



Leader in
Level Measurement

Installation and Operating Instructions

**Total Tank Level System
(Modbus Output)**

**Magnetostrictive
Total Level, Interface Level, & Temperature
System**

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Total Tank Level System Magnetostrictive Total Level, Interface Level, & Temperature System



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Section 1

Section 1: Introduction

1.1 Product Description

The AMETEK Drexelbrook Total Tank Level System is an integral assembly that measures Liquid Level, Interface Level, and Temperature using magnetostrictive technology.

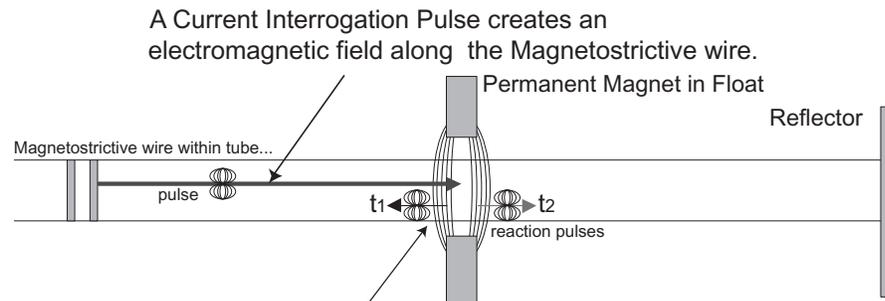
Modbus communications are used to receive information from the level, Interface and temperature sensors.

A variety of floats and mounting accessories are available to fit nearly all applications.

1.2 Terminology

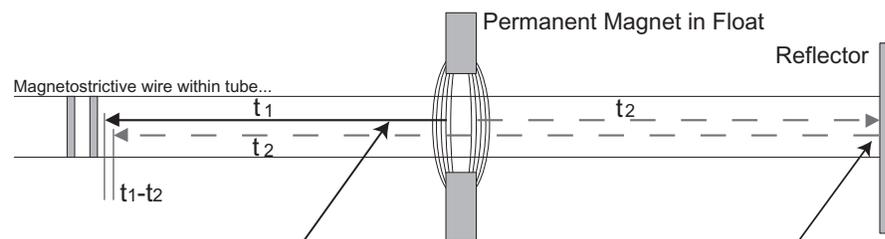
Magnetostriction: A magnetic field produces small change in the physical dimension of ferromagnetic materials on the order of several parts per million in carbon steel and conversely, a physical deformation or strain (torsion) produces a change of magnetization in the material.

1.3 Technology



Strikes field of permanent magnet & creates a torsional strain pulse or wave guide twist.

...causing two torsional strain pulses to travel in each direction along wire (the wave guide) at approximately the speed of sound.



Time between initial pulse t_1 and second t_2 reflected return pulse is used to determine float position & level.

Figure 1-1
Magnetostrictive Theory

1.3 Technology (Continued)

In a magnetostrictive level sensor a current pulse is sent down a wave guide made of a special nickel alloy wire designed to enhance magnetostrictive properties. A permanent magnet within a float is used to indicate the position or level being measured. The interaction of the current pulse with the magnetic field created by a float (with magnet) produces a torsional strain pulse that travels at approximately the speed of sound along the wire. A small induction pickup coil senses the strain pulse. The position of the float is determined with high precision by measuring the time between the launching of the current pulse and the arrival of the torsional strain pulse.

The magnetostrictive wire is linearized during manufacture and the speed of the torsional pulse is determined for the specific sensor. Inherently, magnetostrictive sensors have very high resolution and repeatability.

Magnetostrictive technology is excellent for applications where the dielectric constant is very low or is changing. The technology has been used quite successfully for the detection of leaks in underground storage tanks, for example. The measurement of a 0.1 gallon leak out of a 10,000 gallon tank over a period of one hour is the standard for EPA mandated leak detection.

1.4 Model Number

Model - Total Tank Level System

M Total Tank Level System

Output

1 Modbus

Housing

1 Single compartment powder coated aluminum, 3/4" NPT

Dual Seal

X None

Material

- B** 316 SS Stainless Steel (Rigid) 20" to 378" Long
- V** PVDF (UltraFlex) 65" to 600" Long
- S** Sanitary, 3A (Tri-clamp mounting, polished tubing 240 grit 316 SS Rigid only) 21" to 140"
- F** Food Grade (Tri-clamp mounting, 180 grit 316 SS Rigid only) 21" to 200"

Mounting

- 1** Adjustable, 16" Long Extension Tube UltraFlex Option only
- 2** 3/4 NPT 316 SS Rigid Option only
- 3** Adjustable 316 SS Rigid Option only
- A** 2" Tri-clamp Sanitary or Food Grade Option only
- B** 2 1/2" Tri-clamp Sanitary or Food Grade Option only
- C** 3" Tri-clamp Sanitary or Food Grade Option only
- D** 4" Tri-clamp Sanitary or Food Grade Option only

Level Measurement Span (LMS)

XXX 3 figure number (specified in inches)

Temperature Points

- R1** 1 Sensor (@36")
- R5** 5 Sensors
- T1** 1 Sensor (close to bottom)

Number of Floats

- F1** 1 Float
- F2** 2 Floats

Over All Length (OAL)

XXX 3 figure number (specified in inches)

Float Kit 1 - Total Product Float Kit

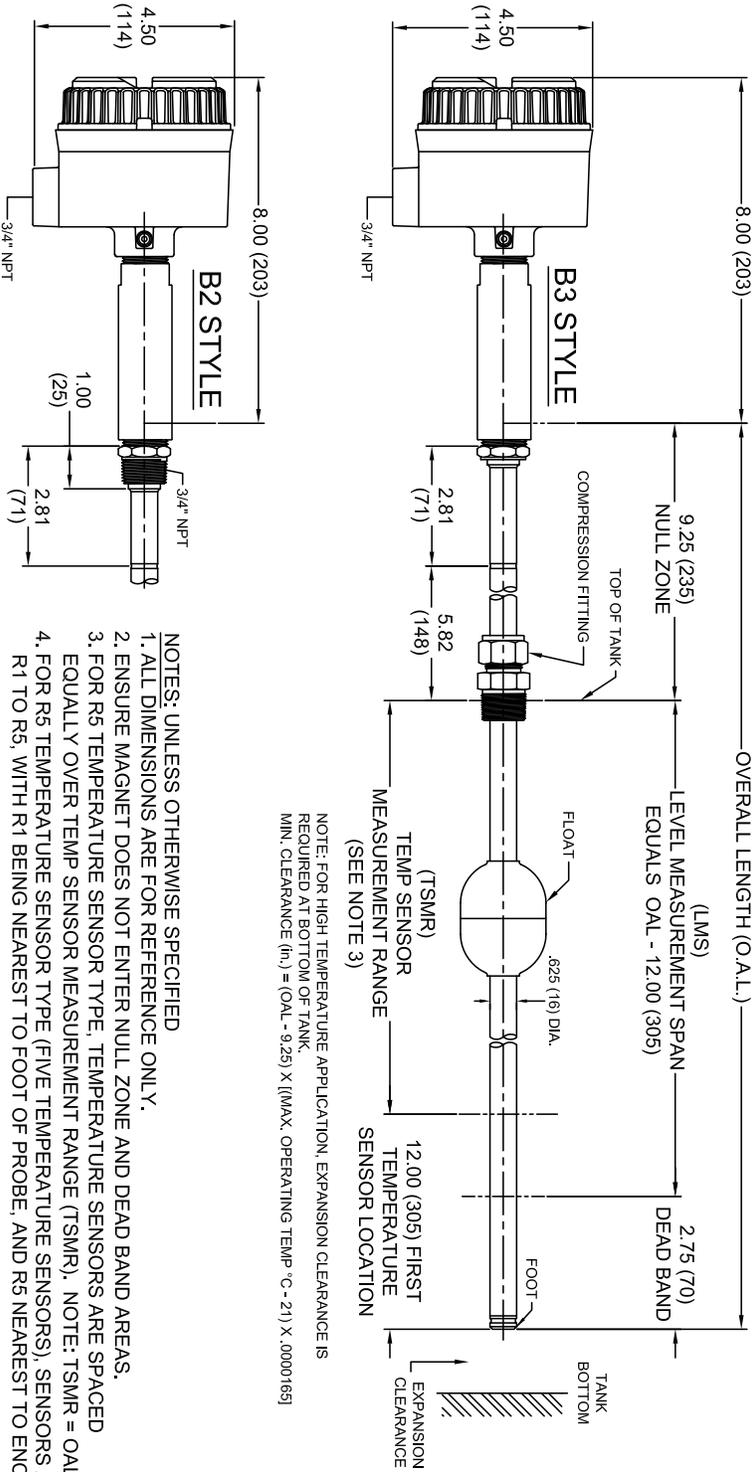
- XXX** = None
- 001** = 316SS, 2.06" Diameter, 0.54 SG. UltraFlex PVDF Option
- 002** = 316SS, 2.06" Diameter, 0.64 SG. UltraFlex PVDF Option
- 003** = 316SS, 2.06" Diameter, 0.54 SG. E-Clip/Spacer 1.25" Long Rigid 316SS Option
- 004** = 316SS, 2.06" Diameter, 0.64 SG. E-Clip/Spacer 1.25" Long Rigid 316SS Option
- 005** = 316SS, 1.83" Diameter, 0.65 SG. R-Clip (3A Sanitary) Rigid 316SS "S" Option
- 006** = 316SS, 1.83" Diameter, 0.65 SG. E-Clip (Food Grade) Rigid 316SS "F" Option

Float Kit 2 - Interface Float Kit

- XXX** = None
- 101** 316SS, 2.06" Diameter, 0.85 SG. UltraFlex PVDF Option
- 102** 316SS, 2.06" Diameter, 0.96 SG. UltraFlex PVDF Option
- 103** 316SS, 2.05" Diameter, 0.85 SG. E-Clip/Spacer .875" Long Rigid 316SS Option
- 104** 316SS, 2.05" Diameter, 0.96 SG. E-Clip/Spacer .875" Long Rigid 316SS Option
- 105** 316SS, 2.05" Diameter, 1.10 SG. E-Clip/Spacer .875" Long Rigid 316SS Option



1.5 316 SS Rigid Probe (B Style) Dimensions - Inches (mm)



