ACE

DOWNHOLE

ESP Downhole Sensor System

User Manual

Version 4.0—August 2025

ACE Downhole Terms and Conditions of Sale

Customer and ChampionX LLC, ACE Downhole brand ("ACE") agree that the purchase and sales of ACE hardware and software products ("the Products") are made under these terms and conditions, and the parties SHALL NOT BE BOUND BY CUSTOMER'S ADDITIONAL OR DIFFERENT TERMS. Customer's order and purchase of the Products shall constitute acceptance of these terms and conditions.

1. TITLE. Title to the Products shall pass at ACE's plant; however, if Customer is the United States or any political subdivision of the United States, title shall pass at Customer's plant. ACE retains a security interest and right of possession in the Products until Customer makes full payment.

2. TAXES. Product prices are exclusive of, and Customer shall pay, applicable sales, use, service, value added or like taxes, unless Customer has provided ACE with an appropriate exemption certificate for the delivery destination acceptable to the applicable taxing authorities.

3. PRICES AND PAYMENT. All quotations shall expire sixty (60) days from date of issuance, unless otherwise set forth on the quotation or agreed in writing. Customer shall make payment in full prior to or upon delivery by cashier's check, credit card, or money order, unless ACE approves Customer for credit terms. If ACE approves Customer's credit application, payment shall be due no later than 30 days from the date of ACE 's invoice. All sums not paid when due shall accrue interest daily at the lesser of a monthly rate of 1.5% or the highest rate permissible by law on the unpaid balance until paid in full. Payments for orders shall be made in U.S. Dollars. In the event of any order for several units, each unit(s) will be invoiced when shipped. Exceptions may be made for government purchase orders.

4. ORDERS. All orders are subject to acceptance by ACE. ACE 's booking of an order shall constitute its acceptance of an order.

5. DELIVERY. ACE shall deliver the Products to a carrier at ACE 's plant and, if the Products are sold to a Customer outside the United States, shall clear the Products for export destined outside the United States. Customer shall pay all freight charges, applicable import duties, and other necessary fees and shall bear the risks of carrying out customs formalities and clearance. Orders are entered as close as possible to the Customer's requested shipment date, if any. Shipment dates are scheduled after acceptance of orders and receipt of necessary documents. Claims for shipment shortage shall be deemed waived unless presented to ACE in writing within twenty-one (21) days of shipment.

6. LIMITED WARRANTY. ACE hardware Products are warranted against defects in materials and workmanship for two years from the date ACE ships the Products to Customer. All software Products are licensed to Customer under the terms of the appropriate ACE license. For a period of ninety (90) days from the Delivery Date, ACE software Products (when properly installed) (a) will perform substantially in accordance with the accompanying written materials, and (b) the medium on which the software product is recorded will be free from defects in materials and workmanship under normal use and service. Any replacement of a licensed software product will be warranted for the remainder of the original warranty period or thirty (30) days, whichever is longer. Customer must obtain a Return Material Authorization number from ACE before returning any Products under warranty to ACE. Customer shall pay expenses for shipment of repaired or replacement Products to and from ACE. After examining and testing a returned product, if ACE concludes that a returned product is not defective, Customer will be notified, the product returned at Customer's expense, and a charge made for examination and testing. This Limited Warranty is void if failure of the Products has resulted from accident, abuse, misapplication, improper calibration by Customer, Customer supplied third party software not intended for use with the applicable ACE software, utilization of an improper hardware or software key or unauthorized maintenance or repair.

7. CUSTOMER REMEDIES. ACE 's sole obligation (and Customer's sole remedy) with respect to the foregoing Limited Warranty shall be to, at its option, return the fees paid or repair/replace any defective Products, provided that ACE receives written notice of such defects during the applicable warranty period. Customer may not bring an action to enforce its remedies under the foregoing Limited Warranty more than one (1) year after the accrual of such cause of action.

8. NO OTHER WARRANTIES. EXCEPT ACE EXPRESSLY SET FORTH ABOVE, THE PRODUCTS ARE PROVIDED "AS IS" WITHOUT WARRANTY OF ANY KIND, AND NO OTHER WARRANTIES, EITHER EXPRESSED OR IMPLIED ARE MADE WITH RESPECT TO THE PRODUCTS, INCLUDING BUT NOT LIMITED TO ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, TITLE OR NON-INFRINGEMENT OR ANY OTHER WARRANTIES THAT MAY ARISE FROM USAGE OF TRADE OR COURSE OF DEALING. ACE DOES NOT WARRANT, GUARANTEE, OR MAKE ANY REPRESENTATIONS REGARDING THE USE OF OR THE RESULTS OF THE USE OF THE PRODUCTS IN TERMS OF CORRECTNESS, ACCURACY, RELIABILITY, OR

OTHERWISE AND DOES NOT WARRANT THAT THE OPERATION OF THE PRODUCTS WILL BE UNINTERRUPTED OR ERROR FREE. ACE EXPRESSLY DISCLAIMS ANY WARRANTIES NOT STATED HEREIN.

9. NO LIABILITY FOR CONSEQUENTIAL DAMAGES. The entire liability of ACE and its licensors, distributors, and suppliers (including its and their directors, officers, employees, and agents) is set forth above. To the maximum extent permitted by applicable law, in no event shall ACE and its licensors, distributors, and suppliers (including its and their directors, officers, employees, and agents) be liable for any damages, including, but not limited to, any special, direct, indirect, incidental, exemplary, or consequential damages, expenses, lost profits, lost savings, business interruption, lost business information, or any other damages arising out of the use or inability to use the Products, even if ACE or its licensors, distributors, and suppliers have been advised of the possibility of such damages. Customer acknowledges that the applicable purchase price or license fee for the Products reflects this allocation of risk. Because some states/jurisdictions do not allow the exclusion or limitation of liability for consequential or incidental damages, the above limitation may not apply. If the foregoing limitation of liability is not enforceable because an ACE product sold or licensed to Customer is determined by a court of competent jurisdiction in a final, non-appealable judgment to be defective and to have directly caused bodily injury, death, or property damage, in no event shall ACE 's liability for property damage exceed the greater of $5,000 or fees paid for the specific product that caused such damage.

10. WARNING: (1) ACE PRODUCTS ARE NOT DESIGNED WITH COMPONENTS AND TESTING FOR A LEVEL OF RELIABILITY SUITABLE FOR USE IN OR IN CONNECTION WITH SURGICAL IMPLANTS OR ACE CRITICAL COMPONENTS IN ANY LIFE SUPPORT SYSTEMS WHOSE FAILURE TO PERFORM CAN REASONABLY BE EXPECTED TO CAUSE SIGNIFICANT INJURY TO A HUMAN. (2) IN ANY APPLICATION, INCLUDING THE ABOVE, RELIABILITY OF OPERATION OF THE SOFTWARE PRODUCTS CAN BE IMPAIRED BY ADVERSE FACTORS, INCLUDING BUT NOT LIMITED TO FLUCTUATIONS IN ELECTRICAL POWER SUPPLY, COMPUTER HARDWARE MALFUNCTIONS, COMPUTER OPERATING SYSTEM SOFTWARE FITNESS, FITNESS OF COMPILERS AND DEVELOPMENT SOFTWARE USED TO DEVELOP AN APPLICATION, INSTALLATION ERRORS, SOFTWARE AND HARDWARE COMPATIBILITY PROBLEMS, MALFUNCTIONS OR FAILURES OF ELECTRONIC MONITORING OR CONTROL DEVICES, TRANSIENT FAILURES OF ELECTRONIC SYSTEMS (HARDWARE AND/OR SOFTWARE), UNANTICIPATED USES OR MISUSES, OR ERRORS ON THE PART OF THE USER OR APPLICATIONS DESIGNER (ADVERSE FACTORS SUCH AS THESE ARE HEREAFTER COLLECTIVELY TERMED "SYSTEM FAILURES"). ANY APPLICATION WHERE A SYSTEM FAILURE WOULD CREATE A RISK OF HARM TO PROPERTY OR PERSONS (INCLUDING THE RISK OF BODILY INJURY AND DEATH) SHOULD NOT BE RELIANT SOLELY UPON ONE FORM OF ELECTRONIC SYSTEM DUE TO THE RISK OF SYSTEM FAILURE. TO AVOID DAMAGE, INJURY, OR DEATH, THE USER OR APPLICATION DESIGNER MUST TAKE REASONABLY PRUDENT STEPS TO PROTECT AGAINST SYSTEM FAILURES, INCLUDING BUT NOT LIMITED TO BACK-UP OR SHUT DOWN MECHANISMS. BECAUSE EACH END-USER SYSTEM IS CUSTOMIZED AND DIFFERS FROM ACE 'S TESTING PLATFORMS AND BECAUSE A USER OR APPLICATION DESIGNER MAY USE ACE PRODUCTS IN COMBINATION WITH OTHER PRODUCTS IN A MANNER NOT EVALUATED OR CONTEMPLATED BY ACE , THE USER OR APPLICATION DESIGNER IS ULTIMATELY RESPONSIBLE FOR VERIFYING AND VALIDATING THE SUITABILITY OF ACE PRODUCTS WHENEVER ACE PRODUCTS ARE INCORPORATED IN A SYSTEM OR APPLICATION, INCLUDING, WITHOUT LIMITATION, THE APPROPRIATE DESIGN, PROCESS AND SAFETY LEVEL OF SUCH SYSTEM OR APPLICATION.

11. FORCE MAJEURE. ACE shall be excused for any delay or failure to perform due to any cause beyond its reasonable control, including but not limited to acts of governments, natural catastrophes, acts of Customer, interruptions of transportation or inability to obtain necessary labor or materials. ACE 's estimated shipping schedule shall be extended by a period of time equal to the time lost because of any excusable delay. In the event ACE is unable to perform in whole or in part because of any excusable failure to perform, ACE may cancel orders without liability to Customer.

12. LIMITED INDEMNITY AGAINST INFRINGEMENT. ACE shall, at its own expense, defend any litigation resulting from sales of the Products to the extent that such litigation alleges that the Products or any part thereof infringes any United States patent, copyright, or trademark, provided that such claim does not arise from the use of the Products in combination with equipment or devices not made by ACE or from modification of the Products, and further provided that Customer notifies ACE immediately upon its obtaining notice of such impending claim and cooperates fully with ACE in preparing a defense. If Customer provides to ACE the authority, assistance, and information ACE needs to defend or settle such claim, ACE shall pay any final award of damages in such suit and any expense Customer incurs at ACE 's written request, but ACE shall not be liable for a settlement made without its prior written consent. If the Products are held to be infringing and the use thereof is enjoined, ACE shall, at its option, either (i) procure for the Customer the right to use the Products, (ii) replace the Products with others which do not constitute infringement, or (iii) remove the infringing Products and refund the payment(s) made therefore by Customer. The foregoing states the Customer's sole remedy for, and ACE 's entire liability and responsibility for, infringement of any patent, trademark, or copyright relating to the Products provided hereunder. THIS LIMITED INDEMNITY IS IN LIEU OF ANY OTHER STATUTORY OR IMPLIED WARRANTY AGAINST INFRINGEMENT.

13. ACKNOWLEDGMENT/GOVERNING LAW. Customer acknowledges reading these Terms and Conditions, under-stands them and agrees to be bound by them. A waiver of any provision of this agreement shall not be construed as a waiver

or modification of any other term hereof. With respect to all orders accepted by ACE, disputes arising in connection with these Terms and Conditions of Sale shall be governed by the laws of the State of Oklahoma without regard to principles of conflicts of laws.

14. APPLICATION LIABILITY. ACE assumes the buyer to be an expert in his intended application of ACE products. ACE claims no special expertise in the application of its products into the buyer's equipment. ACE accepts no responsibility for the buyer's selection and use of ACE products. Buyer's interpretation and implementation of application suggestions and recommendations by ACE, general or specific, transmitted verbally, electronically or in writing, published or unpublished, is strictly at the buyers own risk.

15. NOTICES:

    - A. ACE Sensors are covered by patents 8149552, 9602100, 10012551 with other patents pending.
    - B. SRU / SRU2i / SRU3i / HVI Components Conforms to UL Std. 61010-1
    - C. SRU / SRU2i/ SRU3i / HVI Components Certified to CAN/CSA Std. C22.2# 61010-1

Table of Contents

Safety Instructions

Warnings in this manual appear in two ways:

Danger warnings – The danger warning symbol is an exclamation mark enclosed in a triangle which precedes letters spelling the word "DANGER". The Danger warning symbol is used to indicate situations, locations and conditions that can cause serious injury or death:

 DANGER

Caution Warnings - The caution warning symbol is an exclamation mark enclosed in a triangle which precedes letters spelling the word "CAUTION". The Caution warning symbol is used to indicate situations and conditions that can cause operator injury and/or equipment damage:

 CAUTION

Other warning symbols may appear along with the Danger and Caution symbol and are used to specify special hazards. These warnings describe particular areas where special care and/or procedures are required in order to prevent serious injury and possible death.

