, REPRESENTATION OR TERM TO THE EXTENT TO WHICH THE SAME CANNOT OR MAY NOT BE EXCLUDED OR LIMITED BY LAW APPLICABLE TO YOU IN YOUR JURISDICTION, THE COMPANY AND ITS SUPPLIERS MAKE NO WARRANTIES CONDITIONS, REPRESENTATIONS, OR TERMS (EXPRESS OR IMPLIED WHETHER BY STATUTE, COMMON LAW, CUSTOM, USAGE OR OTHERWISE) AS TO ANY MATTER INCLUDING WITHOUT LIMITATION NONINFRINGEMENT OF THIRD PARTY RIGHTS, MERCHANTABILITY, INTEGRATION, SATISFACTORY QUALITY, OR FITNESS FOR ANY PARTICULAR PURPOSE.

1.7 COMPANY INFORMATION

Sensor Networks, Inc. (SNI), is a technology company headquartered in Boalsburg, PA (USA), focused on permanently installed monitoring solutions (PIMS) utilizing ultrasonic sensor systems to monitor asset integrity in critical energy-sector components. What sets SNI apart from other monitoring companies is our flexible hardware and software platform. SNI has the unique ability to monitor multiple locations (spot, array, area) temporarily or permanently, utilizing a range of ultrasonic transducers (single, dual, high-temperature, shear wave) and collect/transmit data through wired, cellular or wireless protocols. Our systems can be used to monitor corrosion/erosion or crack propagation, calculate corrosion rates or otherwise aid in near real-time assessment of the 'health' of critical components via the industrial internet of things.

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</div>

2 INTRODUCTION TO SMARTPIMS FOR CORROSION/EROSION MONITORING

This chapter gives and introduction and overview of the smartPIMS corrosion/erosion monitoring system including the operational principles and major system components.

Specific topics include:

- smartPIMS Overview
- Operational Principle
- System concept

2.1 SMARTPIMS OVERVIEW

The smartPIMS platform is an automated, permanently (or semi-permanent) installed ultrasonic thickness gauging system that is designed to augment or replace manual UT inspections and existing corrosion-rate monitoring solutions offering high data quality, non-invasive installation and ability to operate remotely without operator interaction. As with UT thickness gauging, the solution is based on ultrasonic principles. Operationally, the installed-sensor solution is similar to manual thickness gauging however it is fundamentally different in that the transducers and instrumentation are deployed permanently (or semi-permanent). This addresses several of the shortcomings of existing solutions. Some of the major advantages are as follows:

- Instrumentation and probes are deployed on the asset in a permanent (or semi-permanent) fashion and can be accessed remotely. As such, the cost of access, preparation & manual oversight is reduced over time and operators are not deployed to the point of the inspection. Once the instrumentation is deployed, data can be accessed from a convenient access point for the manual data collection option or can be accessed remotely, via the Internet, for integrated systems.
- Due to the fixed transducer position and instrumentation, operator-to-operator, probe-to-probe, and instrument-to-instrument variability is eliminated. This removes significant sources of error and allows for improved measurement resolution, precision and accuracy which is particularly important for accurate corrosion-rate trending and overall data quality.
- Data can be collected on a more frequent basis (>1X per hour, day, week, year, etc.) for automated systems. This allows for more accurate corrosion-rate trending through statistical data analysis, such as linear least squares regression. This method can also be

useful for semi-permanent applications where the desired outcome is material loss over a specified period of time.

- The system can be deployed with an integrated temperature measurement device so that changes in material acoustic velocity due to temperature variation can be automatically removed from the measurement, thus eliminating another significant source of measurement error.
- The data is accessible. Wired and/or wireless installed sensor systems can make use of various forms of data backhaul, allowing practically real-time data/asset health availability.

Figure 1: Ultrasonic installed sensor system with up to 8 dual-element transducers (or 16 single element or delay line probes) and cellular connectivity (Modbus version also available).

2.2 OPERATIONAL PRINCIPAL

Like UT thickness gauging, the solution is based on the ultrasonic principle as shown in Figure 2. A transducer is used to convert electrical energy to high-frequency acoustic or ultrasonic energy and vice-versa and is semi-permanently attached to the surface of the object or asset under test. The transducer is electrically pulsed to generate a stress wave in the object and subsequently converts returning echoes to voltage. The resulting waveform (A-scan) is then recorded and measured by the ultrasonic instrumentation. The transit time between the initial pulse and return echoes (or between echoes) is used to calculate wall thickness. Features such as the distance to the back-wall or the distance to a pit or crack can be very accurately measured with this technique.
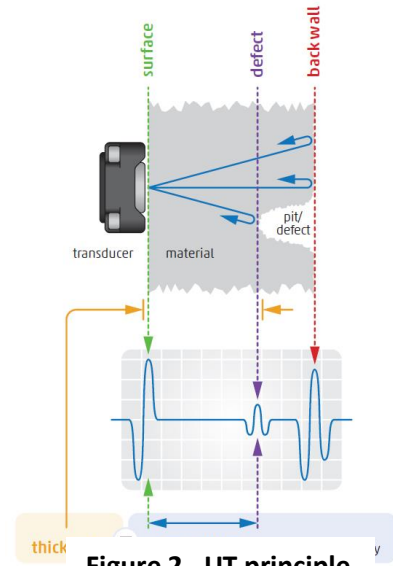
Figure 2. UT principle

2.3 SYSTEM CONCEPT / COMPONENTS

SNI has developed a flexible and cost-effective system for deploying hundreds to thousands of installed ultrasonic sensors. The system is modular, scalable and is offered in both wired and wireless versions, using industry-standard communication protocols to allow integration with existing plant equipment and control systems or backhaul to a cloud-based database using cellular or wireless connectivity.

Figure 3 shows the SNI's product concept as applied to manual data collection on a buried asset – such as a natural-gas distribution line. Figure 4 is a schematic view, showing the basic components of the system:
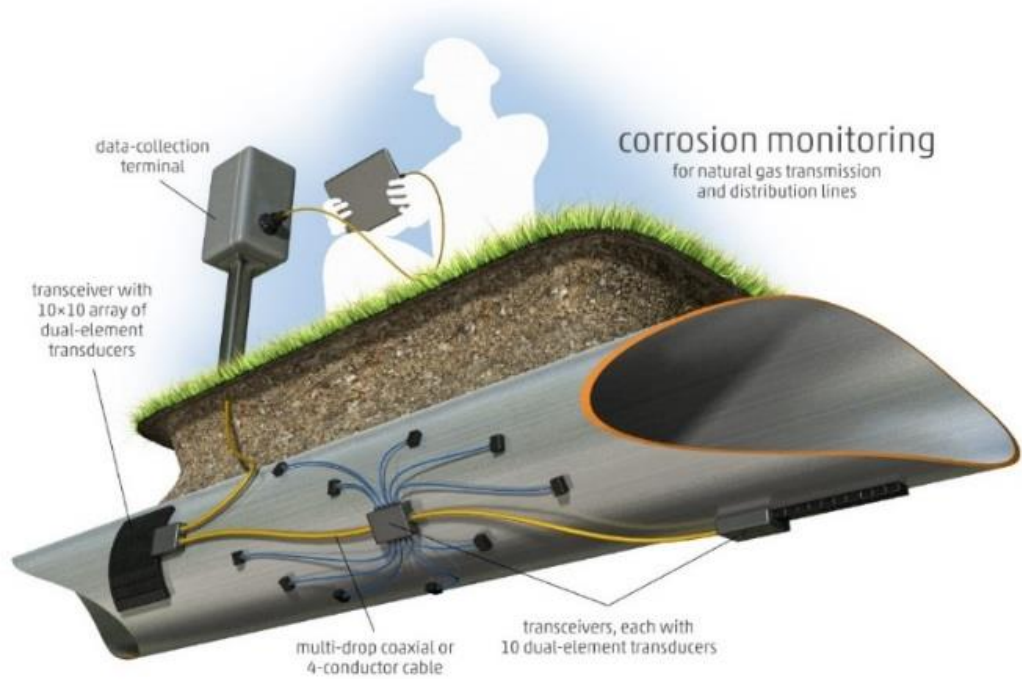
Figure 3. Corrosion monitoring architecture and application for buried pipelines
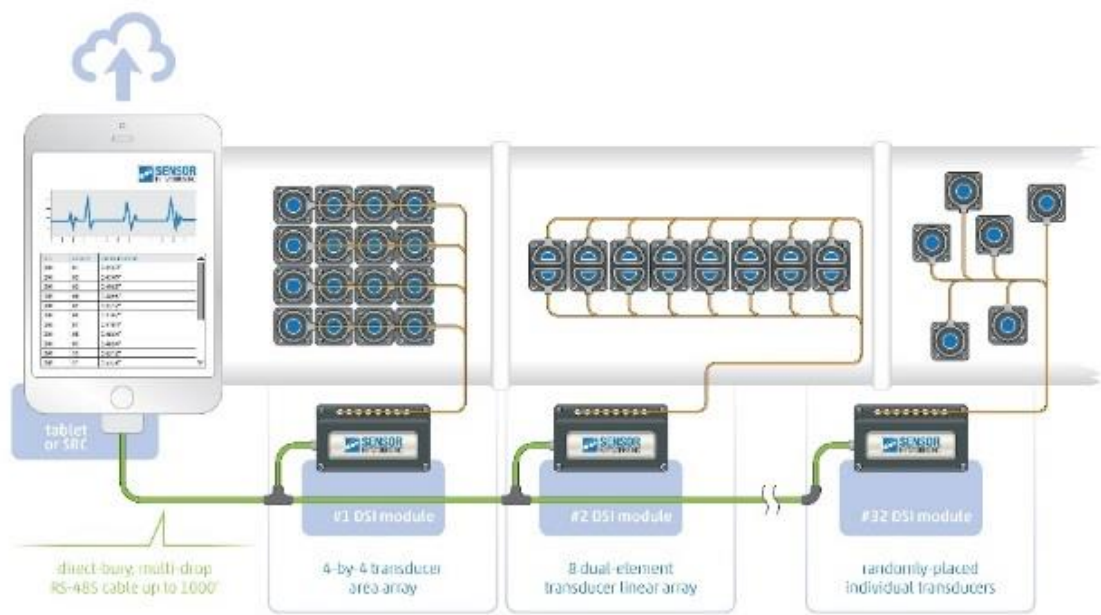
Figure 4. Schematic view including transducer arrays, DSI and tablet PC

2.3.1 System controller

The system controller is a tablet PC, industrial computer, or remote terminal unit (RTU) depending on whether the data collection will be manual, automated (Figure 4a), or integrated with a plant control system (Figure 4b). The system controller communicates with the network of digital sensor interfaces or "DSIs" via Modbus over RS-485 which is a standard industrial instrumentation protocol. The system controller processes the digital ultrasonic data into thickness values and then transmits the data for viewing, analysis and/or archiving.
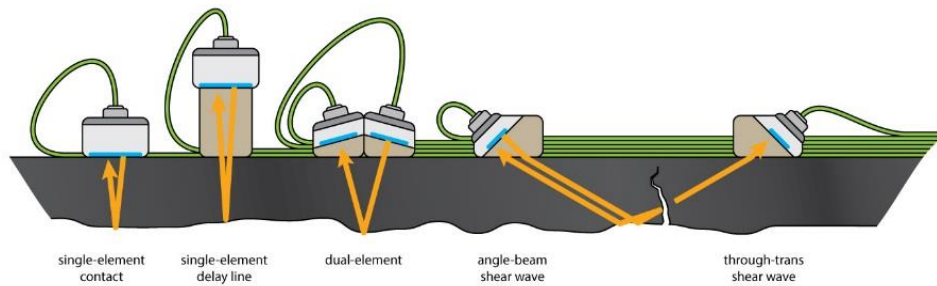
2.3.2 Digital Sensor Interface (DSI)

The digital sensor interface is an ultrasonic data collection instrument that is connected with up to 16 transducers and serves the purpose of pulsing and receiving data from the transducers, digitizing the collected data and transmitting the data to the system controller. The DSIs are arranged on a multi-drop network such that a single cable drop can be used to connect up to 32 DSIs representing a maximum 512 individual transducers. For any given DSI, transducers may be arranged randomly, or in a linear or area array, giving the customer the versatility to monitor specialized infrastructure such as a pipe-elbow extrados.

2.3.3 Transducers

The ultrasonic transducers transmit and receive ultrasound and are available in several models and types based on the application to be solved. For example, dual-element transducers are particularly well suited for thin measurements (< 0.100" or 2.5 mm) and highly-pitted back-wall surfaces. The transducers can be dry coupled to the pipe using a proprietary elastomeric material (for standard temperatures), adhesively bonded, or clamped with metal foil for high-temperature models.

single-element contact   single-element delay line   dual-element   angle-beam shear wave   through-trans shear wave

Type	Temperature	Application
Single-element Contact	Standard / Ambient	General purpose
Delay-line Contact	Medium to High	High precision, High temperature
Dual-element	Medium	General corrosion, pitted surfaces
Angle-beam or shear-wave	Standard to Medium	Crack detection

SNI's Transducers can be arranged in different configurations such as random, linear or area arrays to suit the needs of the application.

2.3.4 Temperature measurement device

To achieve the most accurate and precise readings using ultrasound, it is necessary to correct for the ultrasonic velocity change that occurs due to changes in asset temperature. SNI's system incorporates a RTD (resistance temperature detector) that can be placed on the asset adjacent to the ultrasonic transducers.