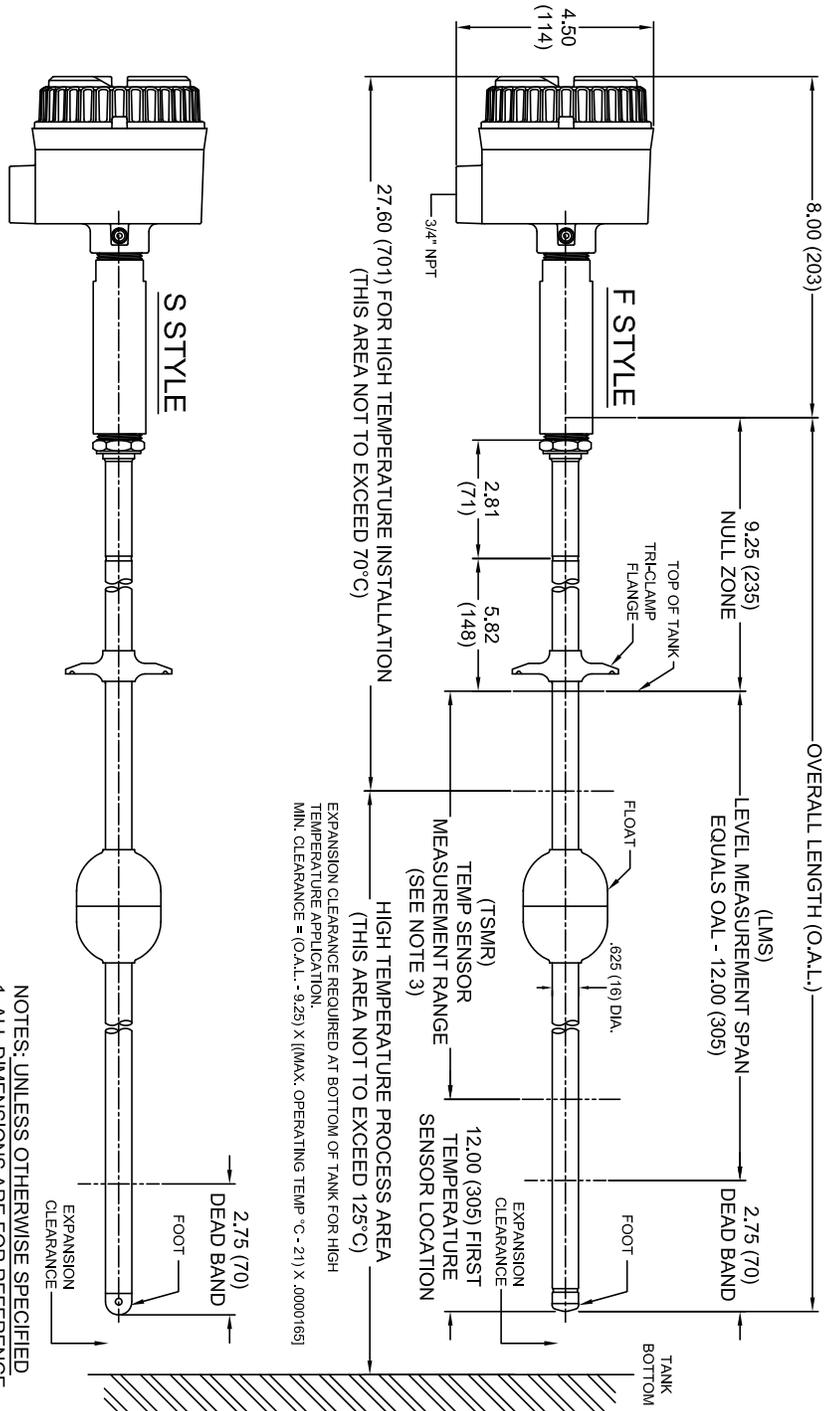
STANDARD PROBE LENGTHS:

TEMPERATURE SENSOR TYPE	MAXIMUM O.A.L. (in)	MINIMUM O.A.L. (in) -40°C TO 70°C	MINIMUM O.A.L. (in) -40°C TO 100°C	FIRST TEMPERATURE SENSOR LOCATION @ 21°C	REMAINDER TEMPERATURE SENSOR SPACING @ 21°C
R5	378	41	47	12" TO PROBE FOOT	TSMR / 5
R1	378	29	33	12" TO PROBE FOOT	N/A
T1	378	21	25	4" TO PROBE FOOT	N/A

OVERALL LENGTH OF PROBE	DESIGNATION	LENGTH
LEVEL MEASUREMENT SPAN	OAL	CUSTOMER SPECIFIED
TEMPERATURE SENSOR MEASUREMENT RANGE	LMS	OAL - 12.00 (305)
	TSMR	OAL - 21.25 (540)

1.6 316 SS Rigid Probe (F & S Style) Dimensions - Inches (mm)

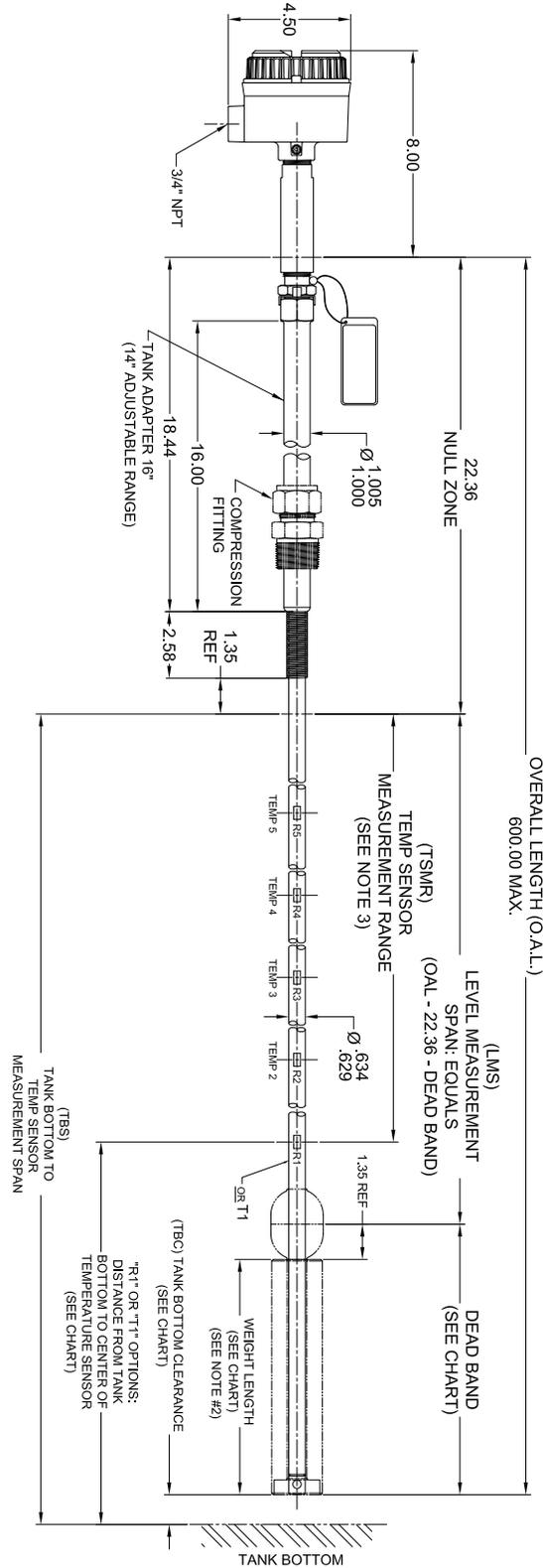
DESIGNATION	LENGTH
OAL	CUSTOMER SPECIFIED
LMS	OAL - 12.00 (305)
TSMR	OAL - 21.25 (540)



STANDARD PROBE LENGTHS:		FOOD GRADE		SANITARY	
TEMPERATURE SENSOR TYPE	MAXIMUM O.A.L. (in)	MINIMUM O.A.L. (in)	FIRST TEMPERATURE SENSOR LOCATION @ 21°C	REMANINDER TEMPERATURE SENSOR SPACING @ 21°C	
R5	200	41	47	TSMR / 5	
R1	200	29	33	N/A	
T1	200	21	25	N/A	
STANDARD PROBE LENGTHS:		SANITARY			
TEMPERATURE SENSOR TYPE	MAXIMUM O.A.L. (in)	MINIMUM O.A.L. (in)	FIRST TEMPERATURE SENSOR LOCATION @ 21°C	REMANINDER TEMPERATURE SENSOR SPACING @ 21°C	
R5	140	41	47	TSMR / 5	
R1	140	29	33	N/A	
T1	140	21	25	N/A	

- NOTES: UNLESS OTHERWISE SPECIFIED
1. ALL DIMENSIONS ARE FOR REFERENCE ONLY.
 2. ENSURE MAGNET DOES NOT ENTER NULL ZONE AND DEAD BAND AREAS.
 3. FOR R5 TEMPERATURE SENSOR TYPE, TEMPERATURE SENSORS ARE SPACED EQUALLY OVER TEMP SENSOR MEASUREMENT RANGE (TSMR).
NOTE: TSMR = OAL - 21.25 (540).
 4. FOR R5 TEMPERATURE SENSOR TYPE (FIVE TEMPERATURE SENSORS), SENSORS ARE NUMBERED R1 TO R5, WITH R1 BEING NEAREST TO FOOT OF PROBE, AND R5 NEAREST TO ENCLOSURE.

1.7 UltraFlex Probe Dimensions - Inches (mm)

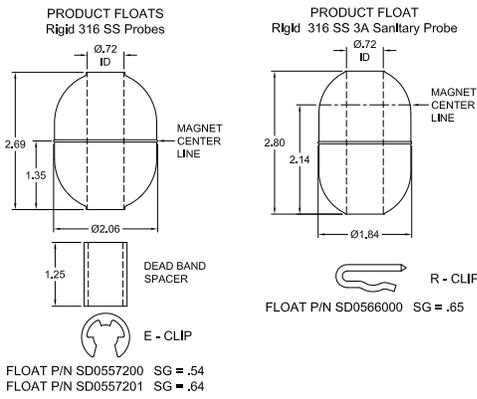
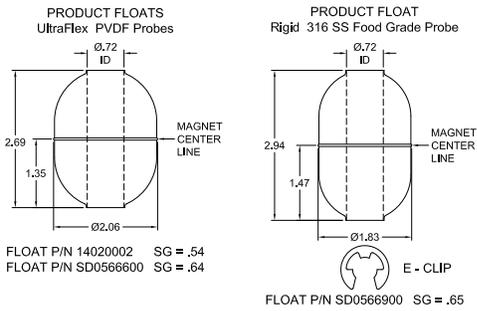


OVERALL LENGTH OF PROBE (O.A.L.)	DEAD BAND	WEIGHT LENGTH (SEE NOTE 2)	TANK BOTTOM CLEARANCE (TBC) @ 70° F (21° C)	DISTANCE FROM TANK BOTTOM TO TEMPERATURE SENSOR: "R1" OPTION	DISTANCE FROM TANK BOTTOM TO FIRST TEMPERATURE SENSOR: "R5" OR "T1" OPTION	REMAINDER OF TEMPERATURE SENSOR SPACING: R5 OPTION
65 ~ 144	4.85	3.50	2.00	27.00	12.13	(OAL - 32.5) / 5
145 ~ 216	7.35	6.00	3.00	30.00	13.13	(OAL - 32.5) / 5
217 ~ 288	7.35	6.00	3.00	30.00	14.13	(OAL - 33.5) / 5
289 ~ 336	8.35	7.00	4.00	35.00	15.13	(OAL - 33.5) / 5
337 ~ 432	8.35	7.00	4.00	35.00	16.13	(OAL - 34.5) / 5
433 ~ 488	12.35	11.00	5.00	39.00	17.13	(OAL - 34.5) / 5
489 ~ 588	12.35	11.00	5.00	39.00	18.13	(OAL - 35.5) / 5
589 ~ 600	12.35	11.00	5.00	39.00	19.13	(OAL - 35.5) / 5

- NOTES: UNLESS OTHERWISE SPECIFIED
1. OPERATING TEMPERATURE -40°C TO +70°C (-40°F TO +158°F)
 2. ALL DIMENSIONS ARE REFERENCE IN INCHES.
 - A) DEAD BAND IS BASED ON THE CENTER LINE OF MAGNET.
 - B) WEIGHT LENGTH IS BASED ON DEAD BAND AND 1.35" FLOAT REFERENCE DIMENSION SHOWN.
 3. TEMP SENSORS ARE SPACED EQUALLY OVER TEMP SENSOR MEASUREMENT RANGE (TSMR).

1.8 Float options (Dimensions) inches

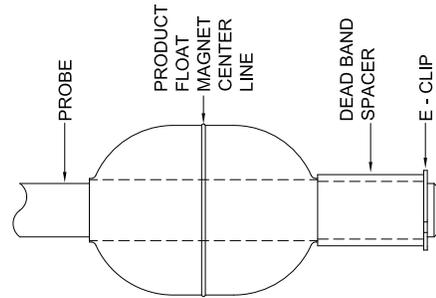
PRODUCT FLOATS



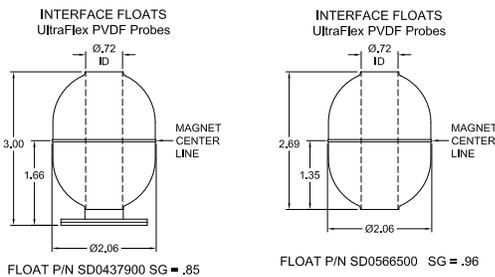
Note: Product level floats must be installed prior to an interface level float. If using with an interface float do not install the float dead band spacer below the product float.

Installation Procedure:

- 1) First, slide float onto probe. Orientation of the top & bottom of these floats is not required (Except for the 3A Sanitary Float SD0566000) since the magnet is located in the middle of the float. For the 3A Sanitary Float, the magnet needs to be at the top of the float.
- 2) Next, slide the float spacer onto the probe.
- 3) Finally, capture the components on the probe with the float retaining E-clip or R-clip. The E-clip presses into the groove at the bottom of the probe. The R-clip inserts into the hole at the bottom of the 3A Sanitary probe.