Electrical Warnings – The electrical warning symbol is a lightning bolt mark enclosed in a triangle. The electrical warning symbol is used to indicate high voltage locations and conditions that may cause serious injury or death if proper precautions are not observed:

For the purposes of this manual and product labels, a Qualified Person is one who is familiar with the installation, construction, operation, and maintenance of the equipment and the hazards involved. This person must do the following:

1. Carefully read and understand the entire manual.
2. Be trained and authorized to safely energize, de-energize, clear faults, ground, lockout and tag circuits and equipment in accordance with established safety practices.
3. Be trained in the proper care and use of protective equipment such as safety shoes, rubber gloves, hard hats, safety glasses, face shields etc. in accordance with established safety practices.
4. Be trained in rendering first aid.

Specifications

Note: Specifications are subject to change.

Downhole Instruments (without motor adapter)

	ACE Xtreme	ACE Xtreme Dual
Intake Pressure	0-6000 psi; 0-8000 psi; 0-10000 psi	0-6000 psi; 0-8000 psi; 0-10000 psi
Intake Pressure Accuracy	+/- 0.1% Typical 0.2% FS	+/- 0.1% Typical 0.2% FS
Intake Pressure Resolution	1 PSI SRU, 0.1psi SRU2, 0.01psi Spooler and SRU3i	1 PSI SRU, 0.1psi SRU2, 0.01psi Spooler and SRU3i
Transducer Type	Digital Strain Gauge	Digital Strain Gauge
Discharge Pressure Range	N/A	0-6000 psi; 0-8000 psi; 0-10000 psi
Discharge Pressure Accuracy	N/A	+/- 0.1% Typical 0.2% FS (optional)
Discharge Pressure Resolution	N/A	1 PSI SRU, 0.1psi SRU2
Intake Temperature Range	32°F–350°F, 0°C–177°C	32°F–350°F, 0°C–177°C
Intake Temperature Accuracy	3.5°F, 2°C	3.5°F, 2°C
Intake Temperature Resolution	1°F SRU, 0.1°F SRU2, 0.01°F Spooler and SRU3i	1°F SRU, 0.1°F SRU2, 0.01°F Spooler and SRU3i
Motor Winding Temperature Range*	32°F–600°F, 0°C–316°C	32°F–600°F, 0°C–316°C
Motor Winding Temperature Accuracy*	3.5°F, 2°C	3.5°F, 2°C
Motor Winding Temperature Resolution*	1°F SRU, 0.1°F SRU2, 0.01°F Spooler and SRU3i	1°F SRU, 0.1°F SRU2, 0.01°F Spooler and SRU3i
Vibration Range	0–10G	0–10G
Vibration Accuracy	0,50%	0,50%
Vibration Resolution	0.01G	0.01G
ESP Insulation Resistance	50 kOmhs–60 MegOhms. Indicates "<50k" and ">60 MEG" if IR is outside of the range.	50 kOmhs–60 MegOhms. Indicates "<50k" and ">60 MEG" if IR is outside of the range.
Maximum Motor Voltage	4160 VAC	4160 VAC
Physical Diameter	3.72" or 3.94" **	3.94" **
Physical Length	18.5"	23.0"
Physical Weight	42 lbs, 19 kG	44 lbs, 20 kG
Material	316 SS	316 SS

*Available with an RTD or a Thermocouple interface

**ACE Xtreme sensors with 3.94" OD are rated up to 11,000 PSI.

Downhole Adapters (connects instruments to motors)

Motor Size	Diameter	Length	Weight	Metallurgy
375	3.75″	7.5″	11 lbs.	316 SS
456	4.56″	8.0″	17 lbs.	316 SS
540	5.4″	8.0″	20 lbs.	316 SS
562	5.62″	8.0″	22 lbs.	316 SS
456/540/562 Generic	4.56″	4.5″	9 lbs.	1020 CS or 316 SS

Surface Readout SRU

Power Required	115VAC +/- 15% 50/60Hz
Display Type	6-digit Alphanumeric LED
Motor Controller Connection (Isolated)	iCON Series Interface. Support for legacy (F3/F5 Commander series) controllers.
Modbus RS-485 (Isolated)	3-wire standard.
Modbus RS-232 (Isolated)	3-wire, no handshaking required.
Operating Temperature	0°F–158°F, -18°C–50°C
Dimensions	6.00″ x 5.25″ x 2.25″
Weight	1.5 lbs
UL Certification	Conforms to UL Std. 61010-1
CSA Certification	Certified to CAN/CSA Std. C22.2# 61010-1
Note: SRU does not support ESP insulation resistance monitoring	

Surface Readout SRU2i

Power Required	115VAC +/- 15% 50/60Hz
Display Type	8-digit Alphanumeric LED
Motor Controller Connection (Isolated)	iCON Series Interface. Support for legacy (F3/F5 Commander series) controllers plus additional RS-485 Modbus port.
Modbus RS-485 (Isolated)	3-wire standard.
Modbus RS-232 (Isolated)	3-wire, no handshaking required.
USB Modbus (Isolated)	Standard USB-B
Ethernet Modbus (Isolated)	Standard CAT5E 8 Pin connector.
Analog Outputs (Isolated)	4x 0-20mA User configurable (SRU2 sources power)
Relay Outputs (Isolated)	2x Form C User configurable 240VAC / 8 Amps
SD Datalogger	Up to 32 GB (SDHC mode supported).
Internal Memory (SRU2X version)	32 GB
Operating Temperature	0°F - 158°F, -18°C to 50°C
Dimensions	9.50″ x 5.75″ x 1.75″
Weight	2.0 lbs
ESP Insulation Resistance Monitoring Range. Used for ESP motor and cable run life prediction.	50 KOhms to 60 Meg Ohms (displayed in KOhms). If IR is less than 50 KOhms, it displays "<50k." If IR is greater than 60MOhm, it displays ">60MEG."
ESP Insulation Resistance Resolution	1000 Ohms.
UL Certification	Conforms to UL Std. 61010-1
CSA Certification	Certified to CAN/CSA Std. C22.2# 61010-1

Surface Readout SRU3i

Power Required	115 VAC +/- 15% 50/60Hz
Modbus RS-485 (Isolated)	3-wire standard
Modbus RS-232 (Isolated)	3-wire standard
USB Modbus (Isolated)	Standard USB-B
CITIbus VSD Interface (Isolated)	Transparent pass through, emulates RDCM
CITIbus Power Consumption	Zero
CITIbus Centinel Interface Module Compatible	Yes
CITIbus Centinel Power Supply Compatible	Yes
CITIbus RDCM Compatible	No
CITIbus Modes Supported	GCS Legacy CITIbus and Advantage CITIbus
Wi-Fi Interface	Standard worldwide, license free 802.11 b/g/n
Cable Insulation Measurement Range	50 KOhms to 60 MegOhms
Cable Insulation Measurement Resolution	1K Ohms
Operating Temperature	0°F to 158°F, -18°C to 50°C
Dimensions	7.38"x 5.75" x 1.75"
Weight	2 lb
ESP Insulation Resistance Monitoring Range. Used for ESP motor and cable run life prediction.	50 KOhms to 60 Meg Ohms (displayed in KOhms). If IR is less than 50 KOhms, it displays "<50k." If IR is greater than 60MOhm, it displays ">60MEG."
ESP Insulation Resistance Resolution	1000 Ohms
UL Certification	Conforms to UL Std. 61010-1
CSA Certification	Certified to CAN/CSA Std. C22.2# 61010-1

High Voltage Interface (HVI)

Maximum AC Voltage	5000 VAC
Fuse Rating	1/8 Amp (Buss HVJ-1/8)
MOV type	Field replaceable
Enclosure Type	NEMA 4, 4X, 12, 13
Operating Temperature	0°F - 158°F, -18°C to 70°C
Dimensions	18" x 16" x 9"
Weight (in enclosure)	53 lbs
UL Certification	Conforms to UL Std. 61010-1
CSA Certification	Certified to CAN/CSA Std. C22.2# 61010-1

SRU / SRU2i / SRU3i / HVI Conform to UL Std. 61010-1

SRU / SRU2i / SRU3i / HVI Certified to CAN/CSA Std. C22.2# 61010-1

SRU Menus

It will take a minute or two for the SRU to display values from the instrument, depending on the instrument model. Different channels will contain values.

Below are the SRU menus. Items marked * are adjustable. As an example of how to make changes, such as how to change the Modbus Baud rate, use the up and down keys to navigate to Menu 19. Press **Enter**. The parameter will start to flash. Use the up and down keys to change the parameter. Press Enter again to save the modified parameter or Cancel to leave the parameter unchanged.

1	Instrument temperature °F (resolution 0.1°F)
2	Intake Pressure PSI (resolution of 1 PSI SRU, 0.1 PSI SRU2)
3	Winding Temperature °F (resolution 0.1°F)
4	X Vibration (x0.001 G)
5	Y Vibration (x0.001 G)
6	Discharge Pressure PSI (resolution of 1 PSI SRU, 0.1 PSI SRU2)
7	Reserved for future use
8	Reserved for future use
9	* Number of channels to read
10	* *Output Voltage set point* (default 3250)
11	Measured output Voltage
12	*Instrument current* (0-1023)
13	*Instrument threshold* (0-1023)
14	*Surface unit DC Voltage* (SRU only) *Total number of data packets received* (SRU2/SRU3 FW 4.3 or higher only)
15	Decode state
16	*Cutoff filter frequency*
17	*Total number of data packets received*
18	*Number of bad data packets received*
19	* Modbus Baud rate
20	* Modbus ID
21	* Modbus gap time
22	*Auto Adjust Threshold*
23	* Instrument Pressure Range
24	* *Factory access code*
Menus 25 to 33 are for extended functions of the SRU2, they do not exist on the SRU. See the following table for the complete SRU2 menu map and navigation structure.	
25	Ethernet IP address, net mask and port
26	Real time clock settings, date and time.
27	Relay 1 settings; Modbus register to use, on and off setpoints.
28	Relay 2 settings; Modbus register to use, on and off setpoints.
29	Analog Output 1 settings; Modbus register to use, process and output values.
30	Analog Output 2 settings; Modbus register to use, process and output values.
31	Analog Output 3 settings; Modbus register to use, process and output values.

32	Analog Output 4 settings; Modbus register to use, process and output values.
33	SD Card Datalogging. Card data flush, logging enable, sample rate and filename.
34	Insulation Monitoring. (SRU2xi versions)
* indicates adjustable	*italics* indicate diagnostic use

Typically up to the first six menus will be used. The remaining menus are for system diagnostics, configuration, and troubleshooting.

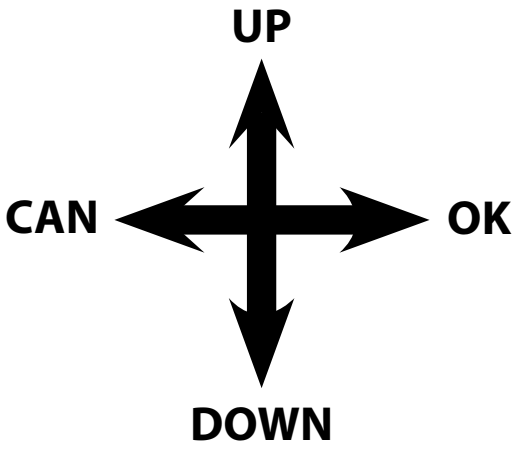
The SRU may be used to directly identify problems in the system, refer to a later section for a detailed troubleshooting guide.

Once the system has been verified, remove power to the SRU, wait a few seconds, and then remove the signal and signal ground lead. The system may now be run downhole. A run-in may be paused at any time, and insulation and system integrity tests may be performed to verify good downhole cable, motor, and instrument integrity.

When the installation is complete, ensure the SRU is connected to the HVI unit. Power may be applied to the SRU, and readings from the downhole instrument should appear within a couple of minutes. The motor may now be started, and the system may be put into service.

SRU Menu Navigation

Note: To switch between the numeric and alpha menus, press the **Up** and **Down** keys together.