Figure 4a. Automated monitoring system   **Figure 4b. Integrated system**

2.4 DATA REPORTING

SNI incorporates a cloud-based solution for data management that allows for real-time access to thickness and corrosion-rate data from any connected device with an internet browser. This allows for accurate and real time data reporting from the sensor locations as well as the ability for reporting alert conditions via email or text. The solution can be hosted by SNI or on a company's internal computing resources. For portable data collection with SNI's tablet solution, data and report files can also be emailed from the device.

3 HARDWARE INSTALLATION

The following instructions cover the safe installation of the electrical hardware (Transmitter / Digital Sensor Interface) of the smartPIMS system, including field wiring instructions for the supplied power and probes. The following topics are covered.

- Installation Overview
- Warnings and Conditions for Safe Use
- Assembly, location and mounting requirements
- Power connections and requirements
- Batteries
- Field Wiring
- Connections
- Hardware Settings
- Software
- Probe Installation

3.1 INSTALLATION OVERVIEW

Hardware installation includes mounting the transmitter and field wiring of the supply power (Non battery powered units) and probes. Probe installation and hardware setup via software is also required but is covered in separate chapters. Chapter 3.3, "Probes" covers probe installation. Chapter 4.2, "Commissioning" covers software setup.

The following tools are required during hardware installation:

- Small flathead screwdriver
- Allen wrench set (Imperial Sizes)
- Drill and drill bits (for drilling mounting holes if required)

The following miscellaneous hardware may be required during installation and is not supplied with the smartPIMS instrument due to the variety of installation scenarios that can be encountered:

- 1/4 – 20 Bolts, Nuts, and Lock Washers of sufficient length to mount enclosure
- Locally fabricated mounting brackets

3.2 WARNINGS AND CONDITIONS FOR SAFE USE

Certain aspects of the installation are considered hot work and can generate arcs or sparks. Do not perform installation, service equipment and/or replace batteries when flammable atmosphere and/or ignitable concentrations are present.

WARNING – EXPLOSION HAZARD – DO NOT DISCONNECT WHILE CIRCUIT IS LIVE OR UNLESS THE AREA IS FREE OF IGNITABLE CONCENTRATIONS.

AVERTISSEMENT – RISQUE D'EXPLOSION – NE PAS DÉBRANCHER PENDANT QUE LE CIRCUIT EST SOUS TENSION OU À MOINS QUE L'EMPLACEMENT NE SOIT EXEMPT DE CONCENTRATIONS INFLAMMABLES.

WARNING – EXPLOSION HAZARD – BATTERIES MUST ONLY BE CHANGED IN AN AREA FREE OF IGNITABLE CONCENTRATIONS

AVERTISSEMENT – RISQUE D'EXPLOSION – LES BATTERIES NE DOIVENT ÊTRE REMLACÉES QUE DANS UN EMPLACEMENT EXEMPT DE CONCENTRATIONS INFLAMMABLES.

3.3 ASSEMBLY, LOCATION AND MOUNTING REQUIREMENTS

Assembly: The product is pre-assembled from the factory with exception of field wiring connections for probes and power. No assembly is required.

Location: The product is suitable for outdoor use. Locate product in area consistent with operating specifications (temperature, humidity, etc.).

Mounting requirements:

- Mount transmitter with Qty. 2, ¼-20 bolts or equivalent to only metallic or concrete structures.
- If mounting to concrete, use appropriate concrete anchors capable of supporting >20kg loads.
- Use lock washers to prevent loosening by vibration.

3.4 POWER CONNECTIONS AND REQUIREMENTS

The smartPIMS product is designed to be an energy limited apparatus that is powered either by internal batteries (for battery powered variants) or by connection to an approved, energy limited DC power supply. For battery powered devices, see section 3.4.3.

3.4.1 Power supply requirements

Product is not intended to be attached to mains power and shall only be powered through an appropriately rated and approved DC power supply with the following characteristics: 10-30 VDC output that is power limited to below 100 VA or 8 A per UL 60950-1.

3.4.2 Permanently Connected Equipment

In permanently connected configuration, wiring should be performed according to local and national electrical codes. As the smartPIMS system is energy limited, special care should be taken to maintain insulation and clearances between smartPIMS field wiring and other non-energy limited circuits such as Mains supplies for adjacent equipment. The smartPIMS instrument shall only be powered through an appropriately rated and listed DC power supply with energy limited outputs per 3.4.1.

3.4.3 Batteries

WARNING – EXPLOSION HAZARD – BATTERIES MUST ONLY BE CHANGED IN AN AREA FREE OF IGNITABLE CONCENTRATIONS

AVERTISSEMENT – RISQUE D'EXPLOSION – LES BATTERIES NE DOIVENT ÊTRE REMLACÉES QUE DANS UN EMPLACEMENT EXEMPT DE CONCENTRATIONS INFLAMMABLES.

For battery operated product versions, use only the following batteries to ensure continued safe operation of the equipment:

| BATTERY SPECIFICATIONS	
TRANSMITTER	
Manufacturer	Tadiran (or equivalent[1])
Model Number	TL-5920 (or equivalent[1])
Size	C
Chemistry	Lithium Thionyl Chloride
Nominal Voltage	3.6 V
Nominal Capacity	8.5 mAhr
USB/RS-485 Interface	
Manufacturer	Inspired Energy
Model Number	ND2034
Size	Custom
Chemistry	Li ION
Nominal Voltage	1.14 V
Nominal Capacity	

1. Equivalent cell must be of the same type, chemistry, nominal voltage and nominal capacity.

3.5 FIELD WIRING

Field wiring should be performed according to local and national electrical codes. As the smartPIMS system is energy limited, special care should be taken to maintain insulation and clearances between smartPIMS field wiring and other non-energy limited circuits such as Mains supplies for adjacent equipment. For non battery powered installations, the smartPIMS instrument shall only be powered through an appropriately rated and listed DC power supply with energy limited outputs per 3.1.5.

3.6 CONNECTIONS

Instrument connections are accomplished on the interconnect board as shown in the following figure. Sections 3.6.1 through 3.6.5 describe the connections in more detail.
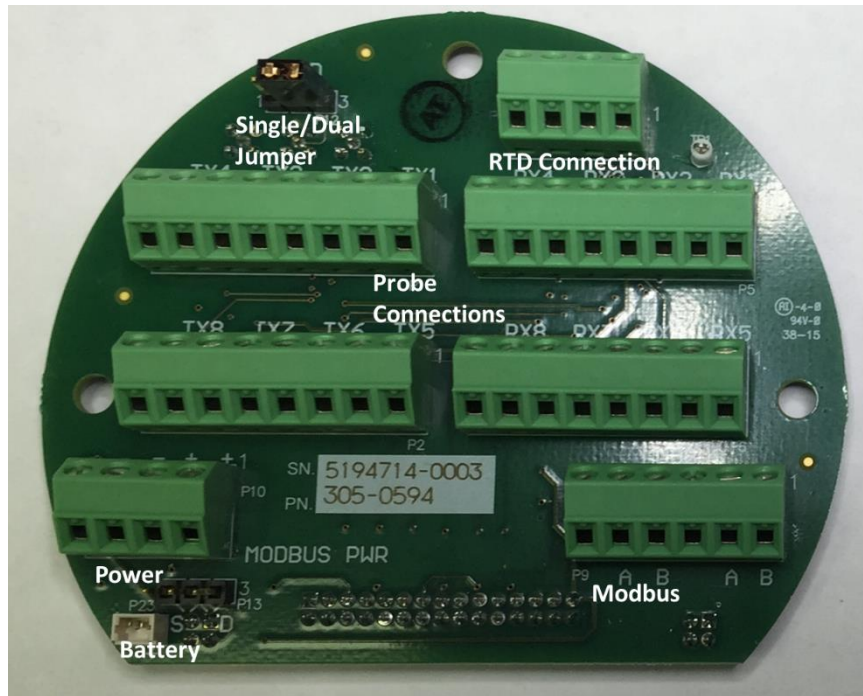

3.6.1 Power In

Power in is provided through the four position terminal block label power. Two positive connection positions "+" and two negative positions "-" are available. Use two positions for power in and two positions for power out when configuring instruments in a multi-drop network.

3.6.2 Probe (1-16)

Probe connections are shown in the following pictures for single element (Qty. 16) and dual element (Qty. 8) connections. Connect the central conductor of the coaxial probe cable to the numbered connection point and the shield to the adjacent connection point marked with the ground symbol.
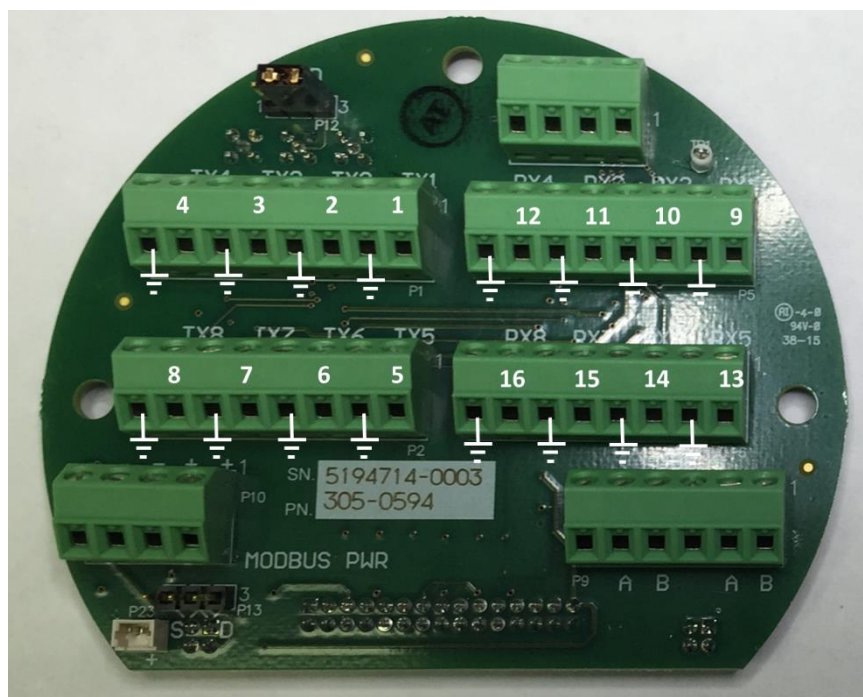
Single element probe connections
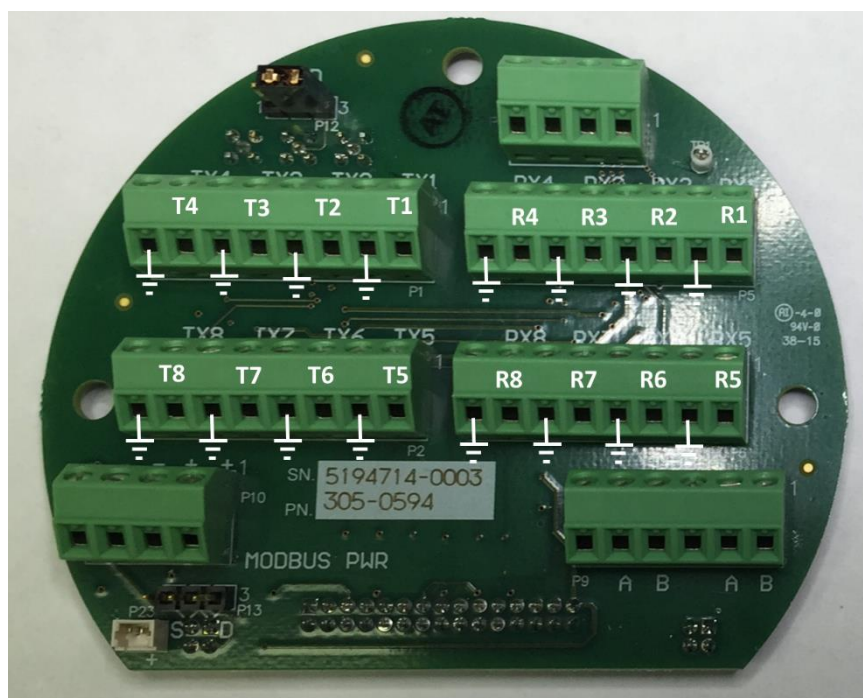
Dual element probe connections

3.6.3 Resistance Temperature Detector (RTD)

Connections for a three wire RTD are available on the four position connector labeled "RTD Connection"

3.6.4 RS-485

Connections for Modbus over RS485 communication are available on the six position connector labeled "ModBus" in the figure. Two connections each are labeled "A" and "B" for the A/B RS-485 connections. The unlabeled connection point is for the drain wire if available. In multi-drop mode, two positions A/B should be used for RS-485 In and two positions A/B should be used for RS-485 out.

Termination resistor: A 100 Ohm termination resistor is factory installed between one set of A/B connector positions. Leave the termination resistor in place if the instrument is singly connected or the last instrument on a multi-drop string. Remove the termination resistor for instruments in the middle of a multi-drop network.

3.6.5 Battery

Battery powered instruments are provided with a battery board. Connection of the battery board is accomplished at the two pin connector labeled "battery" in the figure.

3.7 HARDWARE SETTINGS

The smartPIMS instrument is configured via software settings except for a switch locate on the back side of the UT board to select between wireless and wired operation and a jumper on the front of the interconnect board to select single or dual element probes.