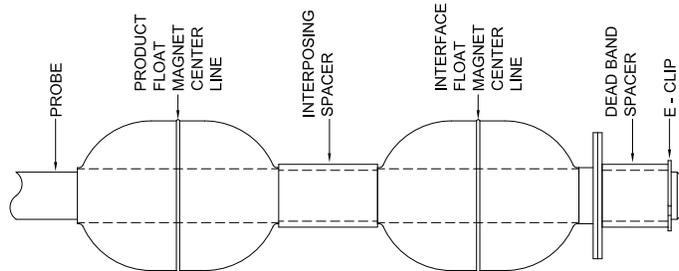
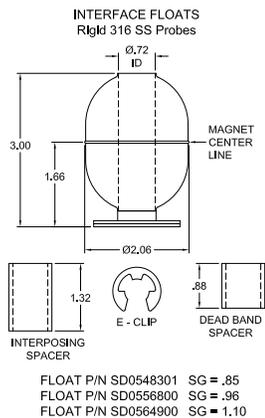
INTERFACE FLOATS



Note: Interface floats are for use below the Product floats.

Installation Procedure:

- 1) First, slide interposing float spacer onto probe.
- 2) Next, slide the interface float onto the probe with the ballast plates at the bottom when provided.
- 3) Now, slide the dead band float spacer onto the probe.
- 4) Finally, capture the components on the probe with the float retaining E-clip. The E-clip presses into the groove at the bottom of the probe.



Section 2

Section 2: Installation

2.1 Mounting Considerations

Mounting considerations may vary (Flanges, Compression Fitting, etc.) depending on the application. For underground tanks, the probe is generally mounted in the riser, resting on the bottom of the tank. Spacers are used to hold the sensor in the riser and a cable is suspended from the tank cap.

While most underground tanks are horizontal and fairly standard in design, above ground tanks vary considerably. The requirements for mounting these probes are fairly simple.

Since the sensor requires a float to provide level position, there is a minimum size required for insertion of the float into the tank. It is recommended that a minimum of 2" diameter be used for the most reliable system.

The size and material of the float being used will have a slight impact on the overall accuracy of the measuring system. In general, the larger the float the easier it is to provide a high accuracy measurement.

2.1.1 Probe Sizes

TERMINOLOGIES

Insertion Length:

Is the actual distance from the top of the tank mounting flange to the inside bottom of the tank.

Overall length (OAL):

Is the actual probe length required, determined by subtracting the tank bottom clearance from the Insertion Length plus the distance selected from the top tank mounting flange.

The amount of Active Range in a tank will vary, depending on the mounting style and probe lengths.

Stainless Steel Rigid probes are available in lengths:

Rigid 316 SS style probes up to 31.5 feet (9.6 M), see drawing on page 4.

Sanitary "S" style probe up to 11.6 feet (3.5 M), see drawing on page 5.

Food Grade "F" style probe up to 16.6 feet (5.0 M), see drawing on page 5.

Stainless Steel Probes are to be mounted with probe end about 1/2" (12.7mm) from the tank bottom. Minimum process connection depends on the diameter of float, but it is suggested to use 2" NPT or larger.

Stainless Steel probes utilizing a compression fitting, the fitting should be positioned no closer than 1" below the "crimp" in the 5/8" diameter tube.

PVDF probes are available in lengths up to 50 feet (15.2 M). Reference drawing on page 6 for dimensional details.

PVDF probes use a (customer supplied) compression fitting at the top of the tank allowing adjustability over a range of 14" (355.6 mm).



IMPORTANT

Be sure to read & understand all of the Installation and handling Instructions procedure provided with product before beginning!

Installation and Handling Instructions can also be found on the website.

<http://www.drexelbrook.com/Continuous-Level-Measurement/Index.aspx>

2.2 Unpacking

Carefully remove the contents of the shipping carton and check each item against the packing list before destroying any packing materials. If there is any shortage or damage, report to the factory at 1-215-674-1234.

2.2.1 Storage

Total Tank Level System systems should be stored in their original shipping containers until ready for installation.

Damage that occurs in storage is not covered under manufacturers system warranty.

2.3 Mounting Conditions

CAUTION



- **When installing probes, do not bend the probes, permanent damage may result.**
- **Longer probes need to be supported at both ends or during uncoiling while handling.**
- **Probes are sealed at the factory and have electronic circuits inside. Do not attempt to open probe or weld the tube.**
- Total Tank Level System is designed for industrial applications, but should be mounted in a location as free as possible from vibration, corrosive atmospheres, or any possibility of mechanical damage.
- Place the level gauge in a reasonably accessible location. Ambient temperature should be between -40°F and 158°F (-40°C to 70°C).
- Mount the probe perpendicular with gravity. See Figure 2-1.
- Float should have free movement along probe. Float dimensions are shown in Section 1.8.

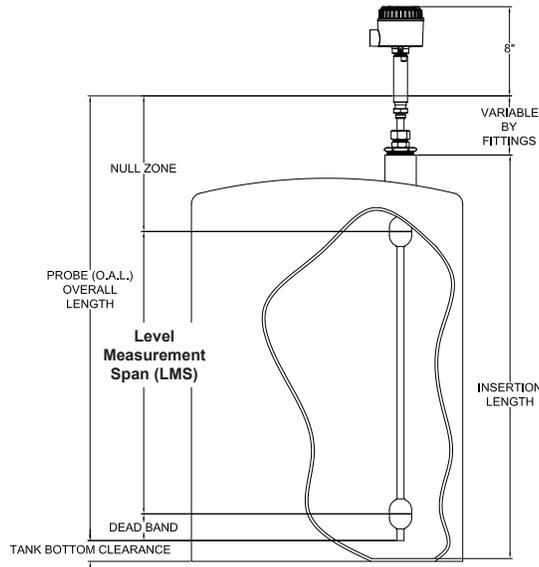
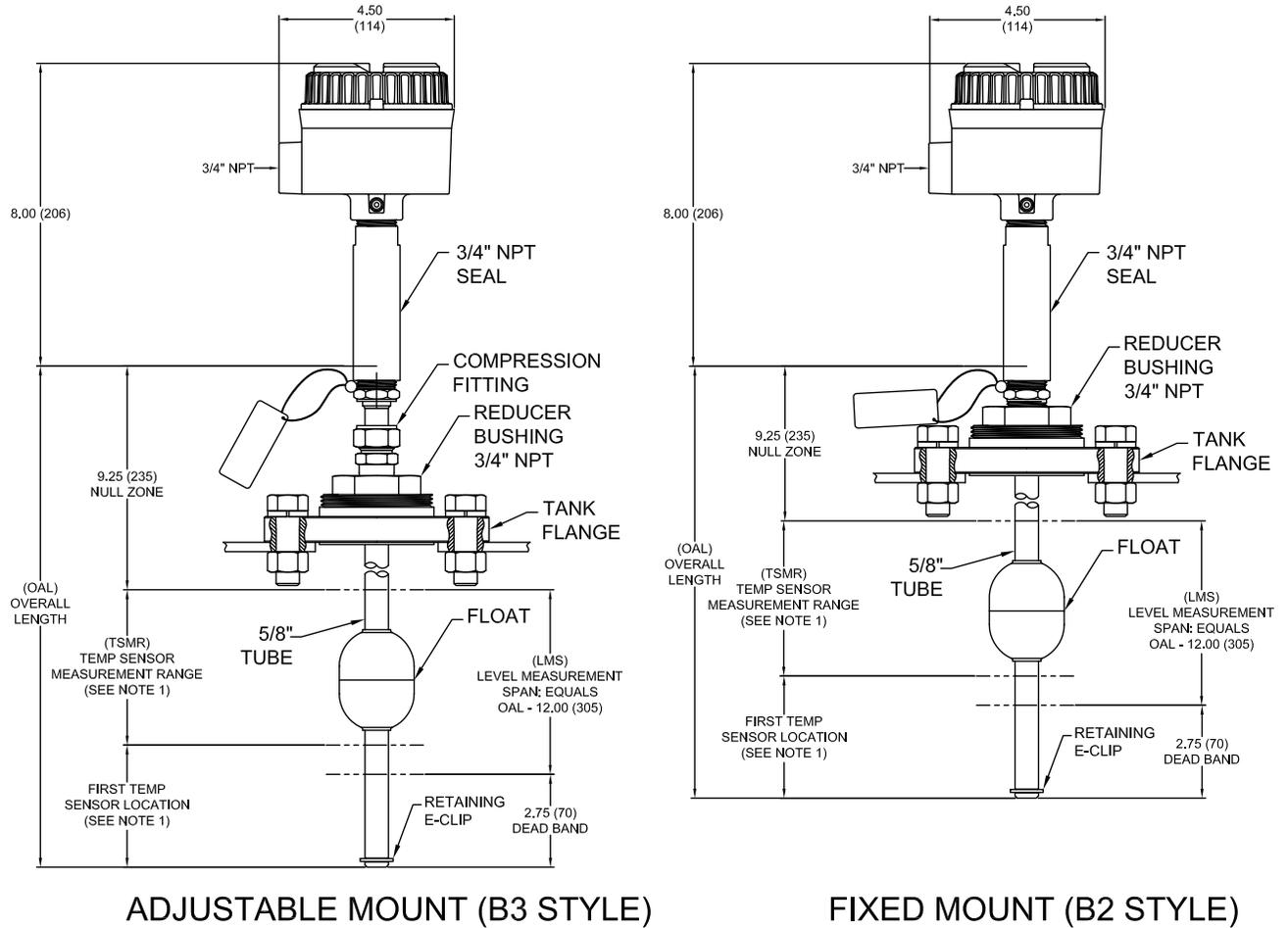


Figure 2-1

2.4 Rigid 316 SS Probe Mounting

RIGID 316 SS SERIES

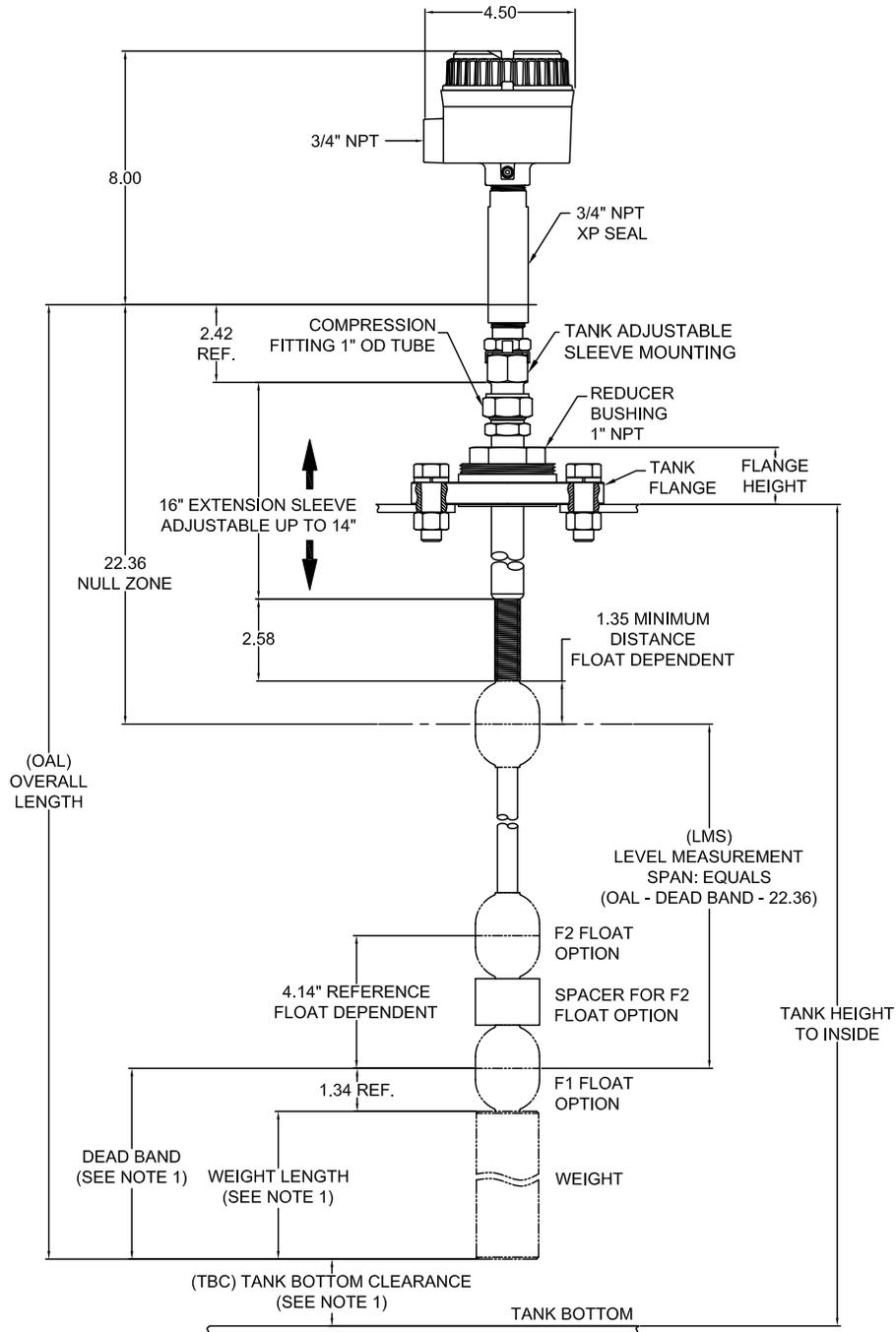


NOTE:
1. REFERENCE DIMENSIONAL DRAWING.