Numeric	Alpha	Menu		
1	TI	Intake Temperature	Highest Since Power Up (HI)	Highest Ever (HE)
2	PI	Intake Pressure	Highest Since Power Up (HI)	Highest Ever (HE)
3	TW	Winding Temperature	Highest Since Power Up (HI)	Highest Ever (HE)
4	Vx	Vibration X	Highest Since Power Up (HI)	Highest Ever (HE)
5	Vy	Vibration Y	Highest Since Power Up (HI)	Highest Ever (HE)

Numeric	Alpha	Menu		
6	PD	Discharge Pressure	Highest Since Power Up (HI)	Highest Ever (HE)
7	TD	Discharge Temperature	Highest Since Power Up (HI)	Highest Ever (HE)
8	X8	Option Channel	Highest Since Power Up (HI)	Highest Ever (HE)
9	CH	Number of channels	Adjust setpoint	
10	VS	Voltage Setpoint	Adjust Setpoint	
11	Vo	Voltage Output (Measured)		
12	Io	Current Output (Measured)		
13	Th	Threshold		
14	PS	Internal DC Voltage (SRU only)		
15	dE	Decode state		
16	LP	Lowpass Filter	Adjust Setpoint	
17	PG	Good Packets Received		
18	PB	Bad Packets Received		
19	Bd	Modbus Serial Baud rate	Adjust Setpoint	
20	Id	Modbus ID	Adjust Setpoint	
21	GA	Modbus Gap time (mS)	Adjust Setpoint	
22	22	Comm reset Threshold		
23	Pr	Instrument Pressure Rating	Adjust Setpoint	
24	FA	Factory Diagnostics	Test number – See below	
25	IP→	Ethernet Enable (IE)	Adjust Setpoint	Submenu 78
		IP Address 1 (I1)	Adjust Setpoint	79
		IP Address 2 (I2)	Adjust Setpoint	80
		IP Address 3 (I3)	Adjust Setpoint	81
		IP Address 4 (I4)	Adjust Setpoint	82
		IP Netmask 1 (N1)	Adjust Setpoint	83
		IP Netmask 2 (N2)	Adjust Setpoint	84
		IP Netmask 3 (N3)	Adjust Setpoint	85
		IP Netmask 4 (N4)	Adjust Setpoint	86
		Ethernet TCP Port (IT)	Adjust Setpoint	87
		Ethernet RTU Port (IC)	Adjust Setpoint	>1
26	CL→	Clock Month (MO)	Adjust Setpoint	88
		Clock Day (dA)	Adjust Setpoint	89
		Clock Year (YE)	Adjust Setpoint	90
		Clock Hour (HR)	Adjust Setpoint	91
		Clock Minutes (MN)	Adjust Setpoint	92
		Clock Seconds (SE)	Adjust Setpoint	93

Numeric	Alpha	Menu		
27	R1→	Relay 1 Control Register (RG)	Adjust Setpoint	52
		Relay 1 On setpoint (ON)	Adjust Setpoint	53
		Relay 1 Off setpoint (OF)	Adjust Setpoint	54
28	R2→	Relay 2 Control Register (RG)	Adjust Setpoint	55
		Relay 2 On setpoint (ON)	Adjust Setpoint	56
		Relay 2 Off setpoint (OF)	Adjust Setpoint	57
29	A1→	Analog1 Control Register (RG)	Adjust Setpoint	58
		Analog1 Process 1 value (P1)	Adjust Setpoint	59
		Analog1 Process 2 value (P2)	Adjust Setpoint	60
		Analog1 Output 1 value (O1)	Adjust Setpoint	61
		Analog1 Output 2 value (O2)	Adjust Setpoint	62
30	A2→	Analog 2 Control Register (RG)	Adjust Setpoint	63
		Analog 2 Process 1 value (P1)	Adjust Setpoint	64
		Analog 2 Process 2 value (P2)	Adjust Setpoint	65
		Analog 2 Output 2 value (O2)	Adjust Setpoint	66
		Analog 2 Output 1 value (O1)	Adjust Setpoint	67
31	A3→	Analog 3 Control Register (RG)	Adjust Setpoint	68
		Analog 3 Process 1 value (P1)	Adjust Setpoint	69
		Analog 3 Process 2 value (P2)	Adjust Setpoint	70
		Analog 3 Output 1 value (O1)	Adjust Setpoint	71
		Analog 3 Output 2 value (O2)	Adjust Setpoint	72
32	A4→	Analog 4 Control Register (RG)	Adjust Setpoint	73
		Analog 4 Process 1 value (P1)	Adjust Setpoint	74
		Analog 4 Process 2 value (P2)	Adjust Setpoint	75
		Analog 4 Output 1 value (O1)	Adjust Setpoint	76

Numeric	Alpha	Menu		
		Analog 4 Output 2 value (O2)	Adjust Setpoint	77
33		SD Logging Flush Card (LF)	Adjust Setpoint	94
		SD Logging Enable (LE)	Adjust Setpoint	95
	LG→	SD Logging Rate (LP)	Adjust Setpoint	96
		SD Logging File Name 1 (N1)	Adjust Setpoint	97
		SD Logging File Name 2 (N2)	Adjust Setpoint	98
		SD Logging File Name 3 (N3)	Adjust Setpoint	99
		SD Logging File Name 4 (N4)	Adjust Setpoint	>0
>2	IN→	Insulation Monitoring Reading (ME)	Take Measurement	>3
		Insulation Reading Delay in hours (dE)	Set Automatic Reading Delay	>4

Factory Tests / Diagnostics. Enter following values at menu 24:	
0	Exit running test modes
1	Display digit test and SRU2 LED test
2	Display sw versions
14	Display SD card error code
15	Display card error status code
16	Display card error function code
17	Display runtime
19	Display SRU hardware version
20	Resets packet counts
21	Clear highs since power up
22	Clear stored high values. Must be unlocked first
23	Start output test for relays and analog outputs for 2 minutes – use caution!
30	Starts generating test values for all channels – use caution!
31	Unlocks readout for 1 minute

Introduction

The ACE Downhole monitoring system collects downhole fluid and equipment data and transmits it to the surface in real time for display, control, and logging purposes. The system operates in conjunction with electrical submersible pumps (ESP), which transmit the downhole data to the surface via the motor power cable.

The ACE instrument utilizes a patented electronic method that protects the device during high voltage and motor current overloads, which often prove damaging to other instruments. As a result, ACE's downhole instrument is much more reliable than competing units. In addition, it is less than half the size and weight of those other units.

The ACE downhole unit is a completely sealed and welded device. As a result, the electronics are not exposed to damaging well fluid that can be caused by leaking threads, seals, O-rings, drain valves or fill valves.

The downhole instrument works with a motor adapter, ensuring industry compatibility on all brands of oil field submersible pump motors. The surface high voltage protection package will directly mount inside or outside most switchboards, variable speed drives, or high voltage transformer packages and will operate accurately and reliably.

The compact surface readout options provide direct connection to the industry standard iCON motor controller and support direct connection to the legacy Commander F3/F5 series controllers. All readings from the surface readout are automatically accessible in the motor controller where they may be used for motor control and data logging. ACE Downhole offers three varieties of surface readouts:

SRU	**SRU2i**	**SRU3i**
RS-485 and RS-232 Modbus ports	Same benefits as SRU	Same benefits as SRU
	32GB of fixed internal memory	Direct CITIbus connection to Baker Hughes VSDs
	Higher-resolution display	Wi-Fi local connection
	Ethernet, USB, analog outputs and relays	
	Built-in datalogging capabilities that record on SD cards	

There are two portable test units available. A self-powered surface readout and downhole tester provide quick and easy verification of the system's integrity. The compact instrument simulator allows for quick verification of the installed surface equipment and simulates signals for testing connections to the control and SCADA systems.

System Parts and Instructions

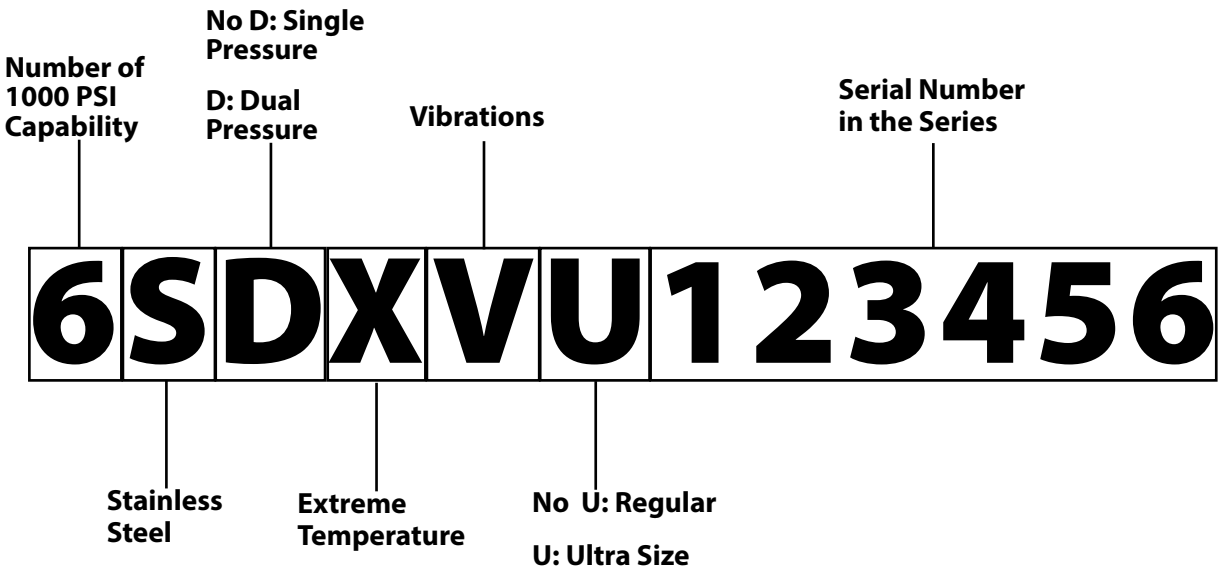
Downhole Instrument

The downhole instrument consists of a completely sealed steel cylinder, approximately 18 inches long (or 22 inches long for the dual pressure input version) and 3.72 inches (or 3.94 inches for the Ultra version) in diameter. The instrument contains various transducers and the device electronics; there are no serviceable parts inside available to users.

At the bottom of the instrument, there is a 2 3/8-inch 8 RND EUE female thread (industry standard) that may be used to mount any additional downhole components, such as sacrificial electrodes.

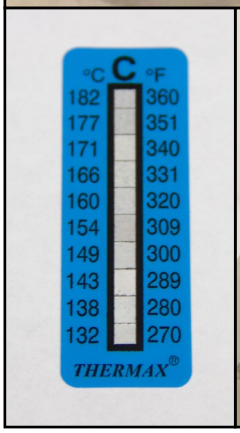
The head of the instrument houses two or three, depending on the version, high-voltage and pressure related connector pins. The smaller pin provides one or two electrical connection to the winding or motor oil temperature transducer. The larger pin or pins provide the electrical connection to a bolted-on motor adapter, which can be bolted to the motor. In addition to those pins, there are a pressure port and a safety-release valve.

Instrument Identification



The first number identifies the pressure rating in 1000 PSI, and may be 6, 8, or 10. The second character identifies the metallurgy, S for stainless steel. D is an optional character and indicates dual pressure input. T is also optional and indicates the thermocouple option. X indicates the extreme temperature rating. V means that the unit reads vibrations. (**Note**: X and V are excluded from the serial number with the T option because X and V are always included with it.) U means the unit is Ultra sized and is optional. The last digits refer to the serial number of this particular configuration. The example pictured has a serial number of 6SDXVU123456. This means it is a 6000 PSI stainless steel, dual input, extreme temperature, ultra-sized unit that supports vibration measurement.

Temperature Tube



The temperature tube is in the hexagonal post at the head of the sensor as shown in the below picture. A temperature strip is attached to the tube. An indication on the temperature strip allows you to quickly check the maximum temperature the sensor has been exposed to. This feature is very useful, especially in cases where the ESP motor has failed due to overheating as a result of pump-off or gas lock. The temperature strip indication can help confirm whether to reinstall the sensor without service.

Temperature Tube Instructions

1. Use a 5/16" hex key to unscrew the socket on top of the temperature post.
2. Retrieve the tube.
3. Before reinstalling the ACE sensor with a new ESP, remove the used temperature strip and wrap a new temperature strip around the tube. Spare temperature strips can be ordered from ACE Downhole.

Discharge Tubing

If a dual pressure input system is being used, then a discharge pressure assembly is also required.

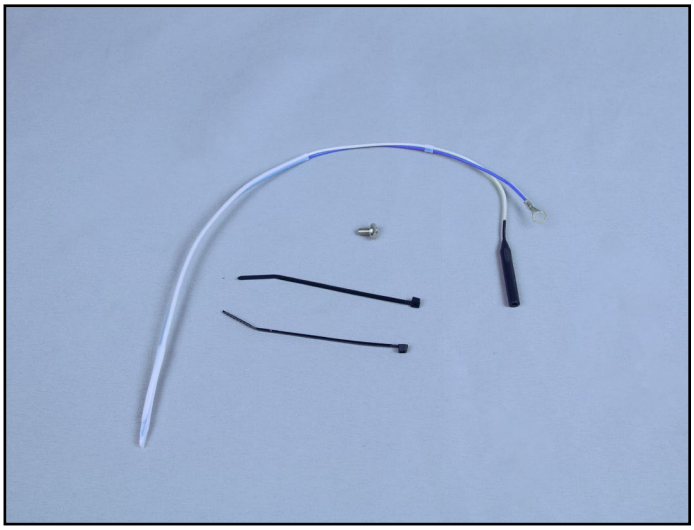
Capillary tubing (measuring 1/4") connects between the sensor lower port and the discharge assembly, which is mounted in the string above the pump. The discharge assembly has a male thread on one end and a female thread on the other, so it may be inserted in the tubing string above the pump.

The discharge assembly has two machined groves to allow the motor power cable to route past the assembly on either side. Discharge assemblies are available in 2-3/8" 8 RND-EUE, 2-7/8" 8 RND-EUE, 3-1/2" 8 RND-EUE, and 4-1/2" 8 RND-EUE sizes.