3.7.1 Wireless/Modbus switch

The Wireless/Modbus switch is used to configure the smartPIMS instrument in either wireless or wired configuration. The switch is located on the back side of the UT board. Place the switch in the 1-2 position for wired (Modbus) communication and in the 2-3 position for wireless communications.
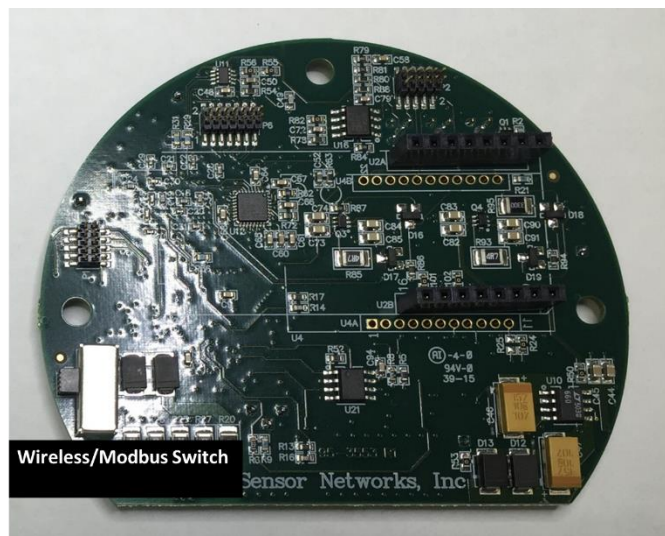
3.7.2 Dual/Single Probe selection jumper

The Dual/Single probe selection jumper is used to configure the smartPIMS instrument for use with either single or dual element probes. The jumper is located on the top of the interconnect board. Place the jumper in single position "S" for single element probes and in dual position "D" for dual element probes.

3.8 SOFTWARE

The smartPIMS system contains two software products:

1. smartPIMS lite – Windows operating system based software for portable data collection and system set-up.
2. webPIMS – Cloud hosted system for data viewing, archiving and analysis.

SmartPIMS lite installation is usually not required as any computing devices supplied with the system will be preloaded with the software. See Chapter 4 for additional instructions.

3.9 PROBE INSTALLATION

This section covers several different aspects of probe installation, including surface preparation, bonding, routing of cables, instrument cable connection, and protective overwrap (optional). These are basic instructions to cover the major concepts. Only factory trained personnel should perform installation.

3.9.1 Surface preparation

Surfaces should be cleaned to bare metal with a 100 grit finish at the point of probe installation. All rust, scale and coatings should be removed. Only local surface preparation (~1.5" diameter) at the point of attachment is necessary. For high temperature transducers, surface should also be filed smooth, maintaining surface flatness.

3.9.2 Bonding (Models XD-101, XD-301)
- Mix bonding epoxy per instructions supplied with kit.
- Apply bonding epoxy to probe face as well as part surface
- Apply transducer to part surface, using magnetic attachment to support probe during epoxy cure.
- Apply secondary mechanical attachment means if applicable
- Proceed to route cables and perform instrument connection, measure signals after bonding, and subsequently after curing.

3.9.3 Clamping (XD-201)
- Apply probe clamp around pipe surface
- Torque strap connection to ft-lbs
- Apply gold foil to probe face using glycerin for temporary adhesion
- Remove probe holder bolts and probe holder

- Apply transducer through the mounting hole in the probe clamp.
- Attach probe holder bolts and torque to 10 ft-lbs.
- Attach A-scan thickness gauge to probe leads and monitor interface echo and back surface signal.
- Further torque probe holder bolts, alternating between the two bolts, until back surface signal is at least 50% as high as the front surface signal.
- Proceed to route cables and perform instrument connection, measure and calibrate the thickness reading.

3.9.4 Cable routing

Special care should be taken to maintain insulation and clearances between probe wiring and other non-energy limited circuits such as Mains supplies for adjacent equipment. Cables should be supported in cable trays and/or attached to support structures with no more than 12" of unsupported cable length. Wire looms or other cable management devices are recommended.

3.9.5 Probe Connections

See 3.6.1, 3.6.2.

4   OPERATING INSTRUCTIONS: SMARTPIMS LITE

The purpose of this chapter is to introduce the smartPIMS Lite PC application. This chapter covers the following information:

- Overview of smartPIMS Lite
- Compatibility
- Logging into the application
- Closing the application

4.1   OVERVIEW:

The smartPIMS Lite application is a data collection and viewing application that is common to Sensor Networks' -PIMS products using wired connectivity. The application is also used as a configuration/commissioning tool for wired and wireless smartPIMS products. The application is offered by Sensor Networks on a Microsoft Windows tablet PC, though it can be run on any computer running Microsoft Windows 8 or Windows 10.

smartPIMS Lite enables users to easily collect and view TML data including ultrasonic waveforms from smartPIMS instruments. It also allows users to easily upload data to smartPIMS Cloud and/or email data directly off of the device. Additionally, the smartPIMS Lite enables administrative users to set up and modify the settings of smartPIMS instruments.
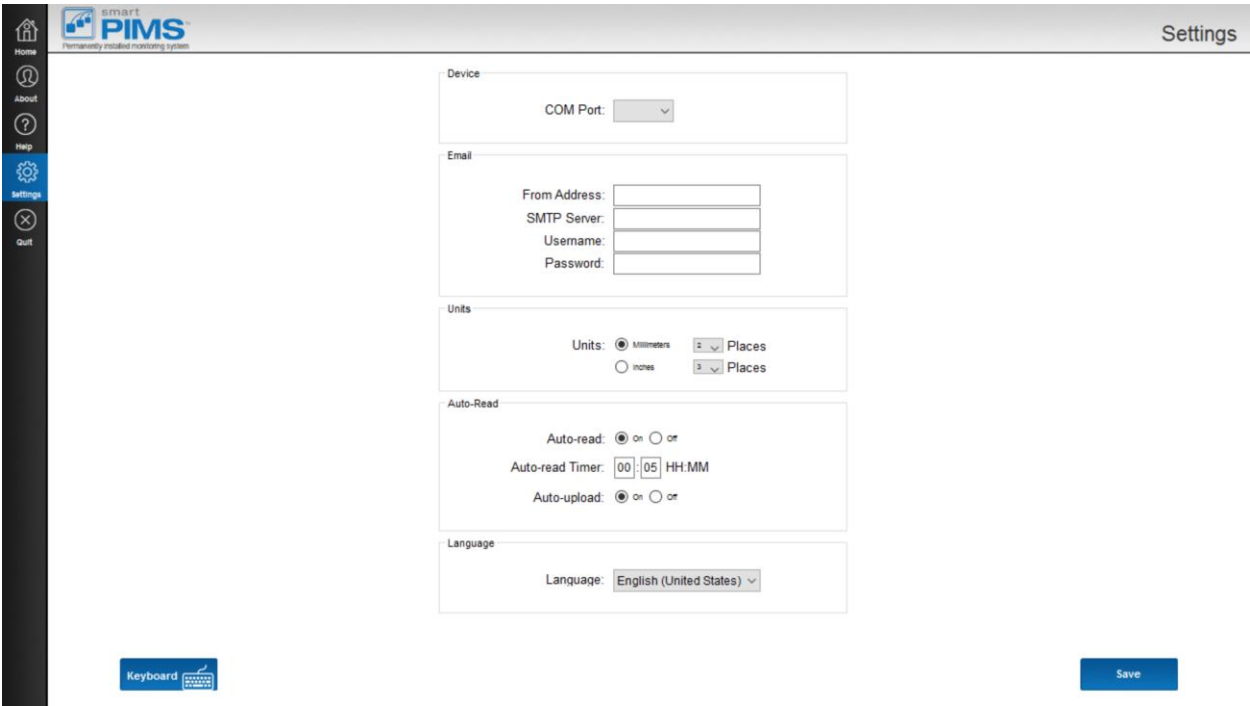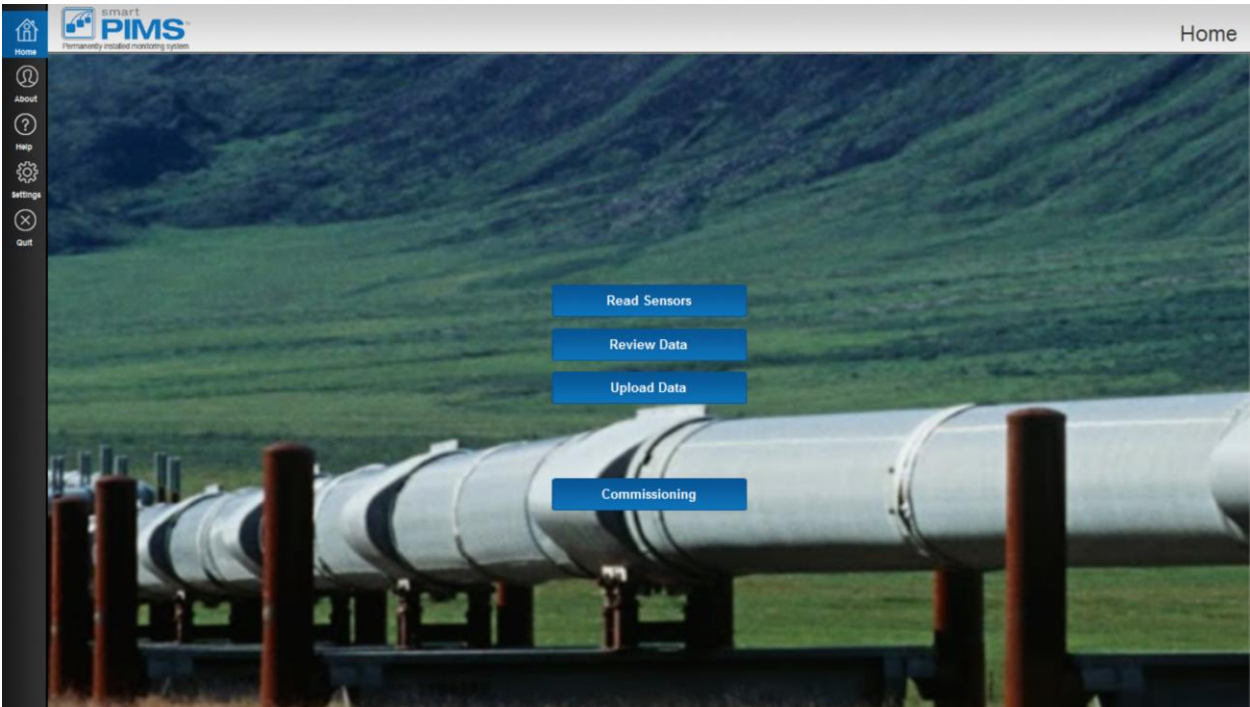
4.2   COMPATIBILITY:

The application is compatible with and has been tested with the following operating systems:

- Microsoft Windows 8
- Microsoft Windows 10

4.3   LOGGING IN TO THE APPLICATION:

- Click the SNI logo on the start menu
- OR double click the SmartPIMS.exe program file in C:\Program Files (X86)\Sensor Networks

5   OPERATING INSTRUCTIONS: SMARTPIMS CLOUD

The purpose of this chapter is to introduce the smartPIMS Cloud web application. This chapter covers the following information:

- Overview of the smartPIMS Cloud
- Compatibility
- Logging into the application
- The home screen
- Basic navigation
- Trend chart view
- Spreadsheet view
- Waveform view
- Reports
- TML Settings
- User Settings
- Logging out

5.1   OVERVIEW:

The smartPIMS Cloud application is a data archiving, viewing, analysis and reporting application that is common to Sensor Networks' -PIMS products. The application runs on Amazon Web Services (AWS) and is accessed through a web browser on an internet connected device, such as a smartphone, tablet, and laptop or desktop computer.

smartPIMs Cloud enables users to easily navigate and view TML data including ultrasonic waveforms. The software also provides a summary view to highlight TMLS that are in an alarm or warning state. Reports are automatically generated and emailed as defined by the user settings. The software also offers post processing of the collected data including short term and long term corrosion rates, predicted maintenance dates, and temperature correction of wall thickness data.

5.2   COMPATIBILITY:

The application is compatible with and has been tested on the following browsers:

- Apple Safari
- Google Chrome
- Microsoft Internet Explorer

While other browsers will generally operate with the smartPIMS application, there may be unexpected visual or formatting errors. For best results please use one of the listed browsers.