Figure 2-2
Rigid Probe Installation Drawing

2.5 UltraFlex Probe Mounting

ULTRAFLEX PVDF SERIES MOUNTING APPLICATION DATA



NOTE:
1. REFERENCE CHART ON DIMENSIONAL DRAWING.

Figure 2-3
UltraFlex Probe Installation Drawing

2.6 Rigid 316 SS F and S Probe Mounting

RIGID 316 SS F and S SERIES

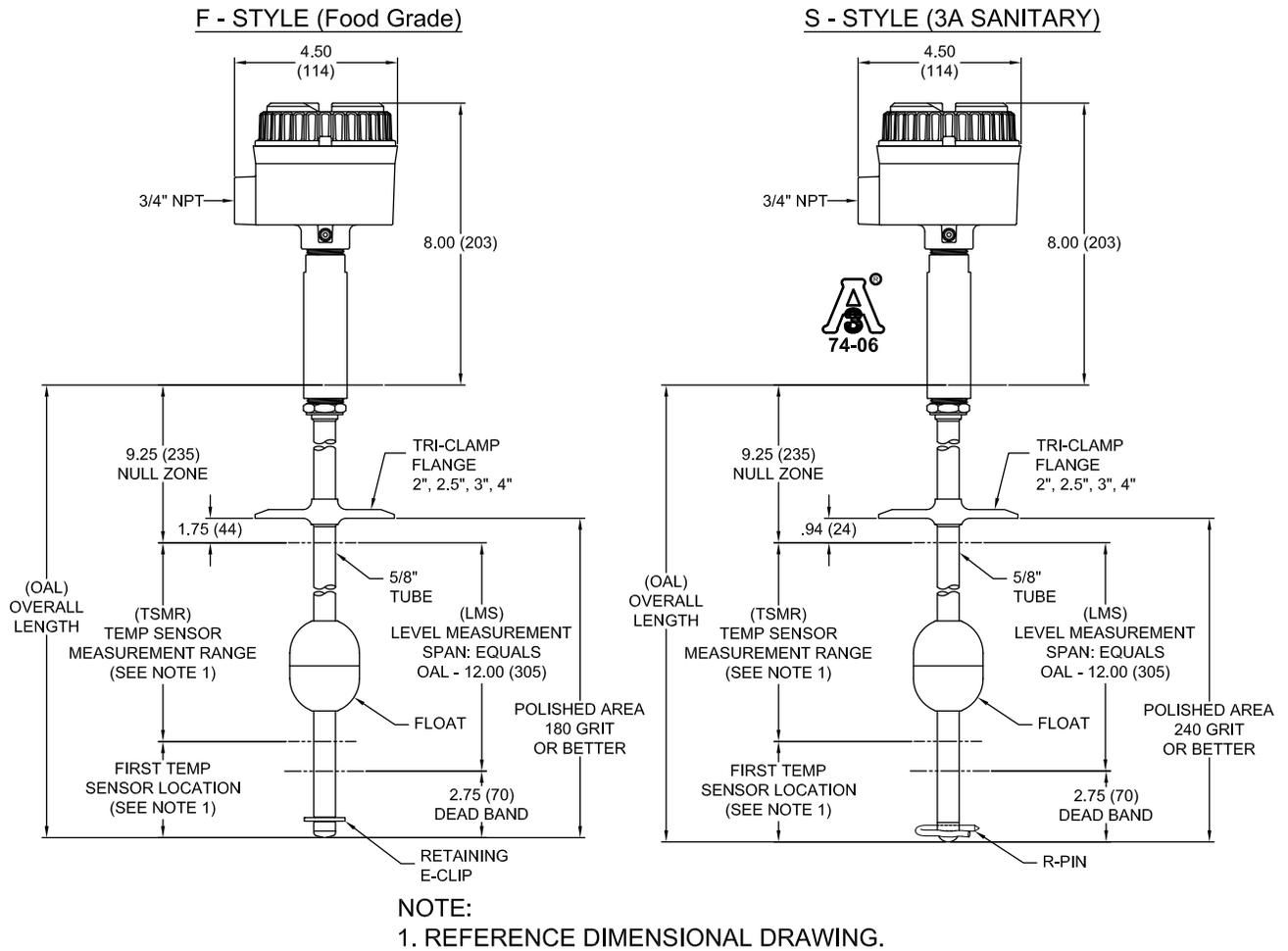
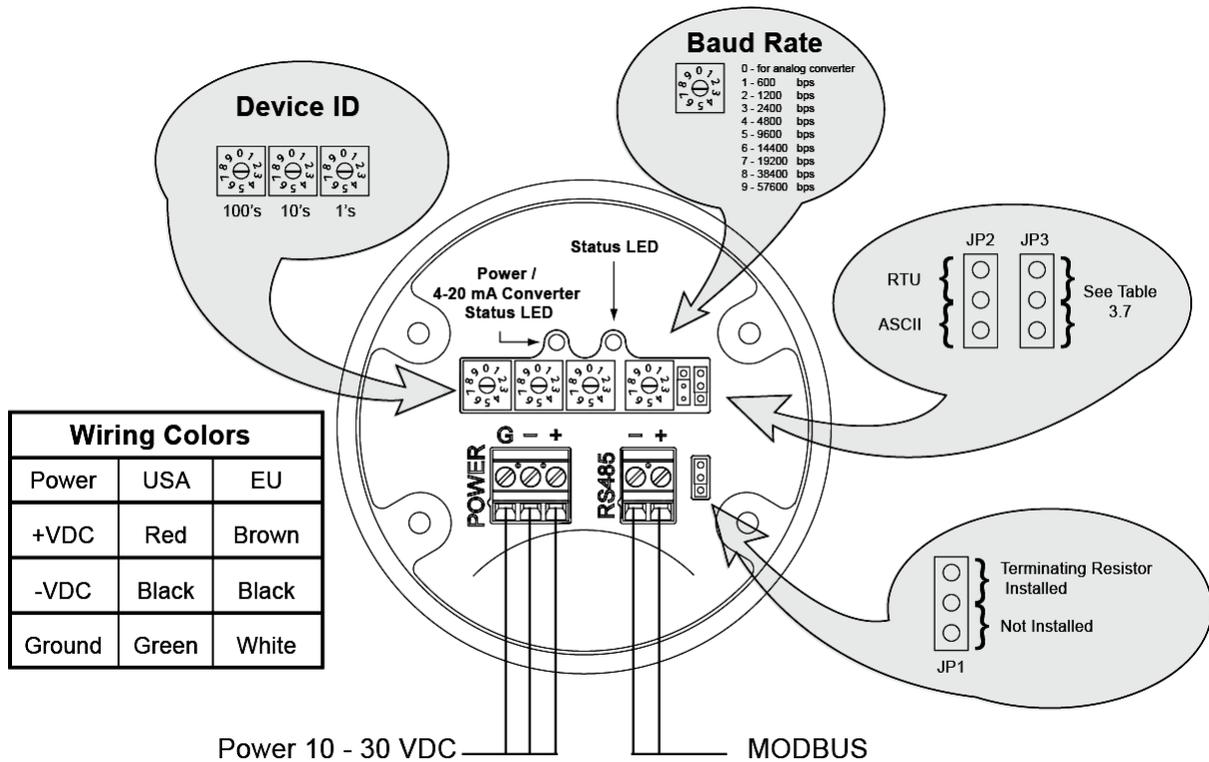


Figure 2-4
Rigid 316 SS F and S Installation Drawing

2.7 Wiring



WARNING! If the Total Tank Level System is located in a hazardous environment, do not open the enclosure cover or make / break any electrical connections without first disconnecting electrical power at the source. Ensure that wiring, electrical fittings and conduit connections conform to electrical codes and Approval Agency Control Drawings for specific location and environment.



Section 3

Section 3: Communications

3.1 Description

The Total Tank Level System uses the Modbus protocol for communicating with a PC or devices such as a programmable logic controller. Modbus is a master-slave protocol that is openly published. Many PC programs currently exist for communicating with Modbus supported devices. The Total Tank Level System supports the RTU / ASCII transmission mode over RS-485 or RS-232.

3.2 Compatibility

The Total Tank Level System supports all the required specifications and is conditionally compliant.

3.3 Implementation Class

The Total Tank Level System uses the Basic Implementation Class of the Modbus protocol. The table below shows configurations capabilities of the basic implementation class.

	Basic
Addressing	Configurable address from 1 to 247
Broadcast	Yes
Baud Rate	9600, 19200 (19200 is default)
Mode	RTU, ASCII
Parity	EVEN, NONE
Electrical Interface	RS485 2W-cabling
Connector Type	3 wire terminal (Adapter Cable Required for RS232)

3.4 Wiring for RS485

RS485 is designed for cable lengths of to 4,000 feet. As many as 32 Modbus devices may be multi-dropped on the same bus. A twisted pair is used to connector the Total Tank Level System to a host such as a PC with a RS485 converter or PC card. It is recommended that the twisted pair be shielded and at least 24 AWG. The shield should be connected to common only at one end.



If the RS485 bus already has terminating resistors installed, the jumper JP1 on the motherboard must be set to position 2-3. This will remove the built-in terminating resistor that is connected by default.

3.5 Configuration

Refer to the illustration for switch and jumper positions.

3.5.1 Baud Rate

The Baud Rate may be adjusted by changing the position of the baud rate switch. The default baud rate is 19200 bps.