Directly below the pressure port is a 1/8" NPT hole plugged with a hollow hex 1/8" NPT SS hollow hex plug. The plug comes hand-tight from the factory for easy removal. The plug must be torqued to 20 Ft-Lbs before installation.

Motor Winding RTD Temperature Transducers

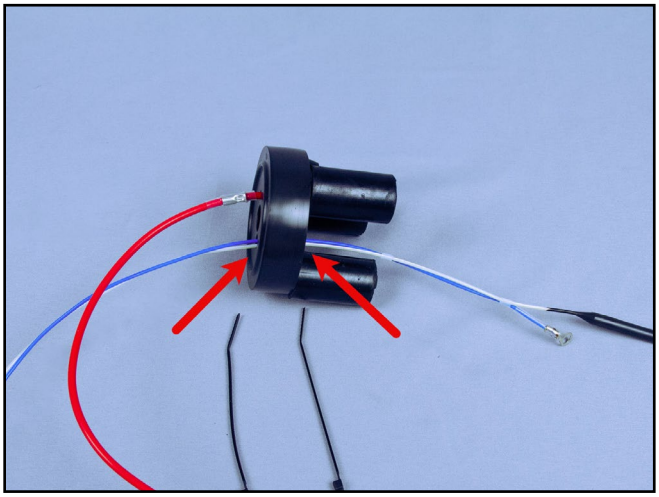
The Motor Winding option may be installed in motors that have been preassembled without removing the lower motor bearing. This transducer measures the temperature of the motor oil as it extends into an oil circulation hole.



Depending on the brand of the motor, the transducer may be placed directly in the lamination slot with one less winding than the other motors, so it can also measure motor winding temperature without requiring to be wound up during the motor assembly. The transducer leads are secured by the support disk located beneath the wye point, which maintains the transducer in a suitable location and prevents it from rubbing on the motor shaft.

1. Insert the RTD probe into a small hole in the ACE wye point ring so that it extends to the correct length for the motor.
2. Install the tie wraps on both ends of the ACE wye point ring and tighten them up. This will prevent any vertical movement of the RTD probe during operation.

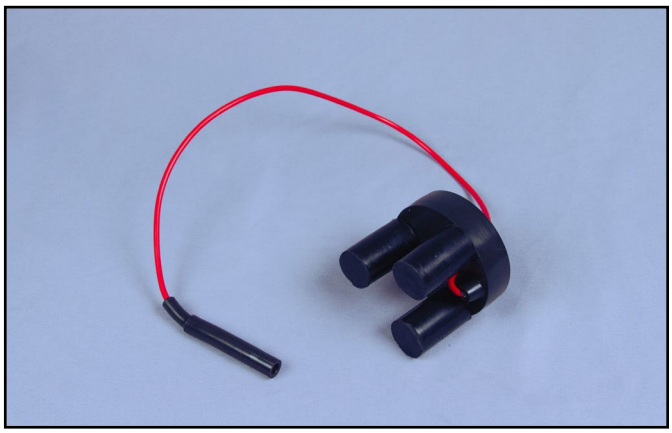
3. Cut off the excess length of the tie wraps.



WARNING: Not installing tie wraps properly can lead to damage of the probe and loss of motor temperature reading during operation.

Motor Adapter and Wye Point

The downhole instrument may be operated with different-sized motors by using a motor adapter. Inside the motor adapter is a mounted wye point, which serves as the junction of the three motor windings. This point is electrically isolated and is typically a rubber-coated ring with three terminals that plug onto the bottom of the motor (otherwise known as an upper-tandem configuration). Attached to the wye point is an instrument wire, terminated with a rubber boot connector, which passes through the center of the motor adapter and plugs onto the larger instrument connector pin. This provides the electrical connection for the instrument up through the motor and onto the motor power cable.



The assembly and connection of these components may vary slightly depending on the manufacturer's motor configuration. The motor adapter and instrument may be coupled together before reaching the well head, and then the assembly attached to the motor. Alternately the instrument may be installed at the wellhead by attaching to a motor adapter that is already mounted on a motor.

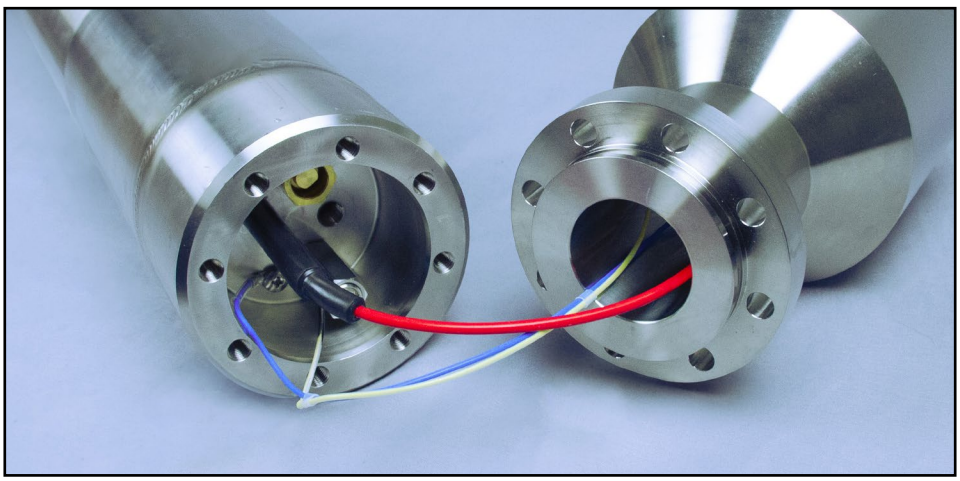
Finally the complete adapter and instrument may be attached to the motor before it is shipped to the wellhead; this gives a controlled environment for assembly however care must be taken during transit to prevent shipping damage.

⚠ CAUTION

The two high voltage, high pressure signal pins may be made from ceramic and will be damaged by any impact or side force. A crack that may be difficult to visually detect will cause high voltage or high pressure failure when downhole. Be careful when connecting to these pins.

A motor adapter is required to physically mount the instrument, but for motors that do not use a wye ring junction, the instrument wire may be directly wrapped into the motor lead junction during the motor assembly. The molded boot is available as an individual item for OEM installation.

Couple the Adapter and the Instrument



1. Smear the O-ring groove with a lubricant that is suitable for the application.
2. Place an O-ring (supplied) in the adapter groove.
3. With assistance, hold the adapter and the instrument close together.

4. With the wye point ring installed in the adapter, pass the instrument wire, rubber boot, and two winding transducer wires through the center of the adapter.

5. Firmly seat the large signal boot on the large signal pin on top of the instrument. It should seat firmly and straight on the pin.

6. Connect the small winding temperature boot to the small pin, and attach the winding temperature terminal ring to the instrument chassis using the stainless 10-32 screw provided.

7. Mate the adapter and instrument together then bolt the two together. Depending on the system metallurgy, Monel coated or stainless 1.25" x 5/16-24 bolts should be used.

Connect the Instrument to the Motor

Once the adapter and instrument are assembled they may be attached to the motor.

1. Attach the wye ring to the motor leads. Be careful not to trap or catch the instrument wire on any of the assemblies.

2. Slide any spare instrument wire into the adapter to make sure it will not damage the wye point or motor components.

3. Mate the motor and the adapter together.

4. Secure the motor and the adapter together with suitable bolts.

SRU, SRU2i, and SRU3i

ACE Surface Readout (SRU), Advanced Readout (SRU2i, also known as SRU2), and SRU3i Wi-Fi/BH Interface (also known as SRU3)

Any of the SRU (Surface Readout Unit) options may be used with any of the downhole sensor options and operate from nominal 120 VAC 50/60Hz line voltage.

The surface device provides these functions:

- Signal power to the downhole device, decodes and verifies encrypted information from the downhole unit, and displays the results on an LED display.
- Downhole data to additional devices via an industry standard Modbus RS-232 and RS-485 ports (both optically isolated).
- A built-in interface, which connects directly to the iCON industry standard motor controller. With a suitable adapter cable, it can connect to the older generation legacy Commander/F5 series controllers, which were sold under several different names.
- Diagnostic information to assist in troubleshooting. Transmit and receive LEDs are associated with each of the communication ports to indicate all communication activity.
- (SRU2i ONLY) Includes Ethernet and USB connectivity, user-programmable relays, analog outputs and datalogging for all readings using removable SD data cards.
- (SRU3i ONLY) The interface connects directly to a Baker Hughes / GE Advantage or GCS drive, plus provides Wi-Fi connectivity for all readings.

Mounting the SRU

DANGER

Lethal line voltages will be present on the various components of the ACE system when connected to AC line power. Before attempting to gain access, test or modify connections refer to a qualified electrician for assistance, instructions on safe operation and to ensure that connections meet all applicable safety procedures, standards and codes.

CAUTION

Do not attach or remove the signal or ground lead while the surface readout unit (SRU) or the Field Test Box is powered on as damage to the equipment may result. There are very high inductances in the system. Connecting or disconecting the signal or ground wire with power applied will result in large arcs that may damage the equipment. Turn off the SRU or Field Test Box before connecting or disconnecting the signal or ground lead.

There are two options of where to mount the SRU: 1) In the low voltage section of the VSD or the switchboard, where it is protected from the environment or 2) Inside a weatherproof NEMA 4X-rated cabinet mounted to the side of the VSD or switchboard. It should be connected to a 115VAC (50 or 60Hz) fused at a 2 Amp power source via a suitable disconnect.

If mounted inside a weatherproof NEMA 4X–rated cabinet mounted to the side of the VSD or switchboard, separate the protective conduits for the power and signal cable. Use a shielded instrumentation wire to connect between the SRU (any version) and the HVI. These conduits also provide strain relief at each end. See Appendix A for typical wiring schematics.

1. Mount the SRU box.
2. Connect the SRU to a 115VAC (50 or 60Hz) fused at a 2-amp power source via a suitable disconnect.

(**NOTE**: If the SRU is mounted inside the cabinet mentioned above, separate the protective conduits for the power and signal cable using a shielded instrumentation wire to connect the SRU and the HVI.)

SRU Menus

To view the SRU Menu tables and tips for menu navigation, go to SRU Menu Navigation (page 6).

Modbus

The SRU has a built-in support for Modbus connections. There are two physical connections available, two wire RS-485 and RS-232, but just one may be used at a time. Both of these connections are optically isolated to prevent ground-based noise and provide electrical protection.

The SRU2 has a built-in support for several Modbus connections. There are four physical connections available. Three of them share the same port, so only one of these three may be used at a time. These three are RS-485, RS-232, and a direct USB connection. All of these connections are optically isolated from the rest of the controller to prevent ground-based noise and provide electrical protection; they are electrically connected to each other.

The settings for Modbus ID, Baud rate, and gap time are in menus 19, 20, and 21. The gap time is a delay in mS before the SRU will respond to a Modbus command. Adjustment may be required when radios are used in the Modbus link because radios may introduce additional delays in the communications timing.

The forth Modbus connection on the SRU2 is via Ethernet, and it uses a completely separate port from the first three connections; therefore, simultaneous Modbus activity via Ethernet and any of the other three serial ports is possible. The Ethernet configuration is setup using menu 25 and its submenus.

The SRU acts as a Modbus RTU slave and responds to the following commands. It may be polled using command 3 or 4, (typically 4xxxx, 3xxxx addresses). The returned values are the same. All are 16 bit unsigned integers. A few are 32 bit unsigned, stored as consecutive 16 bit registers. Some, but not all, of the Modbus registers may be written to typically for configuration changes and setpoints. Note that the configuration program allows for quick and easy SRU2 setup without requiring any Modbus knowledge.

Commonly used registers are shown next; Modbus Map (page 55) is shown in the appendix.

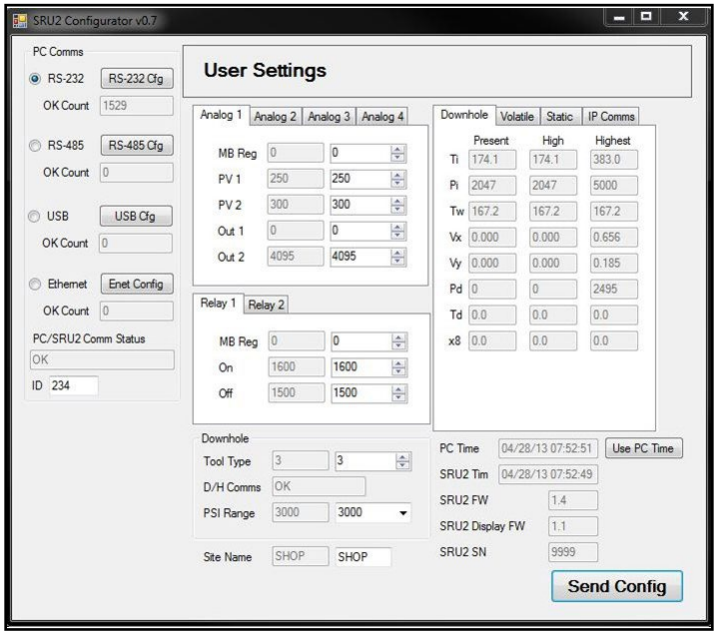
Register	Contents
0	Instrument measured temperature x 10 in °F, e.g., 1234 = 123.4 °F
1	Instrument measured pressure in PSI, e.g., 4327 = 4327 PSI
2	Winding temperature x 10 in °F, e.g., 3476 = 347.6 °F
3	X Vibration (x0.001 G), e.g., 3789 = 3.789G
4	Y Vibration (x0.001 G), e.g., 1234 = 1.234G
5	Discharge Pressure PSI, e.g., 3668 = 3668 PSI

There are further Modbus registers in the SRU. Appendix B contains the complete register map.