5.3 LOGGING IN TO THE APPLICATION:

Logging into the application can be accomplished with the following steps:

1. Open a browser window
2. In the search bar, enter www.smartpims.com, Press enter.
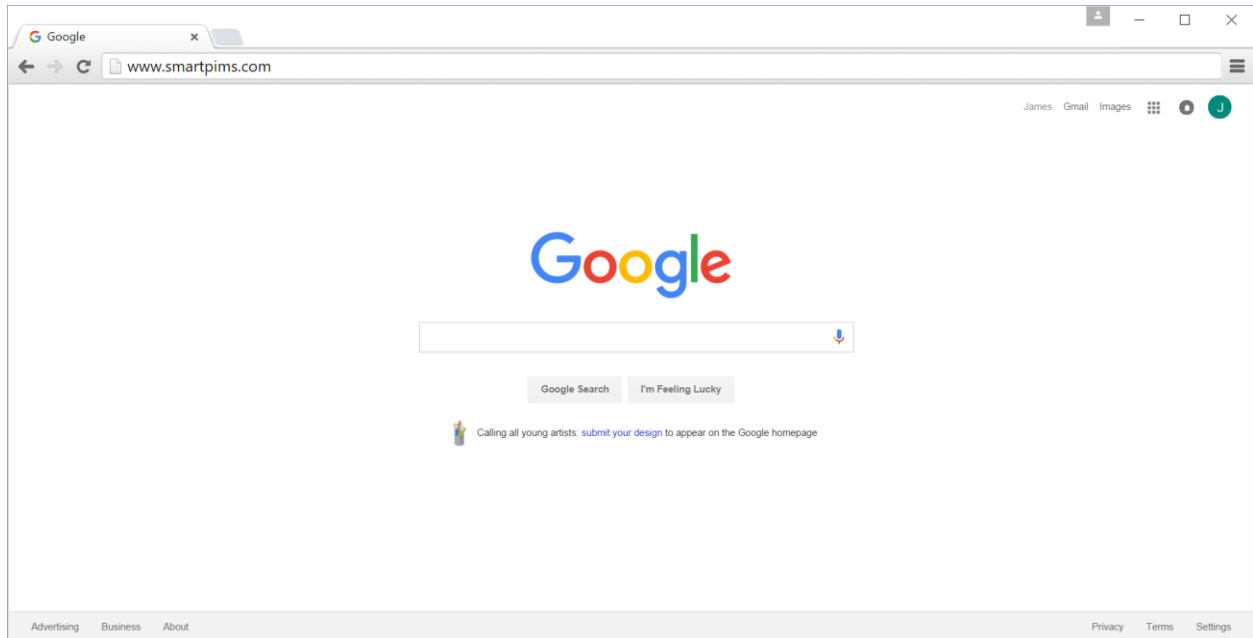
3. Enter your username and password, Click the "Log In" button.
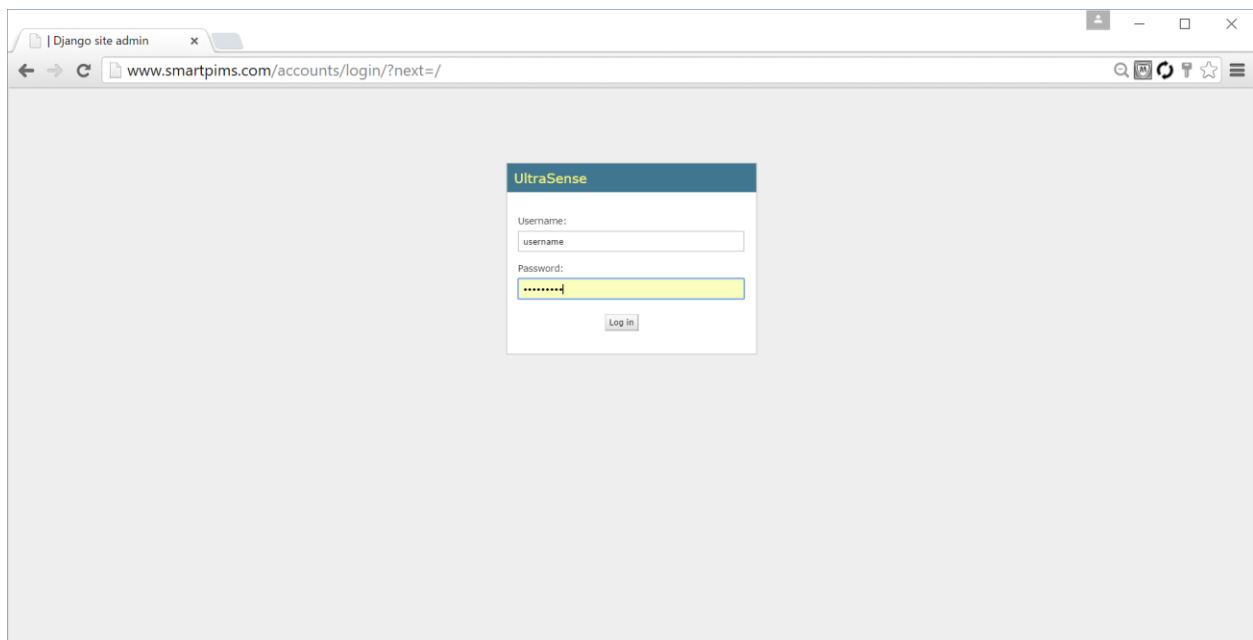
5.4 THE HOME SCREEN

Most users will have a home screen view similar to the following screen capture. This view offers a results summary of the TMLs that are accessible by the user. The summarized results are selectable based upon the user's settings. The home screen is also the starting navigation point.
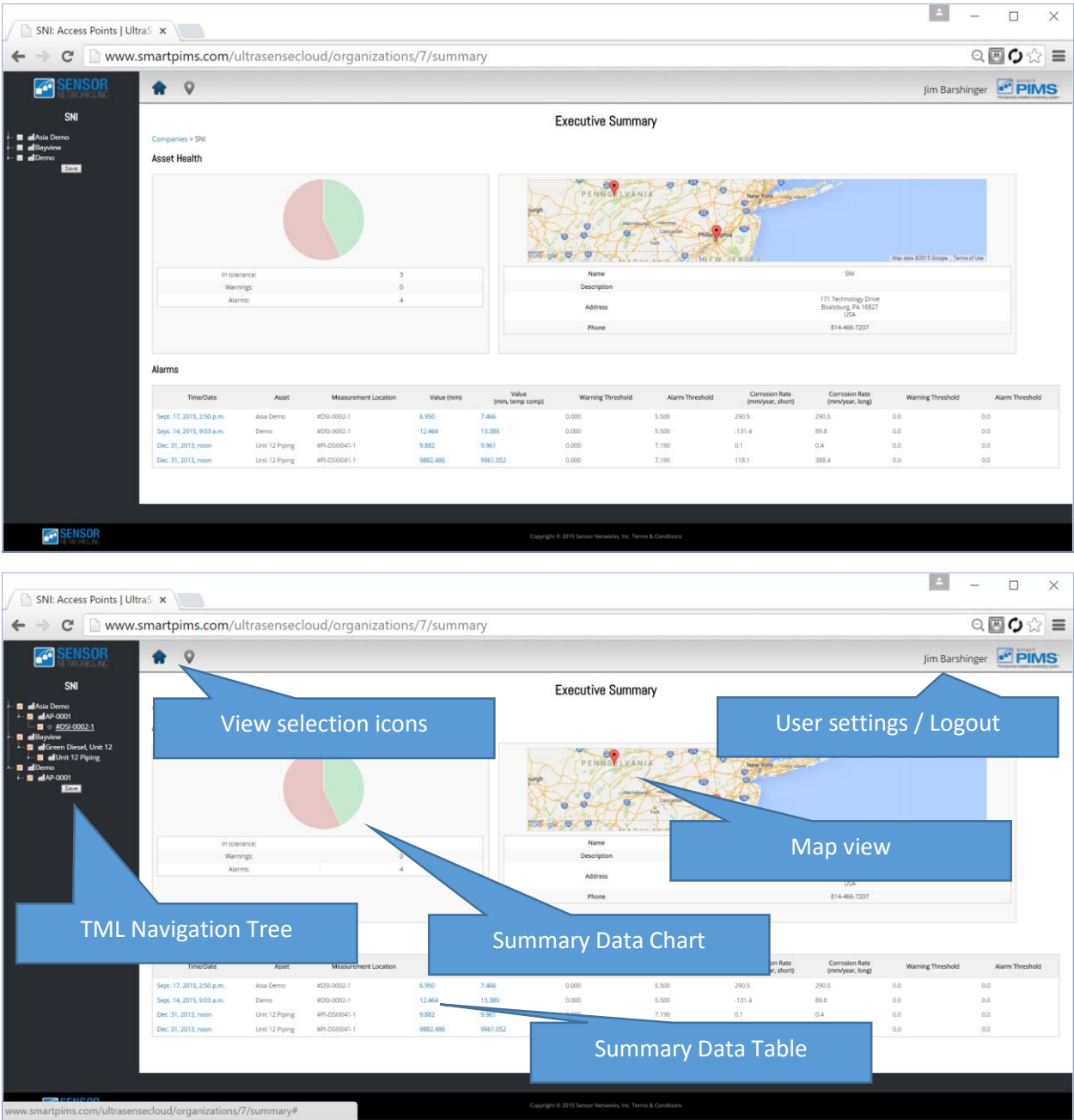
The home screen is divided into several regions as follows:

5.4.1 TML Navigation Tree

The TML navigation tree is at the left side of the screen and serves two purposes. 1) to filter the results summarized in the summary view table and pie chart and 2) to navigate to specific TMLs.

The navigation tree is arranged based on up to five hierarchy levels as defined by the end user at the time of commissioning the PIMS hardware. A typical hierarchy is as follows:

> Company:
>
>> Site:
>>
>>> Plant:
>>>
>>>> Asset:
>>>>
>>>>> TML:

The menu tree can be expanded or collapsed by clicking on the junction points or double clicking on the text description.

Single clicking on the lowest, "TML" level in the tree will navigate away from the home screen view and to the TML trend chart view.

The check boxes in the navigation tree are used to select the points that are summarized in the summary data chart and summary data table. By default, all TMLs are summarized in these views. To select a different set of TMLs, check the boxes of interest and then click the "save" button.

5.4.2 View Selection Icons

The view selection icons on the top menu bar are used to toggle between views that are available for the set of data that is currently active.

There are two views that are available from the home screen as follows:

- Home – the home icon navigates to the summary view of asset health
- Map – the map view navigates to a map view of asset health

When in a TML view, there are additional choices:

- Chart – the chart icon navigates to the trend chart view of the TML. The trend chart view displays a plot of the selected data series as well as an A-scan view.
- Spreadsheet – the spreadsheet icon navigates to a table view of the data series.
- Camera – the camera icon navigates to a page with uploaded photographs of the product installation.
- Information – the information icon navigates to a table of TML and instrument specific information, including status indicators such as battery life.
- Settings – the settings icon navigates to a table of TML specific settings

5.4.3 Summary Data Chart
 The summary data chart graphically shows the number of readings that are in tolerance, subject to a warning, and subject to an alarm.

5.4.4 Summary Data Table
The summary data table shows the most recent measurement data for the selected TMLs. The table can be filtered by the check boxes to display "alarms", "alarms and warnings", and "all". The TML range is controlled by the checked boxes in the TML Navigation Tree. The measurements shown in the table are hyperlinked; the hyperlinks are displayed in blue. Clicking the measurement date navigates to the trendchart view of the TML. Clicking the measurement value navigates to the A-scan view.

5.4.5 Map View
The map view displays the GPS coordinates of the measurement points.

5.4.6 User Settings / Logout
Clicking the user name in the upper write opens a selection box for user settings or to log out of the application.
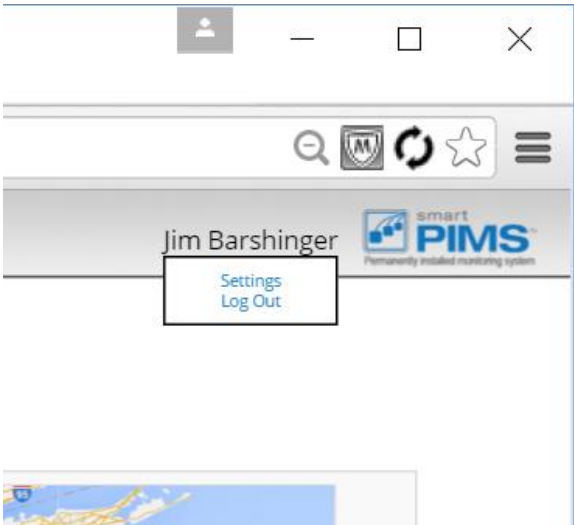
5.5 BASIC NAVIGATION

The smartPIMS cloud navigation is primarily based upon individual TMLs and their descriptive hierarchy. There are five potential layers of description starting with the Company. The level descriptions are then arbitrary but could be as follows: Company>Site>Plant>Asset>TML.

The descriptive hierarchy is organized and displayed as a menu tree along the left side of the screen. The menu tree can be collapsed and expanded to hide or display the levels, ultimately down to the TML level.

Additionally, along the header bar are several view selection icons. These icons toggle between different data views.

5.5.1 TML Navigation Tree

The TML navigation tree is at the left side of the screen and serves two purposes. 1) To filter the results summarized in the summary view table and pie chart and 2) to navigate to specific TMLs.

The navigation tree is arranged based on up to five hierarchy levels as defined by the end user at the time of commissioning the PIMS hardware. A typical hierarchy is as follows:

Company:

Site:

Plant:

Asset:

TML:

The menu tree can be expanded or collapsed by clicking on the junction points or double clicking on the text description.

Single clicking on the lowest, "TML" level in the tree will navigate away from the home screen view and to the TML trend chart view.

The check boxes in the navigation tree are used to select the points that are summarized in the summary data chart and summary data table. By default, all TMLs are summarized in these views. To select a different set of TMLs, check the boxes of interest and then click the "save" button.