Baud Rate Switch Position

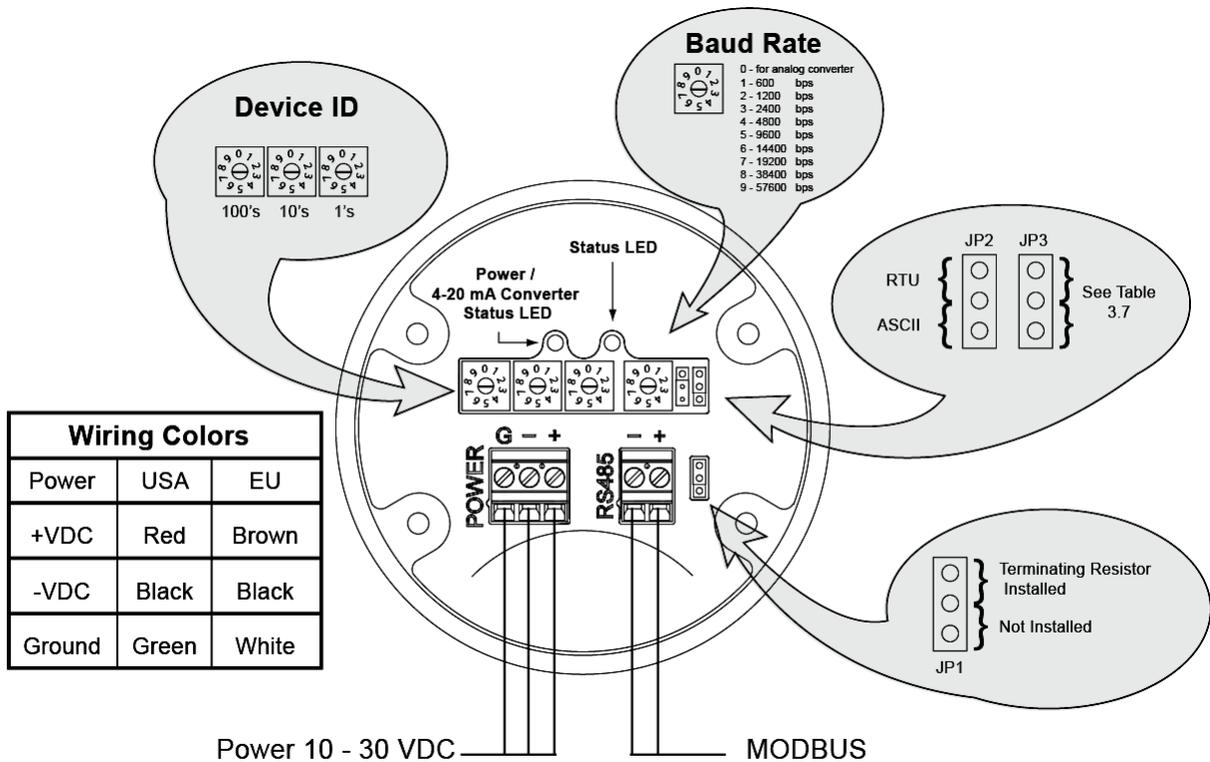
0 - For Use with Modbus RTU to Analog Converter **Only**

1 - 600 bps	4 - 4800 bps	7 - 19200 bps
2 - 1200 bps	5 - 9600 bps	8 - 38400 bps
3 - 2400 bps	6 - 14400 bps	9 - 57600 bps

3.5.2 Device ID

The Device ID is a unique address used to multi-drop the Total Tank Level System with up to 32 Modbus devices using the RS485 Interface.

The Total Tank Level System may be configured for a Device ID of 1 to 247. The Device ID may be adjusted by changing the position of the baud rate switches. The default Device ID is 1 (switch position 0).



3.6 Modbus

The Total Tank Level System has 2 modes: it can act as a Modbus slave, responding to data requests from a Modbus master in RTU or ASCII Modbus, or it can act as a Modbus master for interfacing to an optional Modbus to 4-20 mA converter. The mode is determined by the Baud Rate switch. Position 0 configures the Total Tank Level System as a Modbus Master. Positions 1- 9 configure the Total Tank Level System as a Modbus Slave, and also sets the baud rate at which it will communicate with the master.

3.7 Modbus Slave Operation

When configured as slave, the Total Tank Level System responds to requests for data from a Modbus master. The data available is the product, interface, total covered temperature, product temperature, interface temperature, span (probe length), max temperature, and the individual values of the 5 temperature sensors from the probe as well as the status of the probe.

The Total Tank Level System is capable of communicating using the Modbus RTU or ASCII format. The format is selected by the on board jumper JP2. The serial communication parameters are selected by the on board jumper JP3. The baud rate and Modbus device number are selected by on board switches. Refer to the table below for the jumper settings.

Individual data items (product, average temperature, etc.) are obtained by issuing a Modbus request with a specific register number, as per the Modbus protocol specification. Multiple values can be obtained by specifying a starting register and the number of registers desired.

The data returned from a Modbus request can be in many formats: 16 bit integer, 32 bit integer (long), or floating point. The Total Tank Level System has a unique feature which allows the user to specify the data format desired by the selecting the correct register. For example, the value for the product reading can be obtained as an integer (16 bits), a long word (32 bits), or a floating point value (32 bits) by simply choosing different registers.

In addition to the length of the data, the order of the bytes in the returned data must be known by the Modbus master in order to assemble the data correctly. The Total Tank Level System allows for all byte ordering combinations by specification of the correct register number.

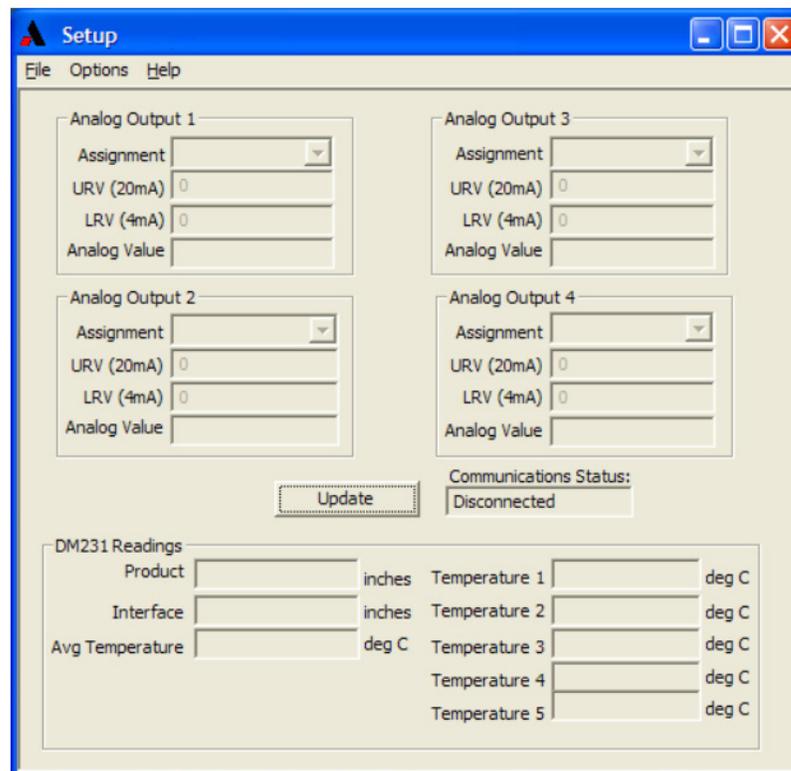
In traditional Modbus, 1 register represented 16 bits of data. To obtain a 32 bit value, the master requested 2 registers to get the 32 bits. A variant of Modbus called Enron Modbus allows for 32 bits of data to be returned with 1 register request. The Total Tank Level System will work with either type of Modbus master. Again, the format type is controlled by the register number requested.

All of the Modbus formats available are shown in Section 3.19

3.8 Modbus Master Operation

When configured as a Modbus master, the communications settings are internally fixed, and all other jumpers and switches are not used. The Total Tank Level System connects to PC Windows based software used to set the configuration, and to a Modbus to 4-20mA converter to drive 4-20mA outputs. The PC software shows the current values for the data points (product, average temperature, etc.) It also allows the user to select one of the variables to represent a 4-20mA analog output. After selecting the desired variable, the user sets the LRV (Lower Range Value) and URV (Upper Range Value), which determines the output current. 4 channels are available for outputs.

3.9 Master Slave Configuration



Screen shot of PC configuration program used to configure the Total Tank Level System when configured as a Modbus master.

3.9 Master Slave Configuration (Continued)

The mode (Modbus master or slave) is controlled by the baud rate switch. Setting the switch to position 0 will configure the Total Tank Level System as a Modbus master. Settings 1 – 9 will configure the Total Tank Level System as a Modbus slave, and set the baud rate.

When configured as a Modbus master, the Device Id switches and communication jumpers are not used.

3.10 Data Points

The data points available are:

Product – position of top float

Interface – position of bottom float

Average Temperature – average temperature of covered product and interface

Product temperature – average temperature of product only

Interface temperature – average temperature of interface only

Individual Temperature sensors – 5 total, 1 is closest to the bottom of the probe, 5 is closest to the top.

Maximum temperature - recorded by any of the sensors, saved through power cycles

Temperature sensor locations- 5 total, indicates sensor location from bottom of tank.

All temperatures are available in both degrees F and C.

All positions are available in inches and centimeters.

A value of 2000 for product or -2000 for interface indicates a float error condition.

A value of 2000 for a temperature sensor indicates a sensor error condition.

A value of 1000 for product or -1000 for interface indicates a communication problem between the Total Tank Level System and the probe.

3.11 Scaling

All integer formats are scaled X 100 so that the last 2 digits represent the decimal portion of the number.

For example:

Product reading: 1790 = 17.90 inches

Interface reading: 563 = 5.63 inches

Average Temperature: 2382 = 23.82 degrees Celsius

3.12 Byte Ordering

In the Modbus slave configuration, data can be accessed as integers (16 bits), long integers (32 bits), and floating point value (32 bits). The order that the bytes are sent must be known by the master in order to assemble the bytes into the correct value. Byte ordering can have a few different terminologies.

- 1) Big/Little Endian
- 2) Byte order by number, with 1 indicating the most significant part of the value, and 4 the least significant,
- 3) Word/Byte, indicating which word (16 bits, high or low) is sent first, and which byte of the word (high or low) come first in that byte.

See the following example for accessing a product reading of 46.60 inches. The integer value will be 4660, which translates to the hex number 0x00001234. The individual bytes, 0x00, 0x00, 0x12, and 0x34 can be sent the following 4 ways for 32 bits values:

- 1) Big Endian, Byte order 1234, High Word High Byte (HWHB)
Order sent: 0x00, 0x00, 0x12, 0x34
- 2) Little Endian, Byte order 4321, Low Word Low Byte (LWLB)
Order sent: 0x34, 0x12, 0x00, 0x00
- 3) Big Endian Byte Swapped, Byte order 2143, High Word Low Byte (HWLB)
Order sent: 0x00, 0x00, 0x34, 0x12
- 4) Little Endian Byte Swapped, Byte order 3412, Low Word High Byte (LWHB)
Order sent: 0x12, 0x34, 0x00, 0x00

The individual bytes 0x12, and 0x34 can be sent the following 2 ways for 16 bits values:

- 1) Big Endian, Byte order 12, High Byte first (HB)
Order sent: 0x12, 0x34
- 2) Little Endian, Byte order 21, Low Byte first (LB)
Order sent: 0x34, 0x12

3.13 Enron Modbus

Enron Modbus has a few differences from Traditional Modbus. One difference is the register offsets follow a different numbering scheme, with integer values residing in the 3XXX range, long integers in the 5XXX range, and floating points in the 7XXX range. The second difference is that 32 bits of data can be returned in one register.

The Total Tank Level System supports both of these features, by selection of the proper register value.

3.14 Jumper Settings

In the Modbus slave configuration, jumpers JP2 and JP3 control the Modbus format (RTU or ASCII) and the communication settings, according to the chart below.

The Data bits for the Down position of JP3 depend upon the setting of JP2 (RTU or ASCII format).



These jumpers have no effect when the Total Tank Level System is configured as a Modbus master.

JP2	JP3	Mode	Data bits	Stop bits	Parity
Up	Up	RTU	8	1	None
Up	Down	RTU	8	1	Even
Down	Up	ASCII	8	1	None
Down	Down	ASCII	7	1	Even

3.15 Baud Rate

The baud rate for a Modbus slave configuration is determined by the Baud rate switch, summarized in the following table:

Switch position	Baud (in bps)
0	Sets Total Tank Level System as a Modbus master
1	600
2	1200
3	2400
4	4800
5	9600
6	14400
7	19200
8	38400
9	57600

3.16 Holding and input registers

All data points can be accessed as either a holding or an input register. Holding registers start with a 3XXXX and Input registers start with a 4XXXX. For example, product can be obtained at both registers 30203 and 40203.

3.17 Maximum registers

The maximum number of registers that can be accessed in a single Modbus request depends on the mode (RTU or ASCII) and the register size of the data (i.e Enron uses 4 data bytes per register for floats and longs)

- For ASCII setting , accessing Enron floats or long integers, the maximum number of registers that can be requested is 30.
- For all other modes, the maximum number is 36, which will retrieve all the data points in a single message.