SRU2, SRU3, and ADCM Configuration

The SRU2 has many control registers for adjusting its extended capabilities. Although all settings may be made using the built in SRU2 keypad a PC program is also available for easy setup, called the SRU2 Configurator. This program also works with the SRU3 and the ADCM. (**Note**: The SRU1 is not compatible with the configuration software.)

When starting the program, be sure to select "Run as Administrator"; otherwise, Windows may block the correct operation of the program. Once the program has started, the screen will look like the image on the right.



The connection to the SRU2 may use any of the serial ports or via Ethernet. The connection port may be selected using the PC Comms buttons on the left of the screen; once connected correctly the "PC/SRU2 Comm Status" will indicate "OK" and the Tx/Rx LED's on the SRU2 will both be flashing. If connecting via the USB port the PC should install correct serial port drivers automatically, if it does not drivers may be downloaded from https://ftdichip.com/drivers/vcp-drivers/

At the bottom of the screen are several status displays. Some items may be changed by directly typing the required values into the boxes or using the up/down arrows. Once the correct values are displayed, they may be saved to the unit by clicking the "Send Config" button.

General Status and Controls

- Tool Type (keypad menu 9) is set to the number of channels being transmitted to the surface from the downhole sensor. See System Integrity Test (page 48) for more information.
- D/H Comms indicates the current state of communications between the SRU2 and the downhole sensor.
- PSI Range (keypad menu 23) is set to the full scale value of the downhole sensor pressure rating.
- Site Name (sub menu below keypad menu 33) is the name used for the SD datalogging files. By default, it is set to the SRU2 serial number; however, it may be changed to any 4 character alpha-numeric name, typically an abbreviated well name.

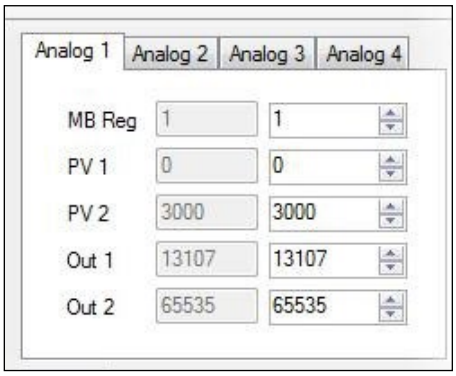
- PC Time shows the current time as reported by the PC.
    - Clicking Use PC Time will set the real time clock in the SRU2 from the current PC time (for keypad operation see menu 26).
- SRU2 Time is the current time in the SRU2, which needs the correct time and date for SD datalogging. The time and date is automatically updated by an internal battery when SRU2 power is off.

There are two boards and software versions in the SRU2. The main board firmware version is shown as SRU2 F/W. The second board controls the display and SD datalogger, and its firmware version is SRU2 Display F/W.

Both firmware versions may be upgraded in the field. The SRU2 F/W may be upgraded using a standard USB cable or RS-232 connection. To upgrade the data logger firmware requires a special cable. Each SRU2 has a unique serial number; this is displayed by SRU2 S/N if it has been previously saved.

Analog Outputs

There are four 0 to 20mA analog outputs on the SRU2. Each may be set to operate based on any register in the SRU2 and may be scaled to any values the user may need.

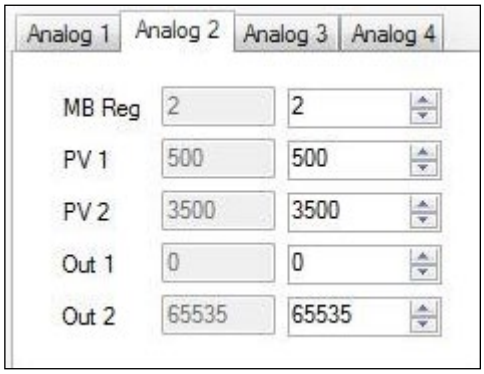


Current Control

In the first example on the right, Analog Output 1 is shown. The sensor is a 3000 PSI rated unit, and the analog output needs to go from 4mA at 0 PSI to 20mA at 3000PSI. First, the MB Reg is set to the register that the control will be based on. In this case, it is register 1, the intake pressure, which will vary from 0 to 3000. Process variable 1 (PV1) is the first (typically lower) value to base the output on. In this case it is set to zero. Process variable 2 (PV2) is the second (typically higher) value to base the output on, shown as 3000.

The analog outputs on the SRU2 go from 0 to 20mA and are scaled by 16-bit registers. Therefore 0.0mA = register value of 0, and 20.0mA = register value of 65535. Since the output needs to start at 4mA (not 0mA) the first, lower output value (Out 1) should be (4/20)*65535 = 13107. The second output value (Out 2) will be full scale at 65535.

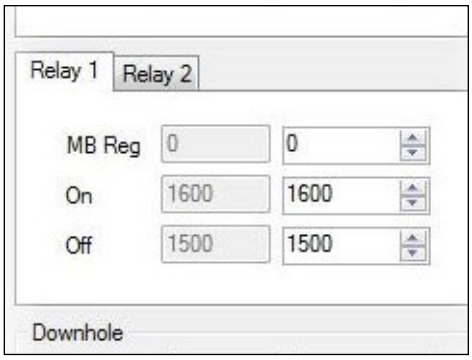
For a second example on the left, Analog Output 2 is set to output the Winding temperature, but in this case, an output of 0 to 10.0 Volts is required. By placing a 500 Ohm 1/2 Watt resistor in parallel across the 0-20mA output the SRU2 may output a 0-10VDC signal. Since the temperature register is stored with a precision of 0.1 °F the PV values are multiplied by 10; i. e., 123.4 °F = register value of 1234. The output is shown configured for 50 °F = 0.0 Volts and 350 °F = 10.0 Volts.



Voltage Control

The SRU2 has built-in Modbus registers that the user may directly write to for control and testing purposes; these are explained in detail further on, but they are very useful for testing and during analog calibration when connected to other devices. The "MB Reg" address can easily be set to one of these user registers for testing or control.

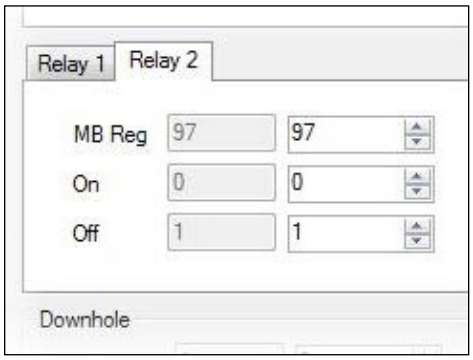
Relay Outputs



There are two general purpose "form C" output relays on the SRU2. Each may be set to operate based on any register in the SRU2, configured in a similar manner to the Analog Outputs.

In the example shown to the right, Relay 1 is configured to be active, or energized, when the intake temperature rises to above 160.0 °F. The register to base the control on is intake temperature, register 0, so "MB Reg" is set to 0.

There are two level set points, "On" and "Off," for the relay control. They allow the relay control to have hysteresis, so chattering can be avoided if levels move just above and below a single set point. The SRU2 will inspect the On and Off set points and determine from them the relay polarity, meaning the normally closed or normally open state may be reversed by swapping these two On and Off values. In the example, the relay will turn on when the temperature rises above 160.0°F. The relay will remain on until the temperature drops below 150.0°F.



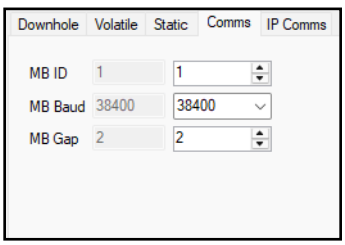
In the second example, Relay 2 is configured to be active when the downhole sensor is connected and communicating correctly with verified readings. Register 97 contains the status of the downhole sensor, with a value ranging from 0 to 4. Zero corresponds to correct, verified communications, and values from 1 to 4 indicate other states, such as beginning communication.

By setting the On level to 0 and the Off level to 1, the relay will only be active when good, verified communications exist, and it will be off for all other states. Using a relay with this register can be useful with 4-20mA output signals. Passing an analog 4-20mA signal from the SRU2 through the relay will mean the 4-20mA signal will drop to zero if there is a downhole fault condition. Most SCADA and control systems will recognize a 4-20mA signal dropping to zero as a fault condition.

User Registers—Volatile and Static

There are eight user volatile and eight user static Modbus registers. These may be used for any general control purpose. For example, when used to drive relays or analog outputs, they allow for remote stopping, starting, or controlling the speed of a VSD attached to the SRU2. These registers may be written to at any time. The volatile ones will retain the values until power is cycled and then reset to zero upon the power being returned; the static ones will retain the values through power failures.

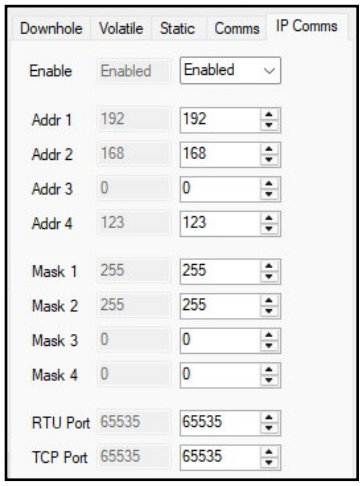
Comms



All SRUs support Modbus communications. The Comms tab contains fields to set the SRU's Modbus ID and the Modbus baud rate and gap time. The Modbus ID is a unique number (0–255) that identifies each device on the Modbus network. Baud rate is the speed at which data is transmitted. Gap time refers to the silent period between the end of one message and the start of the next. The specification for Modbus gap time is

3.5 Character times, which is the time needed to transmit one byte at the specified baud rate. One byte consists of 11 bits (1 start, 8 data, 1 parity, and 1 stop bit), so an equation for one Character time is "11 / baud rate."

IP Comms



The SRU2 supports Modbus over Ethernet (Modbus TCP/IP). This can be enabled or disabled from the IP Comms tab. This tab also includes fields to set the IP Address, IP Netmask, RTU Port, and TCP Port.

SRU Operation with GE Apollo and Borets VSDs

The SRU2i and SRU3i are not normally recognized by some Wood Group, Apollo, or Borets VSDs with older software. Unfortunately, Modbus registers that are polled by these VSDs are used in the ACE readouts for metric values, diagnostics, and high resolution readings, which these drives do not support.

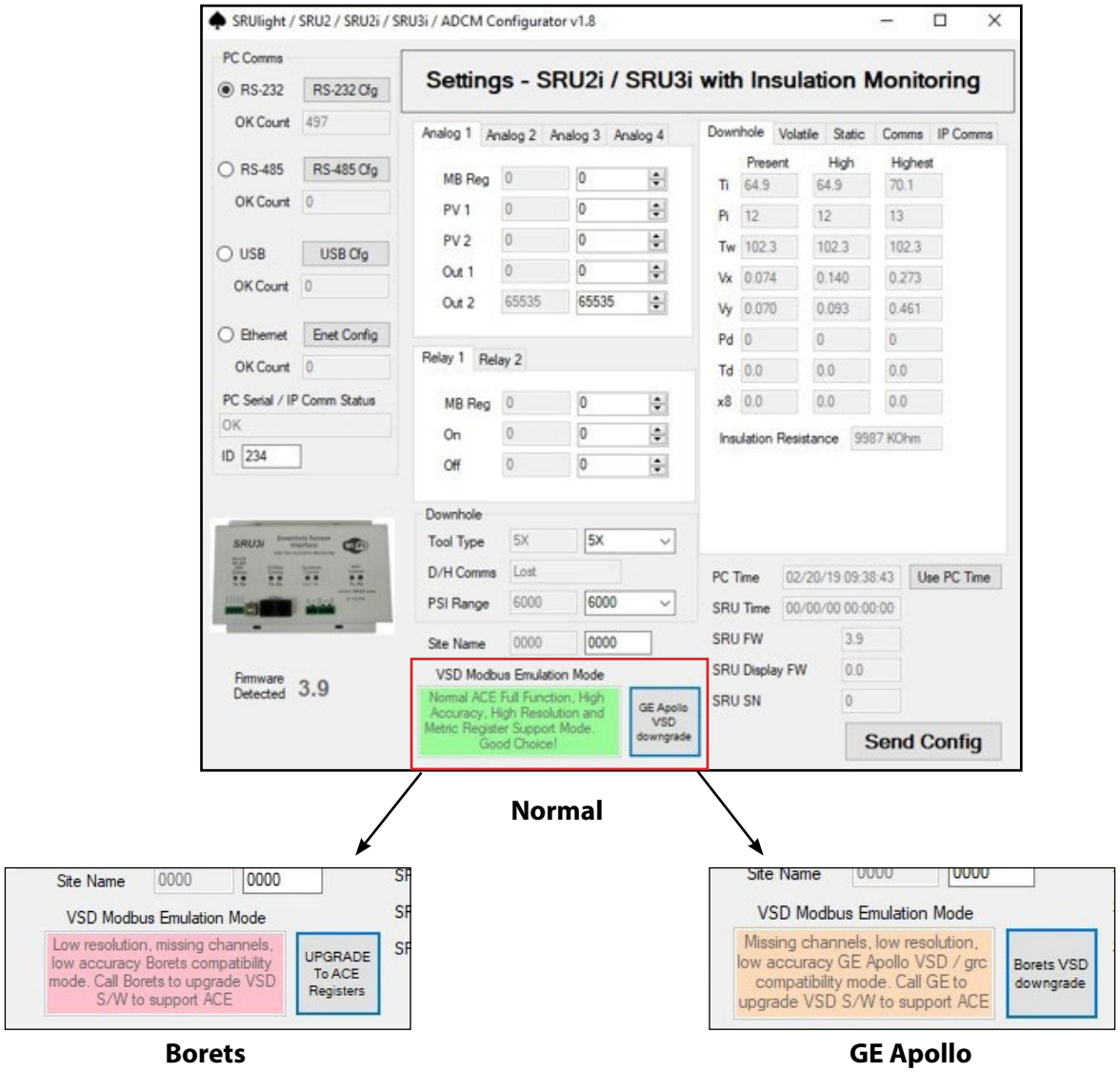
Please ask the Apollo or Borets vendor to upgrade the VSD software to support the ACE high resolution, high accuracy readings with additional channels not supported by the drives, such as insulation measurement readings.