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- Chart – the chart icon navigates to the trend chart view of the TML. The trend chart view displays a plot of the selected data series as well as an A-scan view.
- Spreadsheet – the spreadsheet icon navigates to a table view of the data series.
- Camera – the camera icon navigates to a page with uploaded photographs of the product installation.
- Information – the information icon navigates to a table of TML and instrument specific information, including status indicators such as battery life.
- Settings – the settings icon navigates to a table of TML specific settings

5.6 TREND CHART VIEW
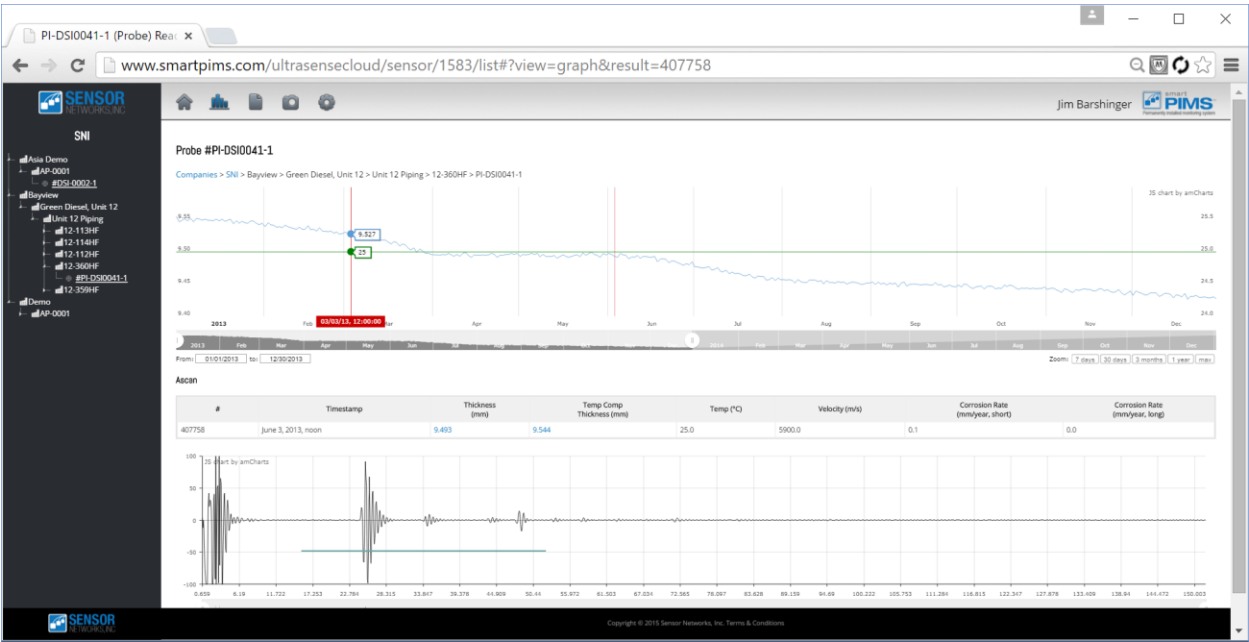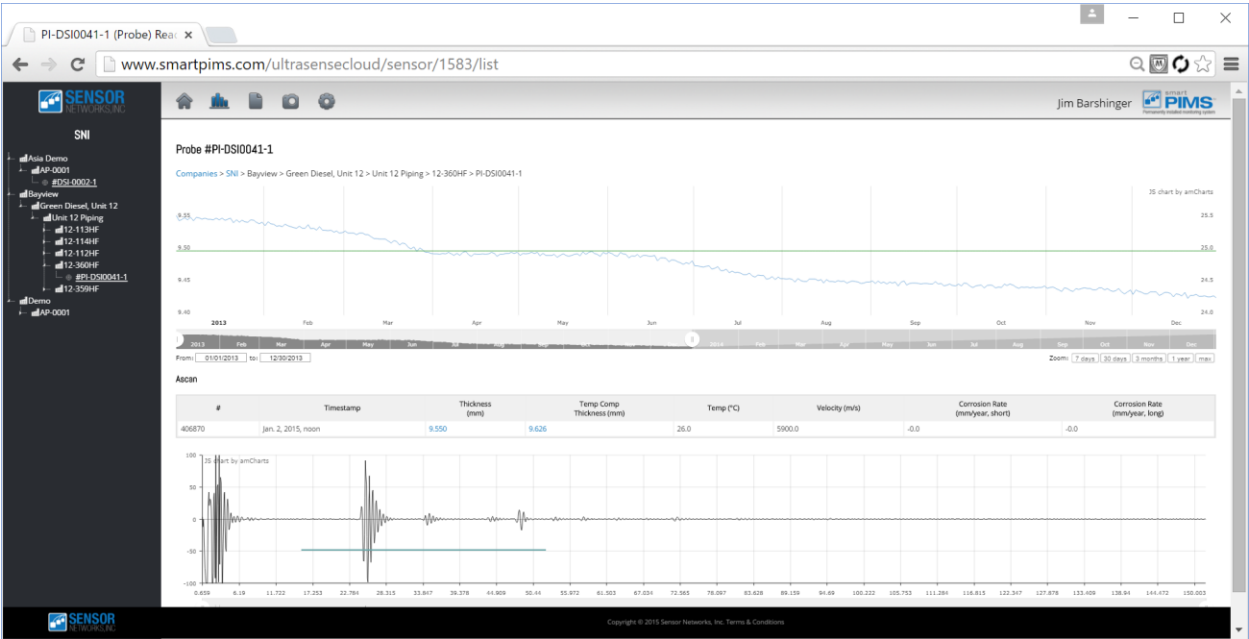
5.7 SPREADSHEET VIEW
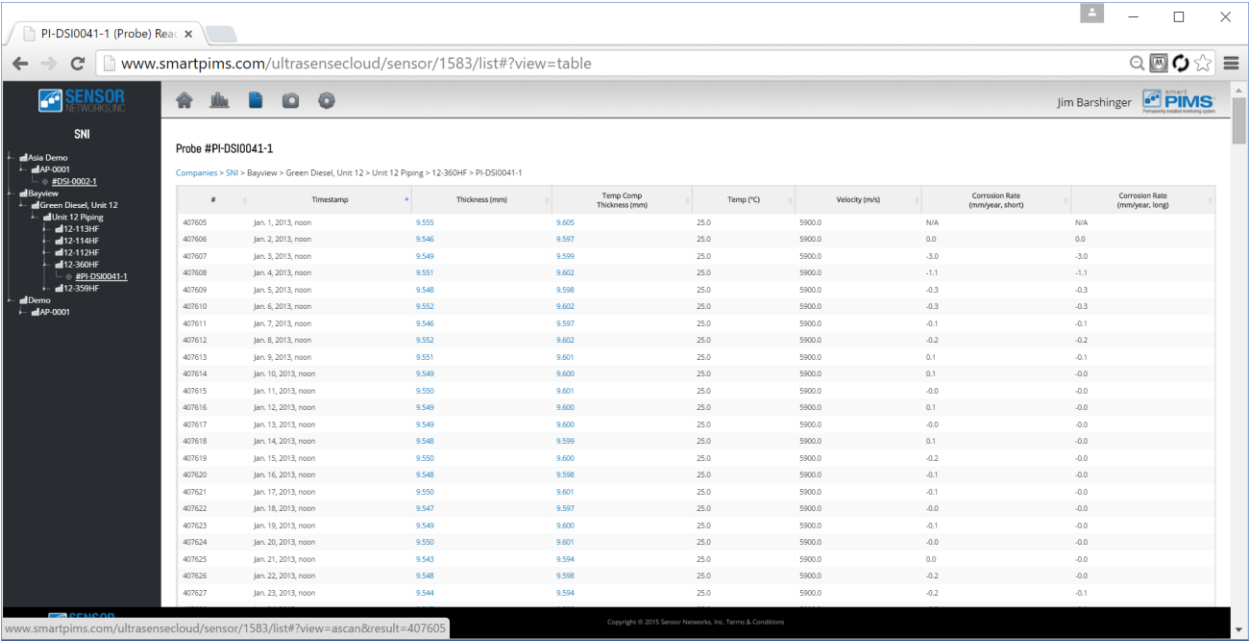
5.8 WAVEFORM VIEW
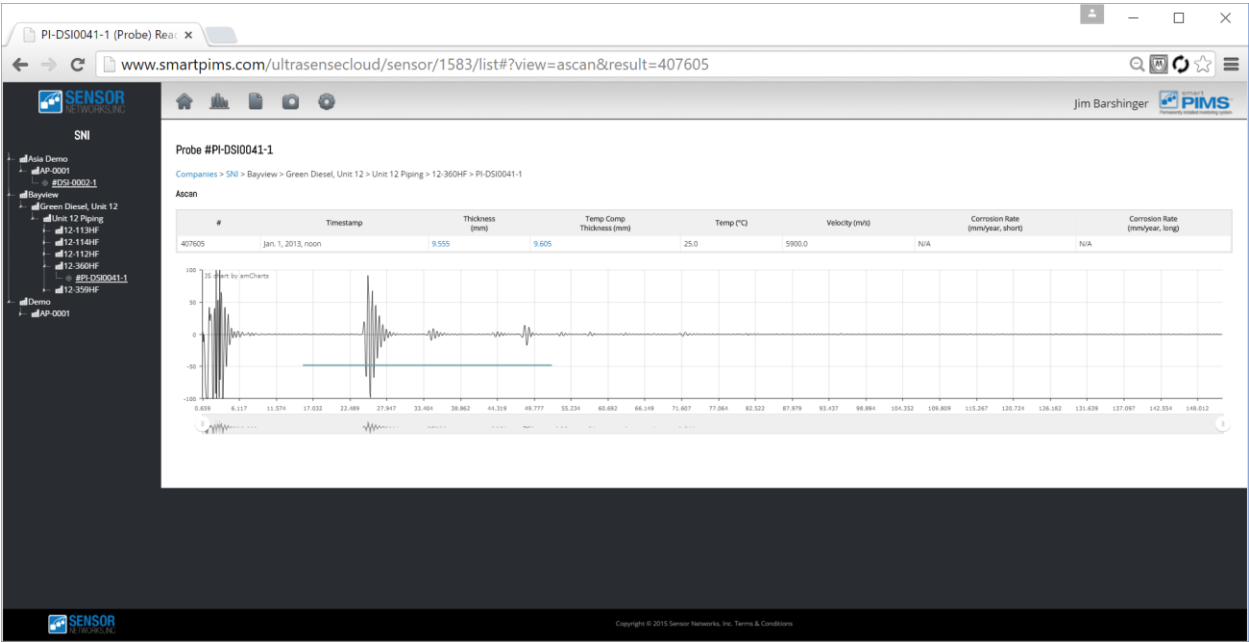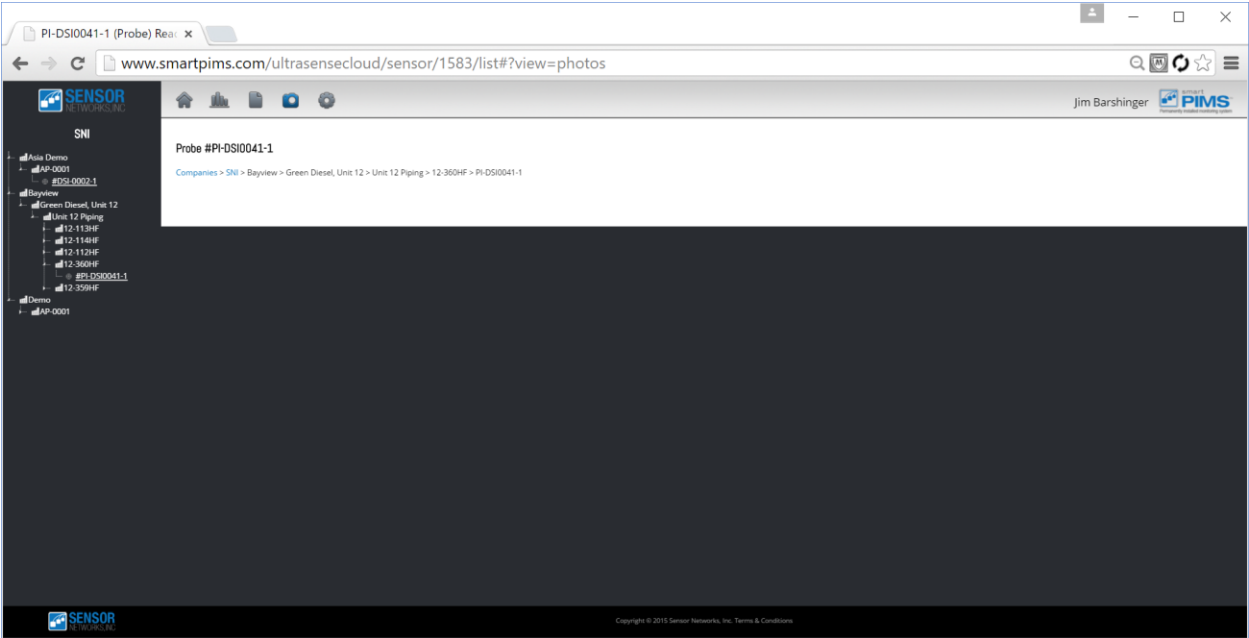
5.9 REPORTS

5.10 TML SETTINGS

5.11 USER SETTINGS / LOGGING OUT
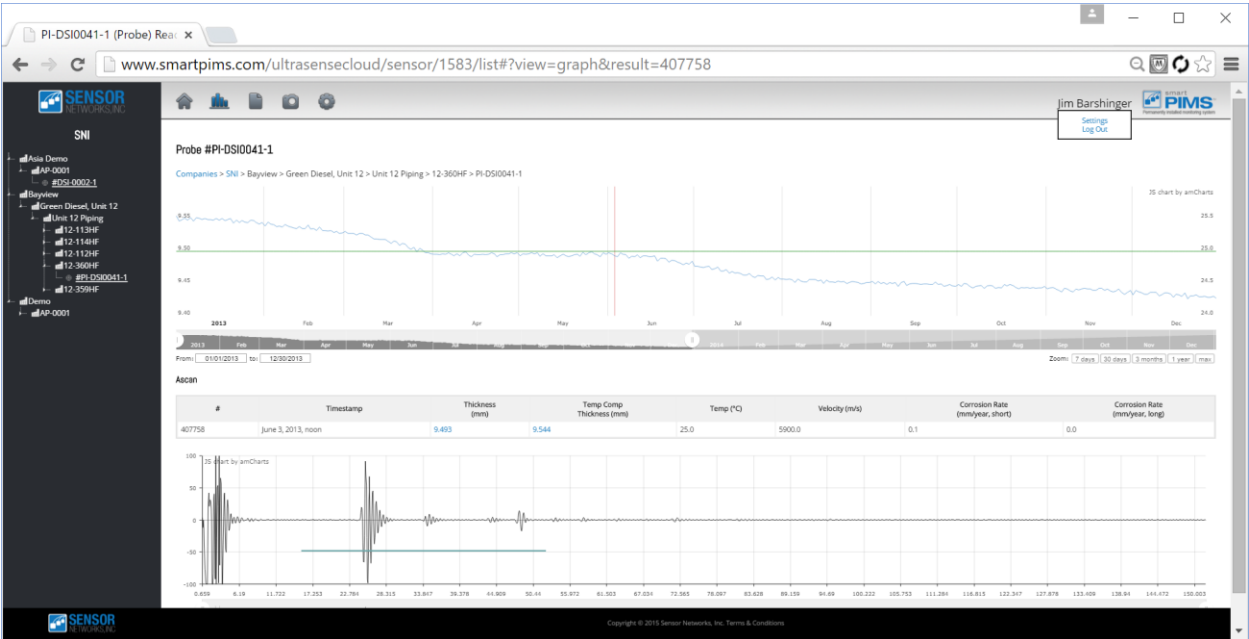
6 ADVANCED MEASUREMENT FEATURES

6.1 TEMPERATURE COMPENSATION

The smartPIMS system offers an optional temperature measurement device that can be used in concert with the implementation of an automated temperature correction algorithm in the smartPIMS Web based software.