3.18 Examples of Accessing Data in the Total Tank Level System

For the following examples, suppose we have these values:

Product (level) reading: 200.74 inches, 509.88 cm

Interface reading: 120.39 inches, 305.79 cm

Average Temperature: 26.94 degrees C, 80.49 F

- 1) To access Product as an integer, Big Endian order, in inches:
Request register 31803, length 1, value returned = 20074
- 2) To access Interface as a Floating Point, Little Endian order, in cm :
Request register 30905, length 2, value returned = 305.79
- 3) To access Avg Temperature as a long integer, Big Endian Byte Swapped, in C:
Request register 31511, length 2, value returned = 2694
- 4) To access product as an integer, Big Endian, in Enron addressing, in inches:
Request register 3002, length 1, value returned = 20074
- 5) To access Interface as a Floating Point, Big Endian, in Enron addressing, in cm:
Request register 7104, length 1, value returned = 305.79
- 6) To access Avg Temperature as a long integer, Little Endian in Enron addressing, in F:
Request register 5610, length 1, value returned = 8049
- 7) To access all of the data points in Floating point, Big Endian, English units:
Request register 30203, length 36
- 8) To access Product, Interface, and product temperature points in Floating point, Big Endian, English units:
Request register 30203, length 6

3.19 Modbus Map

Use the following tables to find the register number for the desired format. First, go to the section for the number format you desire (integer, long integer, or floating point). Then find the table with the desired units, English or metric. Then find the value (product, interface, average temperature, etc) in the left hand column. Next, find the desired byte ordering across the top row. The corresponding entry at the intersection of these 2 items gives the register that should be specified in the Modbus master request message. The number of registers needed to obtain the value is also specified for each format.



HWHB = High Word. High byte
LWHB = Low Word High Byte,
HWLB = High word low byte
LWLB = Low Word low byte

3.19.1 Integer (16 bit Signed) formats

Signed 16 bit Integer, 16 bits of data per register

1 register needed to get value English Units, inches & degrees F

Data	Big Endian Hi Byte first	Little Endian Low Byte first
Product	31803	32003
Interface	31805	32005
product temperature	31807	32007
interface temperature	31809	32009
average temperature	31811	32011
status	31813	32013
Span	31815	32015
temperature 1	31817	32017
temperature 2	31819	32019
temperature 3	31821	32021
temperature 4	31823	32023
temperature 5	31825	32025
max temperature	31827	32027
temperature sensor 1 location (closest to bottom)	31829	32029
temperature sensor 2 location	31831	32031
temperature sensor 3 location	31833	32033
temperature sensor 4 location	31835	32035
temperature sensor 5 location (closest to top)	31837	32037
Software version	31899	32099

3.19.2 Signed 16 bit Integer, 16 bits of data per register

1 register needed to get value Metric Units, centimeters & degrees C

Data	Big Endian Hi Byte first	Little Endian Low Byte first
Product	31903	32103
Interface	31905	32105
product temperature	31907	32107
interface temperature	31909	32109
average temperature	31911	32111
status	31913	32113
Span	31915	32115
temperature 1	31917	32117
temperature 2	31919	32119
temperature 3	31921	32121
temperature 4	31923	32123
temperature 5	31925	32125
max temperature	31927	32127
temperature sensor 1 location (closest to bottom)	31929	32129
temperature sensor 2 location	31931	32131
temperature sensor 3 location	31933	32133
temperature sensor 4 location	31935	32135
temperature sensor 5 location (closest to top)	31937	32137
Software version	31999	32199

3.19.3 Enron Modbus, Signed 16 bit Integer, 16 bits of data per register

1 register needed to get value. English Units, inches & degrees F

Data	Big Endian Hi Byte first	Little Endian Low Byte first
Product	3002	3202
Interface	3004	3204
product temperature	3006	3206
interface temperature	3008	3208
average temperature	3010	3210
status	3012	3212
Span	3014	3214
temperature 1	3016	3216
temperature 2	3018	3218
temperature 3	3020	3220
temperature 4	3022	3222
temperature 5	3024	3224
max temperature	3026	3226
temperature sensor 1 location (closest to bottom)	3028	3228
temperature sensor 2 location	3030	3230
temperature sensor 3 location	3032	3232
temperature sensor 4 location	3034	3234
temperature sensor 5 location (closest to top)	3036	3236
Software version	3098	3298

3.19.4 Enron Modbus, Signed 16 bit Integer, 16 bits of data per register
 1 register needed to get value. Metric Units, centimeters & degrees C

Data	Big Endian Hi Byte first	Little Endian Low Byte first
Product	3102	3302
Interface	3104	3304
product temperature	3106	3306
interface temperature	3108	3308
average temperature	3110	3310
status	3112	3312
Span	3114	3314
temperature 1	3116	3316
temperature 2	3118	3318
temperature 3	3120	3320
temperature 4	3122	3322
temperature 5	3124	3324
max temperature	3126	3326
temperature sensor 1 location (closest to bottom)	3128	3328
temperature sensor 2 location	3130	3330
temperature sensor 3 location	3132	3332
temperature sensor 4 location	3134	3334
temperature sensor 5 location (closest to top)	3136	3336
Software version	3198	3398

Total Tank Level System

3.20 Floating point formats

3.20.1 Floating Point, 32 bit, 16 bits of data per register

2 registers needed to get value. English Units, inches and degrees F

Data	Big Endian HWHB/ 1234	Little Endian Byte Swapped LWHB / 3412	Big Endian Byte Swapped HWLB / 2143	Little Endian LWLB / 4321
Product	30203	30403	30603	30803
Interface	30205	30405	30605	30805
product temperature	30207	30407	30607	30807
interface temperature	30209	30409	30609	30809
average temperature	30211	30411	30611	30811
status	30213	30413	30613	30813
Span	30215	30415	30615	30815
temperature 1	30217	30417	30617	30817
temperature 2	30219	30419	30619	30819
temperature 3	30221	30421	30621	30821
temperature 4	30223	30423	30623	30823
temperature 5	30225	30425	30625	30825
max temperature	30227	30427	30627	30827
temperature sensor 1 location (closest to bottom)	30229	30429	30629	30829
temperature sensor 2 location	30231	30431	30631	30831
temperature sensor 3 location	30233	30433	30633	30833
temperature sensor 4 location	30235	30435	30635	30835
temperature sensor 5 location (closest to top)	30237	30437	30637	30837
Software version	30299	30499	30699	30899

3.20.2 Floating Point, 32 bit, 16 bits of data per register

2 registers needed to get value. Metric Units, centimeters & degrees C

Data	Big Endian HWHB/ 1234	Little Endian Byte Swapped LWHB/ 3412	Big Endian Byte swapped HWLB/ 2143	Little Endian LWLB/ 4321
Product	30303	30503	30703	30903
Interface	30305	30505	30705	30905
product temperature	30307	30507	30707	30907
interface temperature	30309	30509	30709	30909
average temperature	30311	30511	30711	30911
status	30313	30513	30713	30913
Span	30315	30515	30715	30915
temperature 1	30317	30517	30717	30917
temperature 2	30319	30519	30719	30919
temperature 3	30321	30521	30721	30921
temperature 4	30323	30523	30723	30923
temperature 5	30325	30525	30725	30925
max temperature	30327	30527	30727	30927
temperature sensor 1 location (closest to bottom)	30329	30529	30729	30929
temperature sensor 2 location	30331	30531	30731	30931
temperature sensor 3 location	30333	30533	30733	30933
temperature sensor 4 location	30335	30535	30735	30935
temperature sensor 5 location (closest to top)	30337	30537	30737	30937
Software version	30399	30599	30799	30999

3.20.3 Enron Modbus, Floating Point, 32 bit, 32 bits of data per register
1 register needed to get value. English Units, inches and degrees F

Data	Big Endian HWHB/ 1234	Little Endian Byte Swapped LWHB/ 3412	Big Endian Byte swapped HWLB/ 2143	Little Endian LWLB/ 4321
Product	7002	7202	7402	7602
Interface	7004	7204	7404	7604
product temperature	7006	7206	7406	7606
interface temperature	7008	7208	7408	7608
average temperature	7010	7210	7410	7610
status	7012	7212	7412	7612
Span	7014	7214	7414	7614
temperature 1	7016	7216	7416	7616
temperature 2	7018	7218	7418	7618
temperature 3	7020	7220	7420	7620
temperature 4	7022	7222	7422	7622
temperature 5	7024	7224	7424	7624
max temperature	7026	7226	7426	7626
temperature sensor 1 location (closest to bottom)	7028	7228	7428	7628
temperature sensor 2 location	7030	7230	7430	7630
temperature sensor 3 location	7032	7232	7432	7632
temperature sensor 4 location	7034	7234	7434	7634
temperature sensor 5 location (closest to top)	7036	7236	7436	7636
Software version	7098	7298	7498	7698

3.20.4 Enron Modbus, Floating Point, 32 bit, 32 bits of data per register
 1 register needed to get value. Metric Units, centimeters & degrees C

Data	Big Endian HWHB/ 1234	Little Endian Byte Swapped LWHB/ 3412	Big Endian Byte swapped HWLB/ 2143	Little Endian LWLB/ 4321
Product	7102	7302	7502	7702
Interface	7104	7304	7504	7704
product temperature	7106	7306	7506	7706
interface temperature	7108	7308	7508	7708
average temperature	7110	7310	7510	7710
status	7112	7312	7512	7712
Span	7114	7314	7514	7714
temperature 1	7116	7316	7516	7716
temperature 2	7118	7318	7518	7718
temperature 3	7120	7320	7520	7720
temperature 4	7122	7322	7522	7722
temperature 5	7124	7324	7524	7724
max temperature	7126	7326	7526	7726
temperature sensor 1 location (closest to bottom)	7128	7328	7528	7728
temperature sensor 2 location	7130	7330	7530	7730
temperature sensor 3 location	7132	7332	7532	7732
temperature sensor 4 location	7134	7334	7534	7734
temperature sensor 5 location (closest to top)	7136	7336	7536	7736
Software version	7198	7398	7598	7798

Total Tank Level System

3.21 Long Integer (32 bit) formats

3.21.1 Long, 32 bit, 16 bits of data per register

2 registers needed to get value. English Units, inches & degrees F

Data	Big Endian HWHB/ 1234	Little Endian Byte Swapped LWHB/ 3412	Big Endian Byte swapped HWLB/ 2143	Little Endian LWLB/ 4321
Product	31003	31203	31403	31603
Interface	31005	31205	31405	31605
product temperature	31007	31207	31407	31607
interface temperature	31009	31209	31409	31609
average temperature	31011	31211	31411	31611
status	31013	31213	31413	31613
Span	31015	31215	31415	31615
temperature 1	31017	31217	31417	31617
temperature 2	31019	31219	31419	31619
temperature 3	31021	31221	31421	31621
temperature 4	31023	31223	31423	31623
temperature 5	31025	31225	31425	31625
max temperature	31027	31227	31427	31627
temperature sensor 1 location (closest to bottom)	31029	31229	31429	31629
temperature sensor 2 location	31031	31231	31431	31631
temperature sensor 3 location	31033	31233	31433	31633
temperature sensor 4 location	31035	31235	31435	31635
temperature sensor 5 location (closest to top)	31037	31237	31437	31637
Software version	31099	31299	31499	31699

3.21.2 Long, 32 bit, 16 bits of data per register

2 registers needed to get value. Metric Units, centimeters & degrees C

Data	Big Endian HWHB/ 1234	Little Endian Byte Swapped LWHB/ 3412	Big Endian Byte swapped HWLB/ 2143	Little Endian LWLB/ 4321
Product	31103	31303	31503	31703
Interface	31105	31305	31505	31705
product temperature	31107	31307	31507	31707
interface temperature	31109	31309	31509	31709
average temperature	31111	31311	31511	31711
status	31113	31313	31513	31713
Span	31115	31315	31515	31715
temperature 1	31117	31317	31517	31717
temperature 2	31119	31319	31519	31719
temperature 3	31121	31321	31521	31721
temperature 4	31123	31323	31523	31723
temperature 5	31125	31325	31525	31725
max temperature	31127	31327	31527	31727
temperature sensor 1 location (closest to bottom)	31129	31329	31529	31729
temperature sensor 2 location	31131	31331	31531	31731
temperature sensor 3 location	31133	31333	31533	31733
temperature sensor 4 location	31135	31335	31535	31735
temperature sensor 5 location (closest to top)	31137	31337	31537	31737
Software version	31199	31399	31599	31799