If the VSD cannot be upgraded to newer software, then the SRU configuration program may be used to downgrade the SRU2i or SRU3i and set it in emulation mode, where the high performance registers are sacrificed so the ACE readout can supply the VSDs with low accuracy basic sensor readings that are equivalent to the Wood Group, Apollo, and Borets sensor registers. Use the configuration program to enable these (requires SRU2i or SRU3i F/W 4.0 or later) or menu 24.

Note: The ACE SRU2i readout display and SRU3i Wi-Fi readings will all still support hi-res and metric readings; however, the VSDs may not support those readings.

The current emulation mode may be displayed on the SRU2i by going to menu 24 and entering 34, and "Normal," "Apollo," or "Borets" will be displayed. The current mode may be changed by going to menu 24 and entering 134, which will toggle to the next mode.

The Modbus address 1066 contains the current setting, 0x0BAD (2989) for Apollo 0x0DAB (3499) for Borets, anything else is ACE mode.



SRU3i with GCS/VSD Installation Instructions

When a Baker Hughes / Centrilift VSD is being used there are several ways to bring the ACE sensor signal into the VSD. There are many versions, depending on age and installed options of the BH VSD. Early drives, without any digital I/O capability, may use analog inputs driven by an ACE SRU2 readout; however, this usually limits the sensor channels that may be monitored to 2. Some drives are capable of interfacing to an ACE SRU or SRU2 via a Baker Hughes option called a Remote Data Communication Module (RDCM). Programming of the RDCM is required to connect to the ACE sensor SRU or SRU2, consult BH documentation for details.

The SRU3i is an ACE sensor interface that makes connection to a BH VSD fast, easy, more economical and adds features. The SRU3i has a built in high speed, direct interface to the Baker Hughes VSD internal data bus (referred to as 'CITIbus'). When using the SRU3i all sensor readings will appear directly on the GCS drive and are available for all VSD / SCADA control and monitoring functions. The RDCM interface is not required. In addition, the SRU3i has a built in Wi-Fi server and establishes a local Wi-Fi network so that operators close by are able to make adjustments and view readings directly from a phone or tablet. No cell phone service, mobile data, or internet access is required

to use this feature. Like the SRU2i, the SRU3i provides accurate system insulation resistance monitoring. See the SRU2i section on insulation monitoring for further details. Standard electrically isolated Modbus RS-232, RS-485, and USB interfaces are also provided so the SRU3i may also be used in other brands of VSD. The SRU3i Version 2 adds GPS plus data logs of every sensor reading ever taken, all accessible from Wi-Fi.

1. Remove and lock out all power to the system.
2. If an RDCM is installed, disconnect and recycle it. If a Centinel power supply and a Centinel Interface are installed, they may also be disconnected and recycled.
3. Install the SRU3i in a suitable location with screws to one of the metal panels. It will require 120VAC power and be connected via a CAT5 cable in series with the other CITIbus modules.
4. If replacing an RDCM, it can connect to the 2 cables that were plugged into the RDCM. If not, the 2-foot long 8-conductor CITIbus cable (supplied with the SRU3i) will allow it to be located close to the other modules and connected in series with them.

Note: The VSD display is always the last device in the CITIbus chain because it has only one 8-pin connector.

5. Connect the SRU3i signal and SRU3i signal ground (**Note**: This is not connected to the SRU3i safety ground stud, which only connects to the SRU3i metal case.) to the sensor high voltage interface (HVI), typically located in the transformer.
6. Connect a source of 120VAC from the VSD, typically from a control transformer to the SRU3i. It could also come from the 2 disconnected Centinel interfaces.
7. Once the installation is complete the VSD may be securely closed and powered back up.

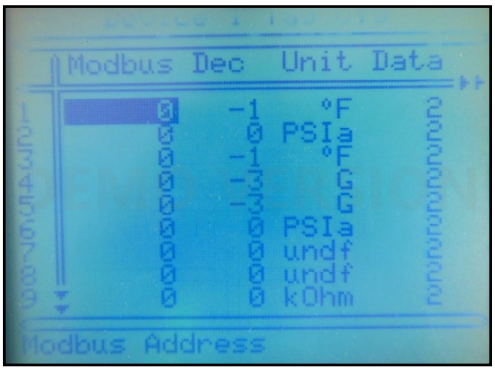
Setup Instructions

To maintain compatibility with the many hardware and software versions of the BH VSD that exist the SRU3i interfaces to the CITIbus by emulating an RDCM, except with more intelligence. The sensor readings and diagnostic information will all appear on the BH VSD RDCM screens.

Note: If the sensor readings are to be monitored only via Wi-Fi or SCADA, there is no need to enter scaling and units for the BH VSD screen.

To display the correct scaling and units proceed as follows:

1. On the main screen choose "select GCS Modules">"GCS Module Status."
2. Ensure that the "Remote Data Com" is enabled so the VSD will communicate with the SRU3i.
3. Press the Menu key to return to the previous menu.
4. Select "Remote Data Com Module."

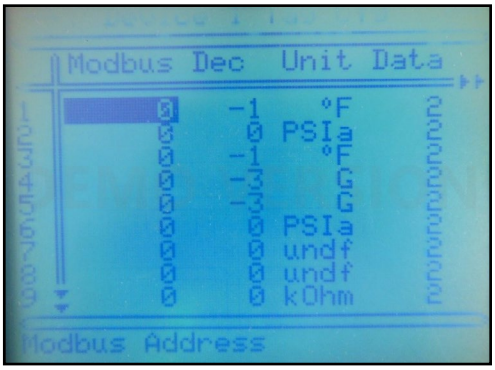


Device 1 Setup

This will take you to the "Device 1 Tags," which shows all live sensor readings. The first of four screens relate to the SRU3i, similar to the picture shown on the right. There are 3 device screens and one RDCM setup screen. In the example shown, the results have been scaled to show the best resolution that the BH VSD display is capable of (note that SRU3i Wi-Fi screens have full resolution for all parameters), and units are visible for some parameters.

5. To set the scale and units, use the left or right keys to get to the "RDCM Setup" screen.
6. Then select "Device 1 Setup," which will show a screen full of parameters related to RDCM setup. The SRU3i will automatically configure itself to communicate and none of these items have any effect or meaning except "Tag Cfg." and "Device Type."
7. To allow setting correct units and scaling, enter "cstm" for "Device Type."
8. Select "Tag Cfg" to bring up a screen similar to what is shown below.
9. Use the cursor, edit, and menu keys to change the display to match the "Dec," "Unit," and "Data" columns.

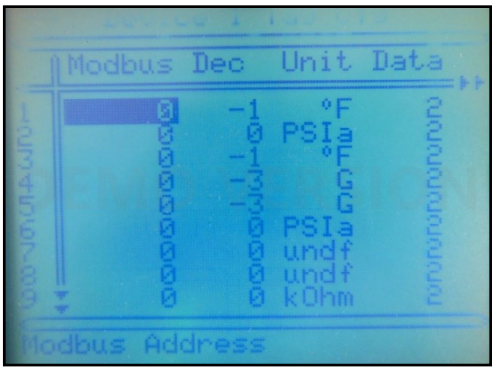
Note: The Data field determines if the VSD handles the register as a 15-bit signed register (if set to 1) or a 16-bit unsigned register (if set to 2). For example, the insulation reading goes up to 60,000 KOhms, so it needs to be set to 2; otherwise, there will be negative readings once the insulation is above 32767 KOhms. For some of the other parameters, it has no effect.



Device 2 Setup

10. Select what needs to change, press the Enter key, and then use up/down to change.
11. Press Enter again to stop editing that parameter.

Note: Depending on the version of sensor connected, the PSIa units may be changed to PSIg. Sensors with an X in the serial number (6K and 8K) use PSIa, all others PSIg.



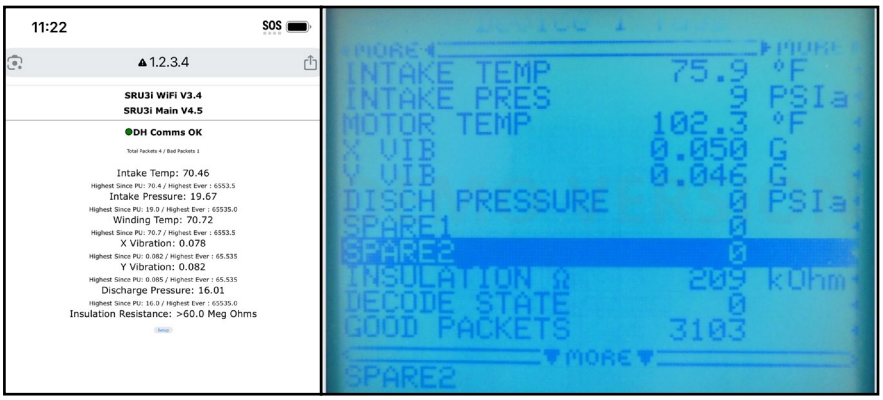
Device 3 Setup

12. Once Device 1 has been setup, back out using the menu key.
13. Repeat the above procedure to set up the similar screen for 'Device 2' (which is a 'high readings' screen). Again use the cursor keys, edit and menu keys to change the display to match the 'Dec' and 'Unit' columns.
14. Repeat the procedure a final time for 'Device 3' (the diagnostics screen).

Note: Depending on the existing VSD settings, some of the changes may be locked out by the VSD. To unlock and allow changes, proceed as follows:

1. On the main VSD screen select Scada / Security.
2. Change the User, Level 1, and Level 2 passwords to 0.
3. Scroll to the right to find "User Menu Level" and set it to Advanced.

The complete setup may be saved to a PCMIA card and easily loaded into another VSD to speed installation. At this point the BH VSD screens should be all set correctly.



Once the VSD display has been configured, it may be used. To see current readings, navigate to the RDCM menu and select "Device 1 Tags." The first 6 readings correspond to the first 6 menus on a standard ACE SRU or SRU2.

Device 1 Tags

1	Intake temperature in deg °F
2	Intake pressure in PSI.
3	Winding temperature in °F
4	X Vibration in G
5	Y Vibration in G
6	Discharge pressure in PSI
7, 8	Reserved for future use
9	This is the true insulation resistance measured in KOhms. If its over 60,000KOhms, it is effectively open circuit
10	Comms status of the downhole sensor. 0 = receiving good data; 1 = connecting; 2 = open circuit; 3 = short circuit; 4 = cannot decode data.
11	Number of good readings received from the downhole sensor. **Note**: Due to the resolution restrictions of the BH VSD, the readings will wrap at 65535 (after approximately two weeks). This count may be reset via scada or from a Wi-Fi keypad.
12	Number of bad readings received from the downhole sensor. This count may be reset via scada or from a Wi-Fi keypad.

Device 2 Tags

The device 2 tags automatically toggle between 2 sets of readings every few seconds. One set of readings are the highest values recorded since the unit was last powered on. The second set of readings are the highest values ever recorded, which are stored inside the SRU3i. Both of these sets may be reset from the Wi-Fi keypad or scada.

1	Intake temperature in deg °F
2	Intake pressure in PSI.
3	Winding temperature in °F
4	X Vibration in G
5	Y Vibration in G
6	Discharge pressure in PSI
7–12	Reserved for future use

Device 3 Tags

The device 3 tags contain diagnostics related to the sensor and CITIbus comms.