Temperature correction is optional and is a user setting in the back end software. Factors to consider include the ambient conditions of the test, the calibration procedure (whether the calibration block is of similar temperature as the object under test) and the desired accuracy and precision required for the test. For most inspections occurring at ambient temperature or slightly elevated temperatures, correction for temperature is usually not considered, but may still be necessary if the desire is to measure thickness very precisely and calculate accurate corrosion rates. An estimate of the error introduced into the reading without temperature correction is 1% per 100°F (55°C) for steels.

Certain codes and standards, such as ASTM E790 and API 570 recognize the effect of temperature on ultrasonic readings and require or recommend a correction of the reading for temperature. For reference, at the time of writing this manual, ASTM E797 recommends temperature correction of readings by -1% per 100°F (55°C) above 200°F (93°C) and below 1000 °F (540°C). API 530 recommends that corrective procedures should be applied above 150°F (65°C), including the use of heated calibration blocks or applying an appropriate temperature correction factor.

6.1.1 Implementation

The direct measurement made in smartPIMS system is time, not material thickness. Rather, material thickness is a measurement derived from the measured round-trip travel time of the ultrasonic wave in the object and the ultrasonic velocity of the material. As temperature is increased or decreased in the part under test, the ultrasonic velocity changes due to changes of the mechanical properties of the material. This velocity change introduces a corresponding change in the measured time of flight and therefore introduces a measurement error if the velocity is not corrected in the thickness calculation. While extensive material velocity data exists in public literature, there are relatively few references characterizing acoustic velocity as a function of temperature. Some reference values that are available are shown in Table 2.

As seen in the table, the ultrasonic velocity decreases with an increase in temperature at a rate of approximately -1% per 100°F (55°C). Consequently, as temperature rises, a thickness gauge will measure an increase in time-of-flight and a corresponding measurement increase if the ultrasonic velocity is not temperature corrected. For example, if a calibration is performed on a room-temperature calibration block at 70°F (21°C) and then subsequently a measurement is

performed on the same block at 970°F (521˚ C)without adjusting the velocity, the thickness will be overestimated by approximately 9% due to the shift in material velocity.

Application of a correction factor is achieved in the software through implementation of Equations 2 and 3, where the correction factor, k is in units of % per °F or °C depending on whether the user setting is in imperial or metric units.

$$d_1 = \frac{1}{2} C_1 \Delta t \qquad\qquad\qquad (2)$$

$$C_1 = C_0(1 + k(T_1 - T_0)/100) \qquad (3)$$

d_1 – temperature corrected thickness
C_1 – temperature corrected velocity
C_0 – reference or calibration velocity
Δt – measured, round-trip time of flight
T_1 – measurement temperature
T_0 – reference or calibration temperature
k – correction factor in % per °F or °C

6.2 CORROSION RATE MEASUREMENTS

Linear regression is a powerful tool for converting measured wall thickness values to corrosion/erosion rate measurements and is the main tool used to calculate corrosion rates with installed sensor data. The term linear regression refers to the process of modeling the relationship between a dependent variable (Y) to one or more explanatory variables (X). The situation where only a single explanatory variable is considered is called simple linear regression.

As we are considering "linear" regression, the explanatory function is that of a straight line where m is the slope and b is the intercept (the Y value when X=0), Equation 5.

$$Y = mX + b \qquad\qquad (5)$$

The parameters m and b are chosen to provide a "best" fit of the line to the experimental data. The scheme used to fit the parameters can vary, though a common method is to minimize the sum of squared errors (the error between the predicted values and the experimental data). This is referred to as least squares regression and is an appropriate method for curve fitting to corrosion/erosion data.

For corrosion/erosion monitoring, the thickness value is assigned to the dependent variable and time is assigned to the independent variable X, thus, the value of slope, m, yields the corrosion rate. Optionally, temperature can be assigned to a second independent variable if a temperature measurement is available for each measured thickness value. In this way, one can statistically explain the effect of temperature on the thickness measurement and thus remove its effect. In order to calculate accurate corrosion rates, it is important to remove the temperature effect by either removing it from the data prior to regression (for instance by using equations 2 and 3) or by removing it by using a second regression variable.
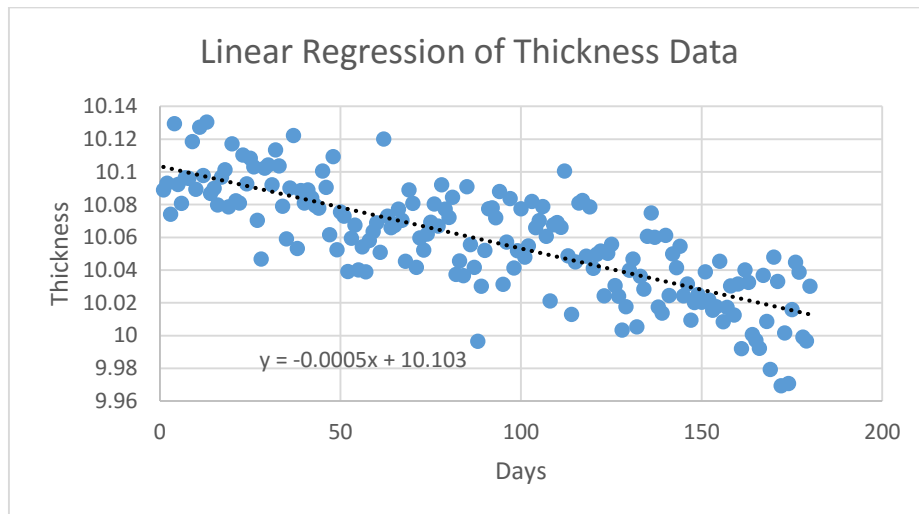
Figure 7. Linear regression of 1X/day thickness measurements

An example of using linear regression to model corrosion rate is shown in Figure 7. In this example, a 0.0005 mm/day (7 MPY) corrosion rate is evident and is accurately predicted using linear regression. The regression process has the ability to predict a corrosion rate very precisely as the process tends to "average" out the measurement noise. In this manner, the precision of the corrosion rate measurement can far exceed that of the base measurement system.

As mentioned, the corrosion rate is often not uniform over an observed timescale so the use of a linear fit can be questionable if the time frame captured is too long. Linear regression can only accurately model a single corrosion rate, thus if the period of data used in the calculation contains more than one corrosion rate, the accuracy and validity of regression is degraded. The use of a goodness-of-fit estimator such as the R-squared value can be used as an indicator that the underlying physical situation is not resulting in a linear change of thickness over time.

It is usually most convenient to think of corrosion rate as two parameters, one "Short" term and one "Long" term. The time frame short and long can only be defined by observing the physical situation presented by the combination of materials and process variables but as a rule of thumb, short term might be defined by measurements collected over several weeks while long term might be defined as measurements taken over a year. The long term rate must be used with care as a linear fit is likely only a poor approximation to the actual corrosion/ erosion process such as the presence of multiple corrosion/erosion rates and episodic events with very high corrosion rates such as shown in figure 6. In that example, a long-term rate would overestimate the "typical" corrosion/erosion rate, yet using this value to predict long-term maintenance could be disastrous if an episodic event were to recur and reduce the wall thickness below a critical threshold.

6.3 PRECISION OF CORROSION-RATE MEASUREMENTS

With certain assumptions, the uncertainty of the slope and intercept coefficients can also be calculated. Figure 8a shows an example calculation for a measurement system with 1 mil standard deviation and measurement intervals from 4X per day to 1X per week. This result makes it clear that the accuracy of corrosion rates calculated from linear regression can be improved by making more frequent measurements over a long time interval, even for a measurement system with modest precision (1 mil (0.001" or 0.025 mm) standard deviation).

While even infrequent measurements such as 1X per week can result in accurate corrosion rate calculations, it is necessary to perform the calculation over a much longer time frame. This is undesirable from a process-feedback perspective and also opens the possibility that the corrosion rate is not uniform over the time period and thus invalidates the use of linear regression to accurately calculate corrosion rate.

Figure 8b shows the same calculation of corrosion rate measurement precision, but for a 10X more precise measurement system: 0.1 mil (0.0001" or 0.0025 mm) standard deviation. Clearly, this results in a drastic improvement in the ability to monitor corrosion rate accurately and quickly. Thus, even though linear regression has the ability to measure accurate corrosion rates by removing measurement noise, the development and use of higher precision corrosion/erosion monitoring systems is very important as well.
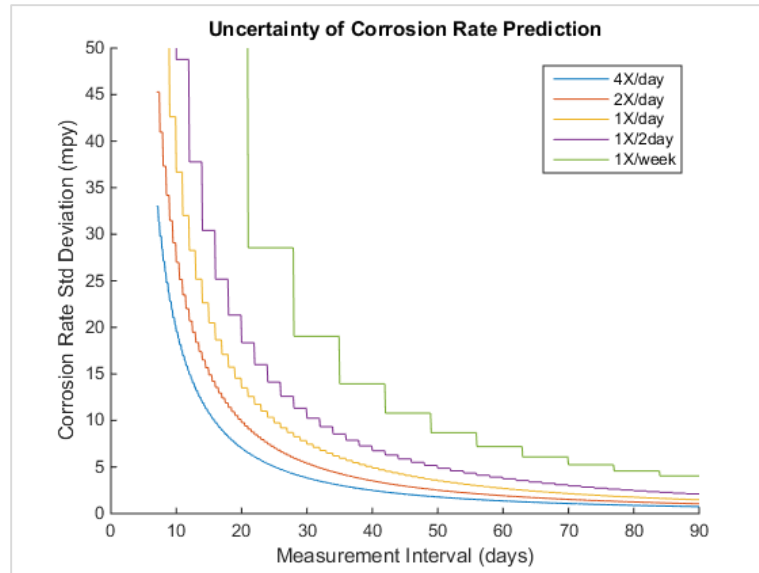
(a)
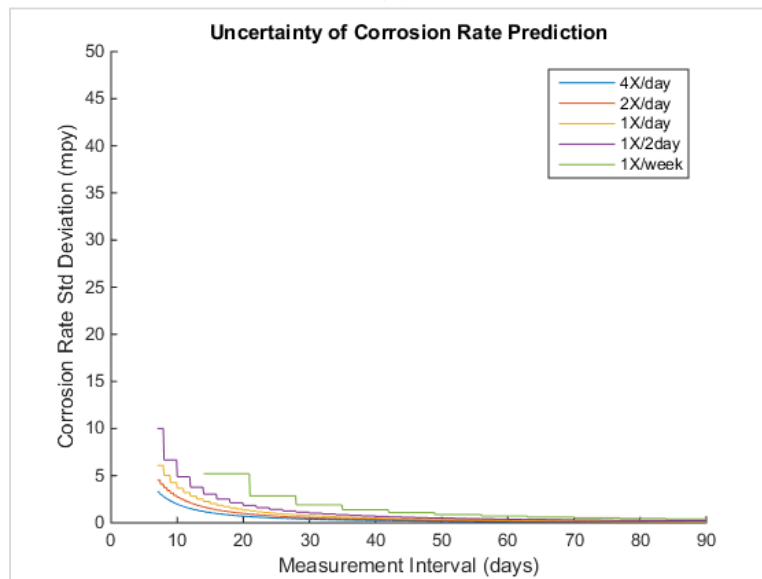
(b)

Figure 8. Uncertainty of corrosion rate from linear regression for a measurement system with (a) 1.0 mil (0.025 mm) standard deviation, and (b) 0.1 mil (0.0025 mm) standard deviation.

7 MAINTENANCE

This chapter includes the basic information and procedures for the safe maintenance of the smartPIMS product. Maintenance should only be performed by trained and authorized personnel.

Specific topics include:

- Warnings and hazards
- Preventative maintenance and inspection
- List of serviceable components
- Basic service procedures

7.1 WARNINGS, HAZARDS, CONDITIONS FOR SAFE USE

The smartPIMS instrument consists of low voltage electrical equipment that is rated for hazardous area locations. Maintenance on the equipment can produce the following hazardous conditions:

- Electrical shock
- Arcs and sparks

Do not perform installation, maintain/service equipment and/or replace batteries when flammable atmosphere and/or ignitable concentrations are present. Remove power to the equipment prior to performing service and maintenance.