3.21.3 Enron Modbus, Long, 32 bit, 32 bits of data per register

1 register needed to get value. English Units, inches & degrees F

Data	Big Endian HWHB/ 1234	Little Endian Byte Swapped LWHB/ 3412	Big Endian Byte Swapped HWLB/ 2143	Little Endian LWLB/ 4321
Product	5002	5202	5402	5602
Interface	5004	5204	5404	5604
product temperature	5006	5206	5406	5606
interface temperature	5008	5208	5408	5608
average temperature	5010	5210	5410	5610
status	5012	5212	5412	5612
Span	5014	5214	5414	5614
temperature 1	5016	5216	5416	5616
temperature 2	5018	5218	5418	5618
temperature 3	5020	5220	5420	5620
temperature 4	5022	5222	5422	5622
temperature 5	5024	5224	5424	5624
max temperature	5026	5226	5426	5626
temperature sensor 1 location (closest to bottom)	5028	5228	5428	5628
temperature sensor 2 location	5030	5230	5430	5630
temperature sensor 3 location	5032	5232	5432	5632
temperature sensor 4 location	5034	5234	5434	5634
temperature sensor 5 location (closest to top)	5036	5236	5436	5636
Software version	5098	5298	5498	5698

3.21.4 Enron Modbus, Long, 32 bit, 32 bits of data per register

1 register needed to get value. Metric Units, centimeters & degrees C

Data	Big Endian HWHB/ 1234	Little Endian Byte Swapped LWHB/ 3412	Big Endian Byte swapped HWLB/ 2143	Little Endian LWLB/ 4321
Product	5102	5302	5502	5702
Interface	5104	5304	5504	5704
product temperature	5106	5306	5506	5706
interface temperature	5108	5308	5508	5708
average temperature	5110	5310	5510	5710
status	5112	5312	5512	5712
Span	5114	5314	5514	5714
temperature 1	5116	5316	5516	5716
temperature 2	5118	5318	5518	5718
temperature 3	5120	5320	5520	5720
temperature 4	5122	5322	5522	5722
temperature 5	5124	5324	5524	5724
max temperature	5126	5326	5526	5726
temperature sensor 1 location (closest to bottom)	5128	5328	5528	5728
temperature sensor 2 location	5130	5330	5530	5730
temperature sensor 3 location	5132	5332	5532	5732
temperature sensor 4 location	5134	5334	5534	5734
temperature sensor 5 location (closest to top)	5136	5336	5536	5736
Software version	5198	5398	5598	5798

3.22 Status Bit Definitions



Status should always be viewed in an integer format (integer or long), as opposed to floating point, in order to see the individual bits.

bit	Definition
0-7	Reserved
8	Magnet missing / Fault with Product or Interface
9	Temperature 1 Fault
10	Temperature 2 Fault
11	Temperature 3 Fault
12	Temperature 4 Fault
13	Temperature 5 Fault
14	Span (Probe Length)
15	Not connected to probe
16-31	Reserved

Common values:

Status = 256 indicates magnet error

Status = 32768 indicates Total Tank Level System not communicating with probe

Section 4

Section 4: Troubleshooting

4.1 Factory Assistance

AMETEK Drexelbrook can answer any questions about The Total Tank Level System instrument. Call Customer Service at 1-215-674-1234 (US and Canada) or +1 215 674-1234 (International).

If you require assistance and attempts to locate the problem have failed:

Contact your local Drexelbrook representative,



Telephone the Service department toll-free:

- 1-215 674-1234 (US and Canada)
- +1 215 674-1234 (International)

FAX: Service Department + 215-443-5117

E-mail: drexelbrook.service@ametek.com

Please provide the following information:

- Instrument Model Number
- Sensing Element Model Number and Length
- Original Purchase Order Number
- Material being measured
- Temperature
- Pressure
- Agitation
- Brief description of the problem
- Checkout procedures that have failed

4.2 Field Service

Trained field servicemen are available on a time-plus-expense basis to assist in start-ups, diagnosing difficult application problems, or in-plant training of personnel. Contact the service department for further details.

4.3 Customer Training

Periodically, AMETEK Drexelbrook instrument training seminars for customers are held at the factory. These sessions are guided by Drexelbrook engineers and specialists, and provide detailed information on all aspects of level measurement, including theory and practice of instrument operation. For more information write to: AMETEK Drexelbrook, Communications/ Training Group or call 215-674-1234.

4.4 Equipment Return

In order to provide the best service, any equipment being returned for repair or credit must be pre-approved by the factory.

In many applications, sensing elements are exposed to hazardous materials.

- **OSHA mandates** that our employees be informed and protected from hazardous chemicals.
- **Material Safety Data Sheets (MSDS)** listing the hazardous materials to which the sensing element has been exposed **MUST** accompany any repair.
- It is your responsibility to fully disclose all chemicals and **decontaminate** the sensing element.

To obtain a return authorization (RA#), contact the Service department at 1-215-674-1234 (US and Canada) or + 215-674-1234 (International).

- Please provide the following information:
- Model Number of Return Equipment
- Serial Number
- Original Purchase Order Number
- Process Materials to which the equipment has been exposed.
- MSDS sheets for any hazardous materials
- Billing Address
- Shipping Address
- Purchase Order Number for Repairs
- Please include a purchase order even if the repair is under warranty. If repair is covered under warranty, you will not be charged.

Ship equipment freight prepaid to:

AMETEK-DREXELBROOK.
205 KEITH VALLEY ROAD
HORSHAM, PA 19044-1499
COD shipments will not be accepted

Section 5

Section 5: Specification

Technology:

- Magnetostrictive

Operating Voltage:

- 10 - 30 VDC, $U_m = 30V$

Output Signal:

- Modbus RTU / ASCII

Response Time:

- 1.0 Second (Approximately)

Temperature Range:

Rigid 316 SS Probe

Options (F and S) Probes only

- Process: -40°F to 257°F (-40°C to 125°C)
- Ambient: -40° F to 185° F (-40°C to 85°C)

Option (B) Probe

- -40°F to 212°F (-40°C to 100°C)

UltraFlex PVDF Probe

- -40°F to 158°F (-40°C to 70°C)

Process Pressure Rating:

- Rigid 316 SS Probe: 1000 psig. (69 bar)
- UltraFlex PVDF Probe: 150 psig. (10 bar)
- Float: Dependent, 316SS floats Typical to 350 psig, (24 bar) Consult Factory

Resolution:

- +/- 0.01"

Repeatability:

- +/- 0.01"

Accuracy:

- Level: 0.01% or +/- 0.039" (1 mm)
Whichever is greater
- Temp. Sensor: +/- 1°F (+/- 0.5°C)

Hysteresis:

- 0.002% or .005"
Whichever is greater

Null Zone (Top of Probe):

Rigid 316 SS Probe

- 9.25" (235 mm)

UltraFlex PVDF Probe

- Variable by selection

Dead band (Bottom of Probe):

Rigid 316 SS Probe

- 2.75" (70 mm)

UltraFlex PVDF Probe

- Variable by selection

Enclosure Rating:

- IP66, NEMA 4-4X

Wetted Parts:

- Rigid - 316 SS
- Flexible - PVDF (Kynar)

Probe Length:

- **316SS**
 - Option (B) 20" to 378" (508 - 9601 mm)
 - Option (F) 20" to 200" (508 - 5080 mm)
 - Option (S) 20" to 140" (508 - 3556 mm)
- **Flexible PVDF (Kynar)**
 - 65" to 600" (915 - 15240 mm)
 - Probes available in 1" (25 mm) increments

Minimum Liquid / Liquid Interface Measurement:

- $\geq 4.2"$ (100 mm)

Hazardous Area Approvals



Rigid 316 SS Option (B) Probe Only

XP CL I, DIV 1, GRP A,B,C,D T4 (US)
XP CL I, DIV 1, GRP B,C,D T4 (Canada)
DIP CL II, III, DIV 1, GRP E,F,G T4
-40°C \leq Ta \leq +100°C

Hazardous Area Approvals



UltraFlex PVDF Probe

XP-IS CL I, DIV 1, GRP C,D T4
NI CL I, DIV 2, GRP A,B,C,D T4
DIP-IS CL II, III, DIV 1, GRP E,F,G T4
CL I, Zone 0/1, AEx ia/db IIB T4 Ga/Gb
Ex ia/db IIB T4 Ga/Gb FM16CA0180X
-40°C \leq Ta \leq +70°C

ATEX



FM 15 ATEX0022X
II 1/2 G Ex ia/db IIB T4 Ga/Gb
-40°C \leq Ta \leq +70°C

IECEX

IECEX FMG 15.0022X
Ex ia/db IIB T4 Ga/Gb
-40°C \leq Ta \leq +70°C

3A Sanitary Option (S) Probe Only

Note: 3A Sanitary Option (S) Probes and
Food Grade Option (F) Probes

DO NOT have Hazardous Area Approvals.



Installation of PVDF Probe

CAUTION!



Part of the equipment enclosure is constructed of non-metallic material; to prevent the risk of electrostatic sparking, the non-metallic enclosure material should be cleaned only with a damp cloth.



74-06

Section 6

6.2 Terms & Conditions

AMETEK, Inc.

TERMS AND CONDITIONS OF SALE

THE FOLLOWING TERMS/CONDITIONS, TOGETHER WITH ANY OTHER TERMS/CONDITIONS SPECIFICALLY AGREED TO IN WRITING BY SELLER, SHALL APPLY TO ALL ORDERS ("Order(s)") FROM, AND SALES OF PRODUCTS ("Products") OR SERVICES ("Services") TO BUYER. ANY ACCEPTANCE OF ANY ORDER OF BUYER IS CONDITIONED UPON THESE TERMS/CONDITIONS. ANY ADDITIONAL OR DIFFERENT TERMS/CONDITIONS PROPOSED BY BUYER IN ANY DOCUMENT ARE OBJECTED TO AND SHALL NOT BE BINDING UPON SELLER. No salesperson is authorized to bind Seller to any promise or understanding not expressed herein.

I. PRICES All prices are subject to change without notice in the event of any changes in cost of materials or labor, specifications, quantities, delivery schedules, customs duties, other factors beyond Seller's control, or in the event of delays caused by instructions of the Buyer, or failure of the Buyer to give Seller adequate information. Further, prices payable by the Buyer shall be subject to immediate increase, should the Seller as a result of governmental action or regulation including, without limitation, those contemplated by an investigation under Section 232 of the Trade Expansion Act of 1962 (19 U.S.C. §1862), incur additional duties, tariffs or restrictions on products sold hereunder, or on the raw materials that are used in making such products. In no event shall prices include any amounts imposed on the Buyer in connection with Buyer's purchases from Seller, such as taxes, including but not limited to Value Added Tax (VAT) or excise taxes, duties, tariffs, or any other costs assessed against the Buyer by a governmental authority.

II. DELIVERY Delivery dates are approximate and are dependent on prompt receipt by Seller of all necessary information. Seller may deliver all or any part of Products/ Services as early as 30 days in advance of agreed schedule. The point of delivery shall be "Ex-works" Seller's premises, unless otherwise specified by Seller. Upon delivery, title to Products and all risk of loss or damage thereto shall pass to Buyer. Where Buyer notifies Seller that it cannot take timely delivery of the Products, Seller may place such Products in storage, at the risk of Buyer, and Buyer shall reimburse Seller for all expenses incurred in connection with such storage. Buyer shall dispose of the packing materials for Products at its own expense, and shall defend, indemnify and hold harmless Seller from any legal obligations in connection with such packing waste.

III. PAYMENT A. The term of payment shall be net 30 days from date of Seller's invoice, unless otherwise specified. Payments shall be made by Buyer without any deduction or set-off. Unless otherwise agreed, payment shall be made in U.S. dollars. Seller may charge late payment fees at the rate of 1.5% per month, or the highest rate permitted by law, whichever is less, accruing daily.