1	Downhole tool type. 2-8 = number of channels, 1 = Xtreme sensor 5 channel
2	Set Voltage value
3	Output Voltage
4	Output current
5	Mean output current
6	Decode state
7	Sensor pressure range
8	SRU3i S/W version
9, 10	Count of readings sent to BH VSD via CITIbus. Tag 9 goes up to 9999 (last 4 digits). Tag 10 contains the first digits for the total (e.g., tag 9 = 1234, tag 10 = 567, total = 5671234 readings)
11	Count of CITIbus timeouts when SRU3i has not received data from BH VSD
12	Spare

ESP Insulation Monitoring

It is possible to obtain an approximate indication of the condition of the motor cable by measuring the insulation between the ground and the three motor cable conductors. Insulation monitoring readings may be useful over extended time periods, as gradual deterioration can indicate impending cable failures. The SRU2i readout has this capability built in, and it can take the reading with any sensor, whether the motor is running or stationary.

The last reading taken may be viewed by going to the last menu, displayed as ">2" (or "IN" if the readout is in alpha-numeric mode), and the last reading taken will be shown displayed in kOhms. The measurement range goes from 200K Ohms to 60000K Ohms (60 Megs Ohms).

1. A new reading may be taken manually at any time by pressing the Enter key on menu >2.
2. The display will change to >3 MEASUR.
3. Press Enter again. This will display a flashing --NO--.
4. Use the Up/Down keys to select YES, and press Enter again to start taking the reading.
5. The display will show MEASUR and then WAIT with a count that will increment as the reading is taken. The reading will complete after approximately one minute.

The SRU2i may be set to automatically take readings every 1 to 2160 Hours (90 days).

1. To do this when displaying the >3 ("ME") menu, press up or down. >4 ("dE") will display the number of hours between taking readings.
2. Press Enter to change to delay; setting it to zero will disable automatic insulation readings (display will show "NoAuto").

If automatic readings are enabled (i.e. not zero), the SRU2i will also take a reading upon power up; it will not take a reading at power up if the automatic readings are disabled.

Motor Control Connections—Direct Connection with iCON Advanced Motor Controller

In addition to the serial and Ethernet connections the SRU and SRU2 have built-in support for direct connection to the iCON advanced motor controller. Simply plug the SRU or SRU2 into the iCON controller or accessory, and it will automatically appear in the iCON display and menus.

The eight readings from the SRU or SRU2 will automatically appear in the iCON display as ACE Channels. Alarms, shutdowns, restarts, data logging may all use the ACE downhole instrument readings. Additionally the SRU / SRU2 firmware version and serial number can be displayed directly in the motor controller. Plus, readings will be logged to the SD memory card by the iCON controller.

Motor Control Connections—Direct Connection with the Commander Series and Similar Obsolete Motor Controllers

The SRU may plug directly into these controllers using an 8-pin shielded (Ethernet type) cable. The SRU2 may use an adapter cable to communicate with these obsolete legacy motor controllers. Simply plug the daisy chained interconnect cable into the SRU2 from the motor control or a motor control accessory. In these motor controllers eight readings from the SRU will typically appear as MODIF channels 1 to 8. Some parameters, such as temperature, will be multiplied by 10 in these motor controllers, which are unable to display decimal points. Some alarms and shutdowns may be set to use the ACE downhole instrument readings by using the MODIF channels.

It is suggested to replace the obsolete motor controller with an iCON controller for better speed, accuracy, performance, connectivity, and reliability as well as extended data logging capabilities.

Third Party Surface Interface with ACE SRU

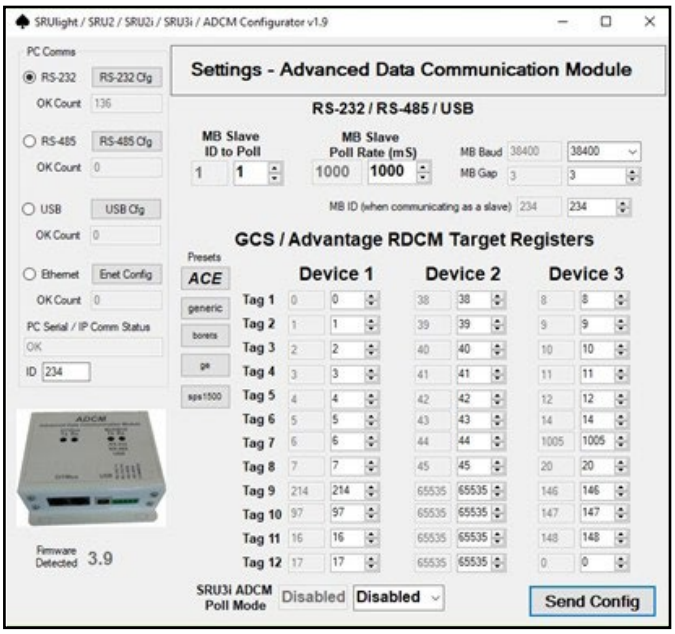
DANGER

Lethal line voltages will be present on the various components of the ACE system when connected to AC line power. Before attempting to gain access, test or modify connections refer to a qualified electrician for assistance, instructions on safe operation and to ensure that connections meet all applicable safety procedures, standards, and codes.

SRU Emulation of Wood Group Smartguard with the Vector 7 VSD

The SRU and SRU2 are capable of emulating a Wood Group (WG) Smartguard surface interface so that direct readings will appear in the Vector 7 drive without any software changes to the VSD. This lets a failed Smartguard downhole sensor and surface interface be replaced with a higher resolution, higher accuracy, and a more reliable

ACE system, while still allowing the existing Vector display to show downhole readings, which are also available via SCADA if the Vector is connected to a SCADA system. There are no changes to the Vector software required. As well as displaying the ACE results, the SRU will also emulate a WG Smartguard interface, so the Vector drive will display readings on its LCD display.



Note: The SRU requires F/W 1.9 or later to support WG emulation.

Disconnect WG Smartguard interface board and dispose of it. The ACE SRU connects as follows to the Vector 7 controller board:

ACE SRU or SRU2	WG Controller Comms Port 6 pin connector (next to SD card)
Comms Port Common	Comms Pin 1 (right hand pin)
Comms Port RS-485 A	Comms Pin 2 (second from right pin)
Comms Port RS-485 B	Comms Pin 3 (third from right pin)

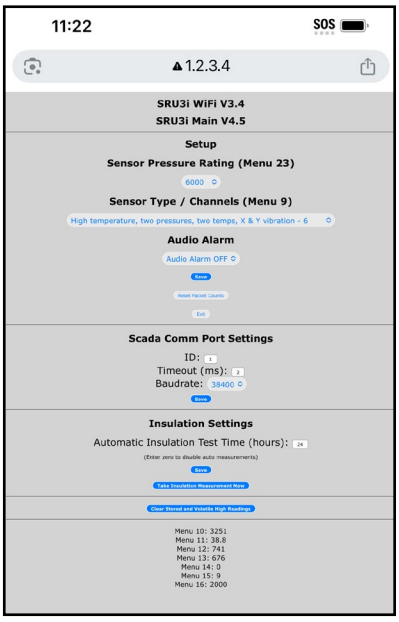
The ACE serial interface should be set to 9600, MB address 1, gap time 3, which allows connection with default Vector VSD settings. The drive power should be cycled to recognize the ACE SRU.

Cautions for the WG Vector Display

Although the Vector drive and SG system claim a resolution of 0.1 psi (and similar resolutions for the other parameters), this is not true. As parameters get into higher ranges, the resolution drops. For example, above 2000 psi, the WG pressure resolution is actually 16 psi, and if the SRU measures a pressure between 2185 and 2201 psi, the SRU will correctly display the pressure to 1 psi resolution (0.1 psi on the SRU2). However, the WG systems will always show 2186.6 psi. When the SRU pressure drops below 2185, the WG system will display 2170.6 psi, and when the pressure rises above 2201, the WG will display 2202.6 psi.

This characteristic is a limitation of the WG equipment, not the SRU or the ACE sensor, which have high resolution across the complete signal ranges. Although the Vector display may be useful for an approximate downhole parameter display, for the highest accuracy readings with true resolution, always refer to the ACE SRU display.

SRU3i Wi-Fi Setup Instructions



The SRU3i may be accessed remotely using any Wi-Fi device, depending on many factors the Wi-Fi range from the BH VSD may range from 50 to 250 feet. This allows for monitoring, configuration, and diagnostics without needing to access the VSD either internally or from the keypad.

The procedure to initially connect to the SRU3i Wi-Fi network is very similar to connecting to a Wi-Fi Spooler. Please refer to the Spooler section for details on initial connection procedure. The only difference in connecting between the Spooler and the SRU3i is that the SRU3i Wi-Fi network is called SRU3i xxxx and the SRU3i IP address is 1.2.3.4.

1. Locate the Wi-Fi network. This can usually be accomplished by going to the device settings and selecting Wi-Fi. The location of the Wi-Fi network selection may change depending on the operating system.

2. Select the Spooler network and connect to it. On some Apple devices, another prompt may need to be acknowledged to connect.

   The Spooler network is identified as Spooler XXXX where XXXX is unique to each Spooler device (XXXX is the last 4 digits of the Spooler MAC address). This allows multiple Spooler devices to be operating in close proximity without interfering with one another.

   Different wireless devices may complain of being unable to access the internet; however, the internet is not required to communicate with the Spooler, and the message should be ignored.

3. Once connected to the Wi-Fi network a browser window may be opened to access the Spooler. Again different devices have different options for browsers, such as Safari for Apple products and Chrome for many Android devices. In this example on the Fire tablet the browser is called Silk.

4. In the browser address bar type 1.2.3.4 This is the IP address of the Spooler and it is always the same for all Spoolers. The following screen should then appear, in this case the sensor is still initializing and the background will be yellow. Notice the IP address of 1.2.3.4 in the address bar. Updated versions of Safari may show an error message that the webpage cannot be parsed. If that occurs, simply connect using another browser, such as Google Chrome, or try another smart device.

Once connected live (and the highest) readings should be displayed. If readings are not being updated go to the diagnostics screen to see what the problem may be .

If additional access is desired, the IP address 1.2.3.4/mb may be accessed. This page allows the user to read data from or write data to any Modbus register. Use caution when writing to registers to not incidentally impede proper functionality.

Advanced Data Communication Module

The ADCM is an interface that directly replaces the Baker Hughes RDCM module. It may be used with third-party sensors or any Modbus device, such as a flowmeter, allowing the device to interface directly into a Baker Hughes / Centrilift VSD. The ADCM operates by impersonating a RDCM module but with more intelligence, and the VSD will display readings as registers as if they came from an RDCM.

The ADCM (or SRU3i) typically would be polling a device of interest as a Modbus master; however, the ADCM or SRU3i will work just as well as a Modbus slave, so registers from any Modbus device may effectively be pulled into the ADCM (master mode) or pushed into the ADCM (slave mode). The ADCM and SRU3i do this automatically.

The ADCM contains and stores its own user configuration for settings, such as which registers to poll, and so on. These settings are entered by using the standard SRUlight/SRU2/SRU3 configuration program (V1.6 or later) rather than having to enter the parameters using the VSD keypad. The settings may also be entered using any standard Modbus PC program that's capable of reading and writing to any of the ADCM/SRU3i's three Modbus ports.

The Modbus map is in Appendix B; however, ADCM pertinent registers are listed below for reference. Connect to the ADCM using 38400, 8-N-1 (38400 baud, 1 start bit – 8 data bits – no parity bit – 1 stop bit) using Modbus address 234 (default for SRU2 / SRU3 / ADCM).

Note: The ADCM (and SRU3i in ADCM mode) may already be transmitting Modbus polls but will switch to slave mode automatically when it receive an incoming Master poll. Stop polling the ADCM for a few seconds, and it will revert back to being a Modbus master and begin polling a device using the user settings.

1015	Modbus ID of ADCM/SRU2/SRU3 when a slave (additional user address to default 234)
1016	Modbus silent time when a slave in mS
1017	Modbus baud rate
1070	This contains the Modbus register to poll by the ADCM for Device 1 Tag 1
1071	This contains the Modbus register to poll by the ADCM for Device 1 Tag 2
etc.	
1081	This contains the Modbus register to poll by the ADCM for Device 1 Tag 12
1082	This contains the Modbus register to poll by the ADCM for Device 2 Tag 1
1093	This contains the Modbus register to poll by the ADCM for Device 2 Tag 12
1094	This contains the Modbus register to poll by the ADCM for Device 3 Tag 1
etc.	
1105	This contains the Modbus register to poll by the ADCM for Device 3 Tag 12
1106	Modbus address of the device the ADCM will poll, 1-255. Address 234 is reserved
1107	Contains 0x1234 (4660 dec) to enable polling. Write this to an SRU3i for ADCM functionality, and then its polled registers will appear in the VSD rather than SRU3i sensor values. Write anything else to place SRU3i back into normal mode

The VSD allows up to 36 registers to be displayed. Since few devices have that many registers of interest, the ADCM will start polling for the Device 1, Tag 1 register. It will continue in sequence until the last register (Device 3 register 12, the 36th) or until it sees a register to poll that has the same address as the first (Device 1, Tag 1) register. Then it will restart at the first. This way, if only a few registers are required, it will just keep repeating those polls and not poll unwanted ones. Each register will be polled individually rather than via a block read command so that they can be polled in any order to match VSD tag preferences.