The following conditions for safe use are associated with the use and maintenance of smartPIMS in hazardous locations.

WARNING – EXPLOSION HAZARD – DO NOT DISCONNECT WHILE CIRCUIT IS LIVE OR UNLESS THE AREA IS FREE OF IGNITABLE CONCENTRATIONS.

AVERTISSEMENT – RISQUE D'EXPLOSION – NE PAS DÉBRANCHER PENDANT QUE LE CIRCUIT EST SOUS TENSION OU À MOINS QUE L'EMPLACEMENT NE SOIT EXEMPT DE CONCENTRATIONS INFLAMMABLES.

WARNING – EXPLOSION HAZARD – BATTERIES MUST ONLY BE CHANGED IN AN AREA FREE OF IGNITABLE CONCENTRATIONS

AVERTISSEMENT – RISQUE D'EXPLOSION – LES BATTERIES NE DOIVENT ÊTRE REMLACÉES QUE DANS UN EMPLACEMENT EXEMPT DE CONCENTRATIONS INFLAMMABLES.

7.2 PREVENTATIVE MAINTENANCE / INSPECTION

smartPIMS contains no wear items that must be serviced or replaced on any schedule. The following inspections are recommended whenever a technician is performing service on the equipment.

- Inspect equipment wiring for any chaffed or missing insulation and replace components if necessary.
- Inspect equipment housing for damage that would cause loss of environmental protection. Replace if necessary.

- If instrument enclosure is opened, inspect circuit boards for damage and verify that instrument connections are tight. Replace damaged circuit boards and tighten any loose connections.

7.3 LIST OF SERVICEABLE COMPONENTS

The following table lists the field serviceable components. No parts are field repairable; corrective action consists of replacement at the major component level.

SERVICEABLE COMPONENTS	
COMPONENT	**SERVICE TYPE / ACTION**
Batteries	Replacement
Enclosure	Replacement
Transmitter Board Stack	Replacement
Transducers / Probes	Replace/Re-install
Temperature Detector	Replace/Re-install

7.4 REPAIR PROCEDURES

7.4.1 Battery replacement

WARNING – EXPLOSION HAZARD – BATTERIES MUST ONLY BE CHANGED IN AN AREA FREE OF IGNITABLE CONCENTRATIONS

AVERTISSEMENT – RISQUE D'EXPLOSION – LES BATTERIES NE DOIVENT ÊTRE REMLACÉES QUE DANS UN EMPLACEMENT EXEMPT DE CONCENTRATIONS INFLAMMABLES.

For battery operated product versions, use only the following batteries to ensure continued safe operation of the equipment:

BATTERY SPECIFICATIONS	
TRANSMITTER	
Manufacturer	Tadiran (or equivalent[1])
Model Number	TL-5920 (or equivalent[1])
Size	C
Chemistry	Lithium Thionyl Chloride
Nominal Voltage	3.6 V
Nominal Capacity	8.5 mAhr
USB/RS-485 Interface	
Manufacturer	Inspired Energy
Model Number	ND2034
Size	Custom
Chemistry	Li ION
Nominal Voltage	1.14 V
Nominal Capacity	

1. Equivalent cell must be of the same type, chemistry, nominal voltage and nominal capacity.

7.4.2 Enclosure replacement

1. Disconnect power by removing battery or de-energizing the power supply feeding the instrument.
2. Remove enclosure lid
3. Disconnect all connections from circuit board.
4. Remove circuit board assembly
5. Remove cables and glands from enclosure
6. Dismount enclosure
7. Mount new enclosure
8. Install cables and glands into new enclosure
9. Install circuit board stack
10. Reconnect all connections per installation procedure.
11. Replace enclosure lid
12. Power and test the device.

7.4.3 Board stack replacement

1. Disconnect power by removing battery or de-energizing the power supply feeding the instrument.
2. Remove enclosure lid
3. Disconnect all connections from circuit board.
4. Remove circuit board assembly
5. Install circuit board stack
6. Reconnect all connections per installation procedure.
7. Replace enclosure lid
8. Power and test the device.

7.4.4 Probe/temperature measurement device replacement

1. Disconnect power by removing battery or de-energizing the power supply feeding the instrument.
2. Remove enclosure lid
3. Disconnect probe / temperature measurement device(s).
4. Loosen cable glands to remove probe cable
5. Install new probe cable through gland
6. Retighten gland
7. Reconnect probe connections per installation procedure.
8. Replace enclosure lid
9. Power and test the device

APPENDIX

ULTRASONIC MATERIAL PROPERTIES

Temperature correction factors for ultrasonic velocity in steels

Material	Correction Factor	Source
Steel (Typical)	-0.0001 per °F (-0.00018 per °C) (-1.0% per 100°F (55°C))	Olympus[1,2]
Steel (Typical)	-1.0 m/s per °C (-0.95% per 100°F (55°C))	SNI rule of thumb
Carbon Steel (Typical)	No Correction T<200°F (93°C)	ASTM E797
Carbon Steel (Typical)	-1.0% per 100°F (55°C) 200°F (93°C) < T < 1000°F (540°C)	ASTM E797
Plain Carbon Steel, AISI 1345	-0.7% per 100°F (55°C)	Marathon Oil Company[3]
Low-Alloy Steels AISI 4130 & 4340	-0.6% per 100°F (55°C)	Marathon Oil Company[3]
316 Stainless Steel	-0.9% per 100°F (55°C)	Marathon Oil Company[3]

[1] Source: Olympus 38DL+ manual

[2] Value is stated as change per degree F, multiply by 1000 to convert to percent per 100°F

[3] Biagiotti, S. (1997) 'Effect of Temperature on Ultrasonic Velocity in Steel' NACE Corrosion 97, Paper number 259, NACE International, Houston, TX.

SENSOR NETWORKS TERMS & CONDITIONS

SENSOR NETWORKS CORPORATION
("Seller")

SALES TERMS AND CONDITIONS

These Sales Terms and Conditions ("Terms") govern all sales of products by Seller ("the Products") to Buyer regardless of whether Buyer purchases the Products through the medium of written purchase orders or electronic orders (collectively, "Purchase Orders"). Seller may decline any Purchase Order for any reason. Seller's acceptance of Buyer's Purchase Order is limited to these Sales Terms without any modification, or exception. Additional terms and conditions on any Buyer document will have no effect. Upon receipt by Buyer of an express acceptance by Seller or upon commencement of performance by Seller, these Terms, the face of the Purchase Order, as modified by Seller's acceptance or order acknowledgment, become a binding contract between Buyer and Seller on the terms reflected in those documents (the "Sales Agreement"). In the event of a conflict between these Terms and the Purchase Order, these Terms prevail except where Seller has expressly agreed to the conflicting term(s) in the Purchase Order in Seller's written acceptance or order acknowledgment. In the event of a conflict between the Purchase Order and Seller's written acceptance or order acknowledgment, Seller's written acceptance or order acknowledgment prevails. In all cases, any and all terms and conditions as may be contained on the reverse side of any request for quotations, request for bids, purchase orders and similar documents issued by Buyer are hereby expressly rejected in their entirety and shall have no force or effect. Seller is not responsible for typographical or clerical errors made in any quotations, orders or publications. All such errors are subject to correction.

1. Specifications: The specifications applicable to the Products will be Seller's standard Specifications for such Products or, in the case of items other than Seller's standard Products, such specifications as are agreed to in writing signed by both Seller and Buyer. All Product designs are the exclusive property of Seller.

2. Changes: Seller reserves the right to make process and design changes in the Products which do not affect form, fit or function without the prior approval of or notification to Buyer. Buyer may request changes in the process or design of the Products only if Buyer agrees to accept such changes in delivery times or prices which are, in Seller's judgment, reasonably necessitated thereby. Should Buyer request changes which are, in Seller's judgment, beyond the ability of Seller to produce or deliver within the schedule, or for the price proposed by Buyer, Seller shall have the right, in its sole discretion to reject or cancel Buyer's order, and, if production on the order has commenced or expenses have been incurred or commitments made as a consequence thereof, Buyer shall pay all reasonable charges based on Seller's costs and commitments.

3. Shipment: The method of packing and shipment of the Products sold hereunder shall be at the discretion of the Seller unless otherwise agreed to by Buyer and Seller.

4. Delivery: The delivery schedule appearing on the face side of Seller's quotation or order acknowledgment is approximate only. Seller will make reasonable efforts to deliver in accordance therewith, but shall have no liability for failure to do so. Pro rata payments will be due from Buyer as deliveries are made by Seller. If a delivery is delayed as a result of any action or inaction of Buyer, Seller may invoice Buyer for the Products as of the scheduled delivery date and may charge Buyer for warehousing and other expenses incurred because of the delay.

5. Excusable Delay: Seller shall not be liable for delays or defaults in delivery due to the acts of God or public enemies, war or military activity, riots, insurrection or sabotage, fires, floods, explosions or other catastrophes, unusually severe weather, accidents, epidemics or quarantine restrictions, acts of local, state or national governments, or public agencies, labor disputes or shortages, energy or material shortages, utility or communication failures or delays, threats or acts of terrorism, delays of a supplier of Seller, or causes beyond the reasonable control and without the fault or negligence of Seller. In the event of any such delay, the date of delivery shall be deferred for a period equal to the time lost by reason of the delay.

6. Price: Quoted prices are subject to change without notice and, unless specifically included in a quote or invoice, do not include any taxes, handling, shipping, transportation, duties or other charges or fees. Buyer is responsible for all applicable fees and all federal, state, municipal, and other government taxes on the sale and delivery of Products. All costs of shipping the Products to Buyer, including without limitation, freight, insurance (for either Buyer's or Seller's benefit) and special packing or

handling, shall be in addition to the stated prices and shall be paid by Buyer. Exemption certificates, valid in the place of delivery, must be presented to Seller prior to shipment if they are to be honored. Payment of all sums invoiced to Buyer shall be in U.S. currency. Seller shall be entitled to interest on all unpaid sums from the due date until paid at the rate of 1 1/2% per month or the maximum rate permitted by law, whichever is lower.

7. Risk of Loss: (a) Ownership, right to possession, legal title and risk of loss or damage to the Products shall pass to the Buyer upon Seller's tendering of possession of the Products to the first common carrier at Seller's facility or to the Buyer's designated freight forwarder at Seller's facility. These terms of ownership, right to possession, title and risk of loss or damage shall apply regardless of how the Products are shipped, for whom they are designed, the time or method of payment, and the commercial abbreviations or other terminology used to describe the sale. (b) Buyer shall, upon request, take all actions and provide all certificates, undertakings or other documents requested to enable Seller to export the Products from the country of manufacture, as applicable. When the Products arrive at a foreign point of entry, Buyer shall take all actions and pay all duties, taxes or other costs necessary to import them.

8. Warranty: Seller warrants that the Products sold to Buyer hereunder will be free from defects in material and workmanship furnished by Seller and will conform, within normal commercial tolerances, to applicable specifications. This warranty shall apply only where Buyer has given Seller written notice of such defect or nonconformity within ninety (365) days after delivery of the Products by Seller. This warranty does not extend to any Product which has been subjected to abuse, misuse, neglect or accident, or to any Product which has been repaired or altered by other than Seller. THE FOREGOING WARRANTY IS BUYER'S SOLE AND EXCLUSIVE REMEDY AND IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING, WITHOUT LIMITATION, MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, DESCRIPTION, QUALITY, PRODUCTIVENESS, OR OTHERWISE.

9. Returns: Written authorization must be obtained from Seller prior to the return of any Products. Upon Seller's verification of defect, Seller retains the option to repair, replace or issue credit, at Seller's option, for the defective Product. Seller shall have the right, prior to return, to inspect at Buyer's plant, any Products claimed to be defective or nonconforming. Risk of loss or damage to any Products returned to Seller for adjustment shall remain with Buyer until they are received by Seller. Shipping charges for returned Products will be paid by Seller only for Products repaired or replaced pursuant to warranty. Otherwise, such charge will be Buyer's responsibility.

10. Experimental Products: If Seller delivers Products identified as "prototypes", "samples", "for engineering approval", "for evaluation", or terms of similar import, Buyer agrees that such Products are confidential and experimental in nature, that Buyer will limit the availability of such only to those of its employees as are necessary to carry out the testing and evaluation contemplated by the parties and to no others without the prior written consent of Seller, and that all information concerning such Products received or generated by Buyer shall be, and remain the proprietary property of Seller and shall not be disclosed to any third party without the prior written consent of Seller. Buyer's receipt, use and evaluation of such Products shall be at Buyer's sole risk. It is anticipated that changes may be made in the manufacture of such Products based on such tests and, therefore, Buyer shall communicate to Seller the data accumulated during its testing and evaluation of the Products. Any and all such changes shall be the proprietary property of Seller. Buyer shall return all such Products covered under this paragraph 12 to Seller within (10) days following its receipt of Seller's request.

11. Tooling: Unless the Buyer pays the full costs of special tooling and other equipment necessary to manufacture the Products as a separate charge, such tools and equipment shall remain the property of Seller. Seller may charge Buyer for the cost of maintenance and rework of such tools and equipment owned and provided by Buyer. Notwithstanding the foregoing, however, Seller shall retain all rights in and to any and all intellectual property that may be contained or embodied in the Tooling irrespective of whether or not Buyer has paid full cost of any such tooling.

12. Relationship: Buyer and Seller are independent contractors. Nothing stated in these Terms will be construed as creating the relationship of employer/employee, franchisor/franchisee, partners or principal/agent between the parties. Neither party will make any warranty, guarantee or representation, whether written or oral, on the other party's behalf.