B. If the financial condition of Buyer is unsatisfactory to Seller, Seller may require full or partial payment in advance, or satisfactory security, in the form of a letter of credit or otherwise. In the event of bankruptcy or insolvency of Buyer, Seller may immediately cancel any Order then outstanding.

C. Buyer grants Seller a purchase money security interest in Products located in the United States, or Services, as well as any proceeds, for the purpose of securing the obligations of Buyer hereunder. Buyer authorizes Seller to execute on Buyer's behalf and file such financing statements as Seller deems appropriate to perfect and notify Buyer's creditors of Seller's security interest.

IV. VARIATIONS IN QUANTITY; CHANGES. Buyer shall accept delivery of quantities greater or smaller than the quantity specified in Order(s), provided that any such variation shall not exceed 5% of the quantity originally specified, or 2 units, whichever is greater. Seller shall not be required to give notice of any such variations other than in the applicable shipping notice and invoice. Seller reserves the option to make changes to Products or Services which do not affect form, fit, or function, and shall deliver Products to the latest configuration part number at the time of delivery.

V. EXPORT CONTROLS; FCPA; ANTI-BOYCOTT

A. Buyer shall not make any disposition of the Products, by way of transshipment, re-export, diversion or otherwise, except as applicable U.S. export laws and regulations may expressly permit, and other than in and to the ultimate country of destination specified on Order(s) or declared as the country of ultimate destination on Seller's invoices or in the End Use Statement that Buyer supplies Seller. Seller shall not be named as shipper or exporter of record or U.S. principal party-in-interest

(USPPI) unless specifically agreed to in writing by Seller in which case, Buyer shall provide Seller with a copy of the documents filed by Buyer for Export clearance purposes. At Seller's request, Buyer shall supply end-use and end-user information to determine export license applicability. Failure of Buyer to comply with this section shall constitute a material default allowing Seller to cancel related Order(s) without liability.

B. Buyer warrants that it shall not violate or cause the Seller to violate the U.S. Foreign Corrupt Practices Act of 1977 (FCPA), as amended, the United Kingdom Bribery Act (UKBA) of 2010, as amended, or their respective implementing regulations in connection with Buyer's sale or distribution of the Products and/or Services, and that Buyer does not know or have reason to believe that any consultant, agent, representative or other person retained by Buyer in connection with the sale and/or distribution of Products/Services has violated, nor caused Seller to violate the FCPA and/or the UKBA. Where Buyer learns of or has reason to know of any violation of FCPA and/or UKBA in connection with the sale or distribution of Products/Services, Buyer shall immediately advise Seller.

C. Buyer further warrants that Buyer shall not violate or cause Seller to violate the U.S. Antiboycott Provisions of the U.S. Export Administration Regulations issued pursuant to the U.S. Export Administration Act of 1979, as amended, in connection with Buyer's purchase of Products/Services and that Buyer shall not request or require Seller to make statements or certifications against countries that are not subject to boycott by the U.S.

VI. WARRANTIES

A. Seller warrants that Products manufactured by Seller, when delivered, shall be free from defects in material/workmanship. Seller warrants that Services shall be performed in accordance with generally accepted industry practice. Seller's obligations under this warranty shall be limited exclusively to repairing or replacing, at Seller's option, any part of Products which, if properly installed, used and maintained, proved to have been defective in material or workmanship within 1 year from the date of shipment, or re-performing the Services. Seller warrants for a period of 1 year from the date of shipment that software or firmware, when used with Products, shall perform in accordance with Seller's published specifications. Seller makes no warranty, express or implied, that the operations of the software or firmware shall be uninterrupted or error-free, or that functions contained therein shall meet or satisfy the Buyer's intended use/requirements. Buyer shall notify Seller of any defect in the quality or condition of Products (including software/firmware) or Services within 7 days of the date of delivery or performance, unless the defect was not apparent on reasonable inspection, in which case, within 7 days after discovery of the defect. If Buyer does not provide such timely notification, it shall not be entitled to reject Products (including software/firmware) or Services, and Seller shall have no liability for such defect.

B. Seller's warranty obligations shall not apply to Products which (1) have been altered or repaired by someone other than Seller, or (2) have been subjected to misuse, neglect, or improper use or application, or (3) are normally consumed in operation, or (4) have a normal life inherently shorter than the warranty period stated therein.

C. No Products may be returned unless authorized in advance by Seller, and then only upon such conditions to which Seller may agree. Buyer must obtain a Return Material Authorization (RMA) number from Seller prior to any return shipment, and such RMA number must appear on the shipping label and packing slip. Buyer shall be responsible for returned Products until such time as Seller receives the same at its facility, and for all charges for packing, inspection, shipping, transportation or insurance associated with returned Products.

D. This section VI sets forth the exclusive remedies and obligations for claims based upon defects in or nonconformity of Products/Services, whether the claim is in contract, warranty, tort (including negligence of any degree or strict liability) or otherwise. **THE FOREGOING WARRANTIES ARE IN LIEU OF ALL OTHER WARRANTIES,**

WHETHER ORAL, WRITTEN, EXPRESS, IMPLIED OR STATUTORY. NO IMPLIED OR STATUTORY WARRANTIES OF MERCHANTABILITY OR FITNESS FOR PARTICULAR PURPOSE SHALL APPLY.

VII. PATENTS/INDEMNITY If Buyer receives a claim that Products, or part thereof manufactured by Seller infringes a patent, Buyer shall notify Seller promptly in writing and give Seller information, assistance and exclusive authority to evaluate, defend and settle such claim. Where Buyer has furnished specifications/designs for the manufacture of the allegedly-infringing Products, Buyer shall defend, indemnify and hold harmless Seller against third-party claims for infringement arising out of Seller's use of such specifications/designs.

VIII. LIMITATION OF LIABILITY
The total liability of Seller on any claim, whether in contract, tort (including negligence of any degree and strict liability) or otherwise arising out of, connected with, or resulting from the manufacture, sale, delivery, resale, repair, replacement or use of any Products/Services, shall not exceed the price allocable to the Products/Services or part thereof which gives rise to the claim. **IN NO EVENT, WHETHER AS A RESULT OF BREACH OF CONTRACT, WARRANTY, TORT, (INCLUDING NEGLIGENCE OF ANY DEGREE, STRICT LIABILITY OR PATENT INFRINGEMENT) OR OTHERWISE, SHALL SELLER, ITS AFFILIATES, SUBCONTRACTORS, OR SUPPLIERS BE LIABLE FOR ANY LOSS OF PROFIT OR REVENUES, LOSS OF USE OF THE PRODUCTS OR SERVICES, OR ANY ASSOCIATED EQUIPMENT, COST OF CAPITAL, COST OF SUBSTITUTE GOODS, FACILITIES, SERVICES OR REPLACEMENT POWER, DOWNTIME COSTS OR CLAIMS OF BUYER'S CUSTOMERS FOR DAMAGES OR FOR ANY SPECIAL, PROXIMATE, CONSEQUENTIAL, INCIDENTAL, INDIRECT OR EXEMPLARY DAMAGES.** If Buyer transfers title to, or leases Products sold hereunder to, or otherwise permits or suffers use by, any third party, Buyer shall obtain from such third party a provision affording Seller and its subcontractors/suppliers the protection of the preceding sentence. Any action against Seller must be brought within 18 months after cause of action accrues.

IX. EXCUSABLE DELAYS A. Seller shall not be liable for delays in delivery or failure to perform due directly or indirectly to causes beyond Seller's reasonable control including but not limited to: acts of God; war; terrorism; civil commotion; riots; embargoes; government regulations, orders, instructions or priorities; port congestion; acts of or failure to act on the part of Buyer or its agents/employees; fires; floods; sabotage; nuclear incidents; earthquakes; storms; epidemics; strikes; lockouts or other labor difficulties; shortages of or inability to timely obtain proper labor, materials, components, shipping space or transportation, fuel, supplies or power at current prices; or due to limitations imposed by the extent of availability of Seller's normal manufacturing facilities.
B. If a delay excused per the above extends for more than 90 days and the parties have not agreed upon a revised basis for continuing providing Products/Services at the end of the delay, including adjustment of the price, then either party (except where delay is caused by Buyer, in which event only Seller) upon thirty (30) days' notice may terminate the Order with respect to the unexecuted portion of the Products/Services, whereupon Buyer shall promptly pay Seller its reasonable termination charges upon submission of Seller's invoices thereof.

X. SOFTWARE/TECHNICAL/PROPRIETARY INFORMATION
A. Buyer shall not acquire any rights to any software which may be delivered with Products, except as granted in Seller's standard software license. Any software license granted in connection with Products shall be an interim license, which may be withdrawn, pending payment for Products in full.
B. The purchase of Products shall not include any right to supply of technical information such as drawings or specifications.
C. Proprietary information, including drawings, documents, technical data, reports, software, designs, inventions and other technical information supplied by Seller in connection herewith (hereinafter called "Data"), shall remain Seller's sole property and shall be held in confidence by Buyer. Data shall not be reproduced, used or disclosed to others by Buyer without

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Seller's prior written consent. Upon completion of Order, Buyer shall promptly return all Data to Seller together with all copies or reprints thereof then in Buyer's possession or control, and Buyer shall thereafter make no future use, either directly or indirectly, of any Data or any information derived therefrom without Seller's prior written consent. The foregoing shall in no way obligate Seller to provide or supply Data.

XI. DIES, TOOLS, PATTERNS Seller's charges for dies, molds, patterns and the like represent the Buyer's proportionate cost thereof, it being expressly understood that they remain the property of Seller. Modifications made to dies, molds, patterns and the like in order to manufacture Products shall be at the discretion of Seller.

XII. GENERAL A. The rights and obligations of the Buyer and Seller hereunder shall be governed in all respects by the law of the Commonwealth of Pennsylvania, U.S.A. The exclusive forum for adjudication of any disputes shall be the federal or state courts of the Commonwealth of Pennsylvania, and Buyer/Seller hereby consent to personal jurisdiction and venue in such courts in any proceeding. The United Nations Convention on the International Sale of Goods shall not apply.
B. These Terms and Conditions of Sale together with any other terms specifically agreed to in writing by Seller constitute the entire agreement between Buyer and Seller and supersede any prior or contemporaneous representations, agreements, proposals, warranties, or understandings, oral or written, express or implied. No waiver, modification, amendment, rescission or other change to these Terms and Conditions of Sale shall be binding unless specifically agreed to in writing by an authorized representative of Seller.
C. The invalidity, of any part hereof shall not affect the validity of the remainder. The failure of Seller to assert any right at any time hereunder shall not prevent Seller's subsequent assertion of the same or different rights.
D. Buyer may not assign this contract without the prior written approval of the Seller.

XIII. PROHIBITION FOR HAZARDOUS USE
Products sold hereunder are not intended for application in, and shall not be used by Buyer in construction or application of a nuclear installation or in connection with use or handling of nuclear material or for any hazardous activity or critical application, where failure of a single component could cause substantial harm to persons or property, unless Products have been specifically approved for such activity or application. Seller disclaims all liability for loss or damage resulting from such unauthorized use and Buyer shall defend, hold harmless and indemnify Seller against any such liability, whether arising under breach of contract, warranty, tort (regardless of the degree of fault or negligence), strict liability or otherwise.

Where Seller approves the application of the Products in a nuclear facility, the Buyer shall, before such use or provision, arrange for insurance or governmental indemnity protecting the Seller against liability and hereby releases and agrees to indemnify the Seller and its suppliers for any nuclear damage, including loss of use, in any manner arising out of a nuclear incident, whether alleged to be due, in whole or in part to the negligence or otherwise of the Seller or its suppliers.

XIV. STATUTORY REQUIREMENTS
Seller reserves the right to make any changes in the general specifications of the Products which are required for the Products to conform to any statutory requirement.

XV. GOVERNMENT CONTRACTS
Only Federal Acquisition Regulation ("FAR") supplement clauses expressly accepted in writing by Seller shall be included or incorporated by reference herein. Seller shall not be bound by and makes no representation of compliance with any FAR or FAR supplement clauses that Seller shall not have expressly accepted in writing.

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