13. Infringement: Buyer shall indemnify, defend and hold harmless Seller, its officers, agents and employees against any expense, loss attorneys' fees, costs, damage or liability arising out of all claims or actions for infringement of patents or copyrights, misappropriation of trade secrets or wrongful use of designs, trademarks or trade names based on Product designs or specifications supplied by Buyer. Upon receipt of notification of any actual or alleged infringement of any patent, trademark,

trade secret, copyright or any other proprietary right., Seller shall, at its option either (i) defend the allegation of infringement,; (ii) modify the design of the challenged product; (iii) negotiate a reasonable licensing arrangement that permits Buyer to continue using the challenged product; (iv) substitute a non-infringing product which meets or exceeds the requirement and specifications of Buyer; or (v) terminate this Contract without further liability.

14. Proprietary Rights: Sale of the Products to Buyer does not convey a license, implied or otherwise, under any patent in which Seller has an interest, nor does it convey any right to any descriptive data, including, but not limited to, Seller's manufacturing drawings, secrets, specifications, designs, processes or tooling.

15. Financial Responsibility: In the event that Buyer fails to fulfill the terms of payment for any shipment of Products or if Seller shall have a reasonable doubt at any time as to Buyer's ability to pay for Products ordered Seller may, at its option and without liability, (i) change the terms of payment or (ii) defer further production and shipments until satisfactory performance has been made by Buyer and Seller is satisfied as to Buyer's financial ability, and such change or deferment shall not prejudice any claim for damages Seller may otherwise have against Buyer.

16. Cancellations: (a) Seller may, at its option, cancel Buyer's order if (I) Buyer's payments are in default or Buyer breaches any material provision hereof, (ii) any cause specified in Paragraph 5 hereof ("Excusable Delay"), makes it commercially impracticable, in Seller's judgment for delivery of the Products within a reasonable time, or (iii) Buyer becomes insolvent or the subject of a proceeding under any bankruptcy law. Such cancellation shall not prejudice Seller's right to any amounts then due or affect any other rights Seller may have under the applicable provisions of controlling law.
(b) Buyer may cancel the remaining unfilled portion of its order upon written notice to Seller and upon payment of reasonable cancellation charges invoiced by Seller which may include the profit that would have been made on the canceled portion of the order and shall take into account the Products already produced or in process, the expenses already incurred and the commitments already made as a consequence of the order. In no event will the cancellation charges exceed the purchase price of the canceled product.

17. Claims: Claims for shortages, incorrect materials or invoicing errors must be made by Buyer in writing within five (5) days after receipt of shipment. Claims for non-receipt of shipment must be made in writing within five (5) days after receipt of invoice. If Seller has agreed to pay for any transportation charges, claims for such charges must be made in writing within ninety (90) days after shipping date.

18. Product Liability: Buyers shall indemnify and hold harmless Seller, its directors, officers, agents and employees against all expense, loss, attorneys' fees, costs, damage or liability arising from any claim or action for Product defect where the alleged defect relates to design, labeling or manufacture specifications supplied by Buyer. At the request of Seller, Buyer shall defend at its own expense all such claims or actions, provided that Seller shall be entitled at its election, at participate in such defense.

19. Limitation of Liability: Seller's liability for defective or nonconforming Products, whether based on breach of warranty, negligent manufacture or product liability, is exclusively limited to repair or replacement, at Seller's election, of such Products. Seller assumes no risk and shall NOT be subject to ANY liability for any damages or loss resulting from the specific use or application made of the Products. Seller's liability for any other claim, whether based on breach of contract, negligence or product liability, relating to the Products shall not exceed the price paid by Buyer for such Products. In no event shall Seller be liable for any special, incidental, consequential or other damages, including, but not limited to, loss of profits, cover damages and claims of third parties, howsoever caused, whether by the negligence of Seller or otherwise.

20. Compliance with Laws: Seller warrants and certifies that it complies with all applicable statutes, rules, regulations and orders of the United States, including those pertaining to labor, wages, hours and other conditions of hiring and employment.

21. Government Contracts: If the Products are to be used in fulfilling a contract with the United States Government, Seller will comply with all mandatory requirements of such contract which are applicable to Seller provided that Seller has received written notice of such requirements from Buyer in sufficient time to incorporate their impact into the price and delivery schedule for such Products. In addition, Seller may at its option adopt any provisions of the FAR, DFAR, DAR or other federal statutes or regulations which are applicable to Seller.

22. Publicity: Except for any announcement intended solely for internal distribution by either party or any disclosure required by legal, accounting, or regulatory requirements, all media releases, public announcements, or public disclosures by either

party or its employees or agents relating to these Terms, the relationship between Seller and Buyer, or including the marks of the other party or any affiliate of that party, must be approved in writing by the other party prior to release.

23. Waiver: The rights and remedies of Seller as set forth in this Agreement shall be in addition to any other rights and remedies provided in law or equity and the failure or delay by Seller to exercise any rights or remedies hereunder shall not operate as a general waiver thereof.

24. Assignment: Buyer shall not assign any of its rights or obligations hereunder without the prior written consent of Seller.

25. Notices: Any notices and other communications required or permitted to be given hereunder shall be in writing and shall be effective when delivered personally, electronically transmitted (later confirmed in writing) or air mailed, postage prepaid.

26. Corrections: Clerical errors, typographical errors or other obvious errors or omissions are subject to correction by Seller.

27. Severability: In the event that one or more previsions hereof should be held to be unenforceable in any respect, this document shall be construed as if such unenforceable provision(s) had not been contained herein.

28. Survival: No termination of these Terms will affect any rights or obligations of either party: (i) which are vested pursuant to these Terms as of the effective date of such termination; or (ii) which, by their sense and context are intended to survive completion of performance or termination of these Terms, including, without limitation, Confidentiality, Warranties / Indemnities, and Limitation of Liability, all of which will survive.

29. Entire Agreement: These terms and conditions supersede all other agreements, representations, warranties and undertakings of the parties with respect to the subject hereof and may not be modified except by a writing signed by an authorized employee of Seller. If Buyer and Seller have executed an overriding agreement covering the sale of Products to which this document relates, the terms of said overriding agreement shall prevail over the terms stated herein only to the extent of any conflict.

30. Governing Law: Buyer's purchase of Products hereunder shall in all respects by governed by the laws of the State of New Jersey without regard to its conflicts of laws provisions.

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and other proprietary notices that appear on or in the Software. Client agrees not to modify, adapt or translate the Software. Client also agrees not to reverse engineer, decompile, disassemble or otherwise attempt to discover the source code of the Software except to the extent you may be expressly permitted to decompile under applicable law, it is essential to do so in order to achieve operability of the Software with another software program, and you have first requested the Company to provide the information necessary to achieve such operability and the Company has not made such information available. The Company has the right to impose reasonable conditions and to request a reasonable fee before providing such information. Any information supplied by the Company or obtained by you, as permitted hereunder, may only be used by you for the purpose described herein and may not be disclosed to any third party or used to create any software which is substantially similar to the expression of the Software. Requests for information should be directed to the Company's Customer Support Department. Trademarks shall be used in accordance with accepted trademark practice, including identification of trademarks owners' names. Trademarks can only be used to identify printed output produced by the Software and such use of any trademark does not give you any rights of ownership in that trademark. Except as expressly stated above, this Agreement does not grant you any intellectual property rights in the Software.

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5. Multiple Environment Software / Multiple Language Software / Dual Media Software / Multiple Copies/ Bundles / Updates. If the Software supports multiple platforms or languages, if you receive the Software on multiple media, if you otherwise receive multiple copies of the Software, or if you received the Software bundled with other software, the total number of your computers on which all versions of the Software are installed may not exceed the Permitted Number. You may not, rent, lease, sublicense, lend or transfer any versions or copies of such Software you do not Use. If the Software is an Update to a previous version of the Software, you must possess a valid license to such previous version in order to Use the Update. You may continue to Use the previous version of the Software on your computer after you receive the Update to assist you in the transition to the Update, provided that: the Update and the previous version are installed on the same computer; the previous version or copies thereof are not transferred to another party or computer unless all copies of the Update are also transferred to such party or computer; and you acknowledge that any obligation the Company may have to support the previous version of the Software may be ended upon availability of the Update.

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7. LIMITATION OF LIABILITY. IN NO EVENT WILL THE COMPANY OR ITS SUPPLIERS BE LIABLE TO YOU FOR ANY DAMAGES, CLAIMS OR COSTS WHATSOEVER OR ANY CONSEQUENTIAL, INDIRECT, INCIDENTAL DAMAGES, OR ANY LOST PROFITS OR LOST SAVINGS, EVEN IF A COMPANY REPRESENTATIVE HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH LOSS, DAMAGES, CLAIMS OR COSTS OR FOR ANY CLAIM BY ANY THIRD PARTY. THE FOREGOING LIMITATIONS AND EXCLUSIONS APPLY TO THE EXTENT PERMITTED BY APPLICABLE LAW IN YOUR JURISDICTION. THE COMPANY'S AGGREGATE LIABILITY AND THAT OF ITS SUPPLIERS UNDER OR IN CONNECTION WITH THIS AGREEMENT SHALL BE LIMITED TO THE AMOUNT PAID FOR THE SOFTWARE, IF ANY. Nothing contained in this Agreement limits the Company's liability to you in the event of death or personal injury resulting from the Company's negligence or for the tort of deceit (fraud). The Company is acting on behalf of its suppliers for the purpose of disclaiming, excluding and/or limiting obligations, warranties and liability as provided in this Agreement, but in no other

respects and for no other purpose. For further information, please see the jurisdiction specific information at the end of this Agreement, if any, or contact the Company's Customer Support Department.

8. Export Rules. You agree that the Software will not be shipped, transferred or exported into any country or used in any manner prohibited by the United States Export Administration Act or any other export laws, restrictions or regulations (collectively the "Export Laws"). In addition, if the Software is identified as export controlled items under the Export Laws, you represent and warrant that you are not a citizen, or otherwise located within, an embargoed nation (including without limitation Iran, Iraq, Syria, Sudan, Libya, Cuba, North Korea, and Serbia) and that you are not otherwise prohibited under the Export Laws from receiving the Software.   All rights to Use the Software are granted on condition that such rights are forfeited if you fail to comply with the terms of this Agreement.

9. Governing Law. This Agreement will be governed by and construed in accordance with the substantive laws in force in the State of New Jersey. The respective courts of Morris County, New Jersey shall have non-exclusive jurisdiction over all disputes relating to this Agreement. This Agreement will not be governed by the conflict of law rules of any jurisdiction.

10. General Provisions. If any part of this Agreement is found void and unenforceable, it will not affect the validity of the balance of the Agreement, which shall remain valid and enforceable according to its terms. This Agreement shall not prejudice the statutory rights of any party dealing as a consumer. This Agreement may only be modified by a writing signed by an authorized officer of the Company. Updates may be licensed to you by the Company with additional or different terms. This is the entire agreement between the Company and you relating to the Software and it supersedes any prior representations, discussions, undertakings, communications or advertising relating to the Software.

DATA SHEETS

smart PIMS™
Permanently installed monitoring system

specifications

transmitter

model no.	C-PIMS 100 Modbus
protocol	Modbus
communication	RS-485, 2-wire, max. 1000'
power	10-20VDC

ultrasonic system
channels	16 ultrasonic, 1 temperature
pulser voltage	±5V bipolar square wave
receiver	1–10 MHz (-3dB)
gain	-10dB to +70dB
digitizer frequency	40 Msps
certification	Class 1, Div. 1, ATEX Zone 1 (coming 2Q16)

enclosure
type	instrumentation housing
material	aluminum
rating	Class 1, Div. 1, Group BCD, NEMA 4X, IP66
dimensions/weight	5" × 5¾" × 4¼" / 4 lbs.

tablet PC datalogger

performance
processor	Intel i5-4200U 1.6GHz w/ 3MB L3 cache (dual-core)
memory	8 GB RAM
storage	M2-SATA SSD, 64 GB
operating system	Windows 10

connections	network power, data via RS-485-to-USB adapter

physical
drop/shock resistance	MIL-STD-810G
environmental	IP65, 14–131°F (-10 to +55 °C)
dimensions/weight	11.4" × 7.48" × 0.78" / 2.73 lbs.

tranducer cable

type	armored, ¼" dia.
maximum length to transducer	standard 10' (3.0m), custom to 25' (7.6m)

transducers

	single-element contact	delay-line contact	dual-element	angle-beam or shear-wave
model	XD-101	XD-201	XD-301	custom
application	general purpose	ultra-high temp	severe pitting	cracking
frequency	5 MHz	7 MHz	5 MHz	2.25–10 MHz
active area (dia.)	0.25"/6.35mm	0.375"/10mm	0.375"/10mm	custom
overall (dia. x h)	1.0 × 1.0" 25.4 × 25.4 mm	0.8 × 2.25" 20.3 × 57.2 mm	0.75 × 0.75" 19 × 19 mm	custom
no. transducers	1–16	1–16	1–8	2–8 (TT), 1–16 (PE)
resolution	0.001"/0.025mm	0.001"/0.025mm	0.001"/0.025mm	custom
thickness range	application-dependent	0.125–1.0" 3.0–25.0mm	0.040-6.0" 1.0–150.0mm	custom
temp range	application-dependent	-5 to +932 °F -20 to +500 °C	-5 to +300 °F -20 to +150 °C	custom
attachment	magnet/adhesive	mechanical clamp	magnet/adhesive	custom

TT= through-transmission, PE = pulse-echo

smartPIMS systems are available for rent or purchase, or as a service.

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