The ADCM (and SRU3i) may be used in another mode. The registers acquired by the ADCM or SRU3i that are to be written to the VSD via CITIbus are in locations 219–254 in the ADCM. If a device is set up as a Modbus master connected to the ADCM / SRU3i, the master may write to these locations pushing registers into the ADCM and the register contents will then be passed on and appear on the VSD as Device 1 Tag 1 (from ADCM register 219) up to Device 3 Tag 12 (ADCM register 254).

High Voltage Interface (HVI)

The high voltage interface (HVI) connects between the motor power cable and the SRU. It provides an artificial wye point from the motor power cable at the surface and then translates it into a safe signal level for connection to the SRU.

The HVI also provides the protective safety interface between the high voltage three-phase ESP power and the SRU, containing a fuse and protective circuitry to limit possible damaging levels of energy from being applied to the SRU if a phase-to-ground fault occurs in the motor or the motor power cable.

The HVI is not required for testing the ACE system on the surface; however, the HVI is required to be used when there is a connection to a motor with high voltage applied. The HVI may be ordered as a separate component to be installed in an existing high voltage cabinet, such as an output transformer.

The ACE HVI is specifically designed to protect the operator from lethal voltages and the surface readouts from damage during motor or cable fault conditions. The HVI is certified to conform to UL and CSA safety standards, and every one is tested at 7000VAC during manufacturing.

Other brands are not certified and may not protect the surface readouts from being damaged or protect operators from being exposed to lethal voltages. The GRC/Sercel ESP Surface Package, which is a direct copy of an obsolete REDA design from 40 years ago, is not certified, is not safe, and does not protect the surface readouts from damage during fault conditions. This unit should never be used with ACE equipment.

HVI Installation

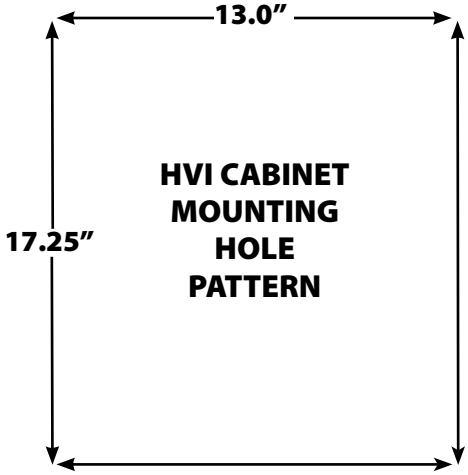
CAUTION

The high voltage interface (HVI) weighs in excess of 40 pounds/18 kg. To avoid injury, two people are required to carry and install the unit.

The HVI is typically mounted inside or on the outside of the switchboard, VSD, or transformer. If the high voltage wires leave the enclosure of the switchboard, VSD, or transformer to connect to the HVI cabinet, they must be inside a protective conduit with no other power or signal cables. The ground termination in the HVI must be connected to the wellhead ground. This is typically done at the main ground connection on the transformer.

In addition to the supplied hardware, four 5/16"-18 1" long 316L stainless steel bolts and matching 316L stainless steel nuts and lock washers are required as well as a suitable conduit for the connecting wires. To mount the HVI, first drill four holes, each 3/8" diameter, in the cabinet where the HVI is to be mounted using the following pattern.

1. Secure the four mounting brackets to the rear corners of the cabinet using the stainless steel screws (supplied).
2. Using assistance to lift the cabinet, secure it to the switchboard or VSD cabinet using the 5/16" hardware.
3. Drill 2 holes in the HVI cabinet to accommodate both conduits, and then run the shielded instrumentation wires inside one conduit and the high voltage wires and the ground wires in the other.

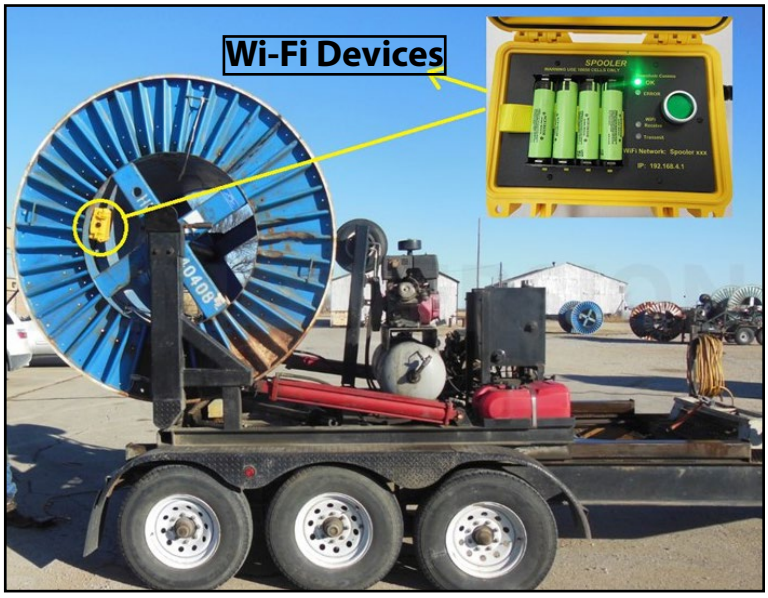


The three high voltage wires and ground wires are connected to the motor power cable. They must be on the secondary side of the transformer windings. A 5 kV 1/8 Amp fuse type Buss HVJ-1/8 is in series with each of these three wires. See appendix A for typical wiring schematics.

Accessories

Spooler

Introduction



The ACE Spooler allows continuous, safe monitoring of an ACE ESP downhole sensor, a downhole motor, and the connecting cable in real time during installation. The unit magnetically mounts inside the rotating cable spool and is electrically connected to the end of the cable inside the spool. The Spooler provides electrically limited power to the downhole sensor via the ESP cable, decodes the sensors transducer readings, and monitors the ESP power cable condition. The Spooler establishes a local Wi-Fi network, so readings may be monitored continuously by any personnel within range using standard cell phones, laptop computers, handheld tablets, etc. Multiple personnel may all monitor the system at the same time, anywhere within range of the Wi-Fi signal.

Any fault conditions from the cable, sensor or interconnect during installation will be apparent within seconds to everyone monitoring the system. Rather stopping the rig periodically, attaching a test unit to the end of the cable, and then waiting to verify downhole readings, any errors are now reported instantly. The unit is battery powered and will typically operate for 15 hours on the field replaceable, rechargeable batteries. A spare set of batteries and charger are provided, so the device may be up and running again within a minute or two of the batteries being changed.

- Does not require any internet, wireless, or cell phone service to operate.
- No license required to operate anywhere.
- Error indication within seconds helps pinpoint a downhole error location.
- Easy for all rig personnel to monitor the system.
- No need for sensor service personnel to remain on-site during a run in.
- Faster, safer, verified system installs.
- Use any brand of tablet, cell phone, or wireless device to monitor with.

Magnet Warnings

- KEEP AWAY from persons with medical implants.
- WEAR OSHA / PPE GLOVES when attaching the Spooler to the inside of a cable spool.
- MAKE SURE the Spooler is powered off when attaching or removing the Spooler from the cable spool.
- KEEP AWAY from metal or conductive objects to prevent attachment.
- DO NOT use if the magnet is chipped or broken.

- DO NOT modify, disassemble, puncture, cut, crush, or incinerate.
- DO NOT expose to excessive high temperatures.

⚠ CAUTION

The SPOOLER uses two strong magnets to secure the device to the inside of a cable spool. Observe the following warnings for safe operation.

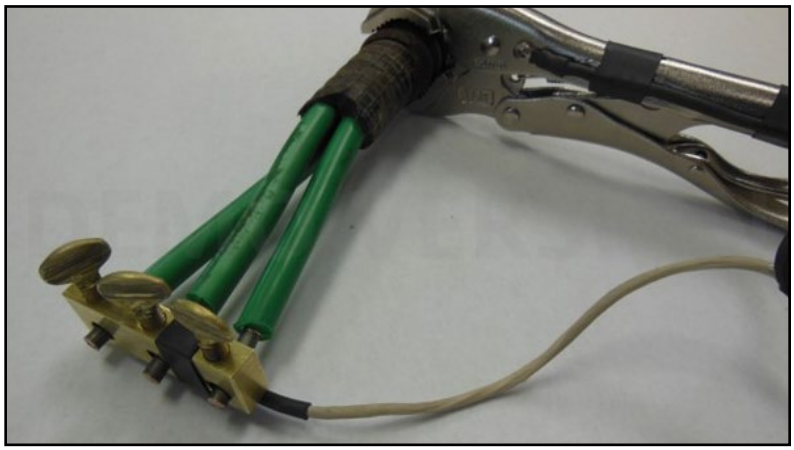
Spooler Installation and Operation

⚠ CAUTION

The SPOOLER is not designed or intended to be used within 25 Meters of the well head. When not in storage, it may be located inside the cable spool by means of its built in magnets, and the cable spool is located on the spooling truck some safe distance away from the well head. Since the Spooler uses four high capacity Lithium Ion (Li-ion) batteries, it should never be taken with 25 Meters of the well head.

1. Ensure the Spooler is turned off and the four charged batteries are installed correctly.
2. Mount the Spooler inside the cable spool using the magnets attached to the Spooler. **NOTE**: Be sure to mount the Spooler box close to the end of the cable that comes out of the center of the cable spool.
3. Peel back the insulation on the end of the cable and expose the three cable conductors.
4. Attach the brass signal block to the three cable conductors and tighten the thumbscrews so they grip the conductors securely.
5. Secure the large locking clamp onto the cable sheath tightly enough to prevent it from coming loose but not damage the cable sheath.

6. Ensure the brass signal block is well clear of the metal spool holding the cable and will not short to the cable spool during rotation.



7. Open the Spooler and turn it on by pressing the green push button; LED's should flash as it powers up and attempts to connect to the downhole sensor via the power cable.

8. There are no other adjustments or controls on the Spooler device; they are all provided on any connected Wi-Fi device.

9. Close the Spooler box and snap the two latches closed. Depending if the beeper is enabled the box may chirp until sensor initialization is complete (the beeper may be enabled or disabled remotely via the Wi-Fi device).

Wi-Fi Connection

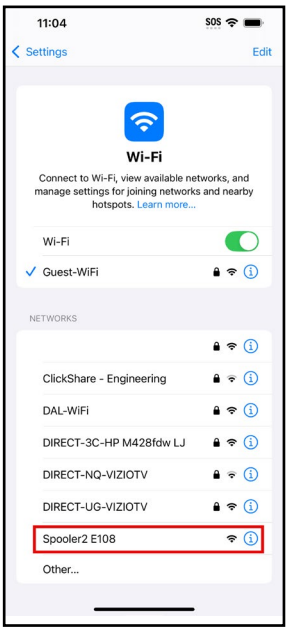
Once the Spooler has power, it will begin to generate a standalone Wi-Fi access point. Almost any type of device with Wi-Fi capabilities, such as a modern smartphone (even an obsolete smartphone without cell service), a portable tablet, laptop computer, and so on, may be used to monitor and control the Spooler. In the following examples, a low-cost Amazon Fire tablet is being shown; however, similar screens would appear on any other type of device.

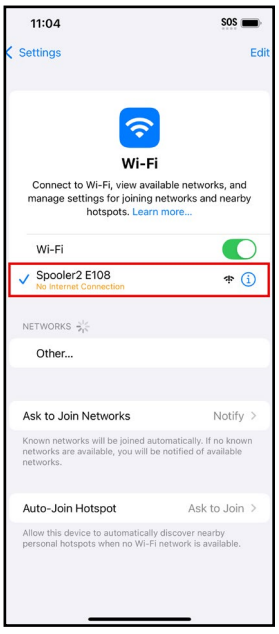
1. Locate the Wi-Fi network. This can usually be accomplished by going to the device settings and selecting Wi-Fi. The location of the Wi-Fi network selection may change depending on the operating system.

2. Select the Spooler network and connect to it. **Note:** On some Apple devices, another prompt may need to be acknowledged to connect.

   The Spooler network is identified as Spooler XXXX where XXXX is unique to each Spooler device (XXXX are the last 4 digits of the Spooler MAC address). This allows multiple Spooler devices to be operating in close proximity without interfering with one another.

   Different wireless devices may complain of being unable to access the internet; however, the internet is not required to communicate with the Spooler, and the message should be ignored.

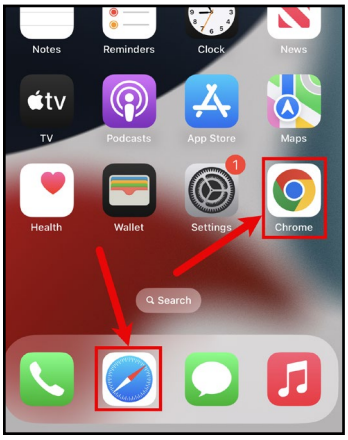


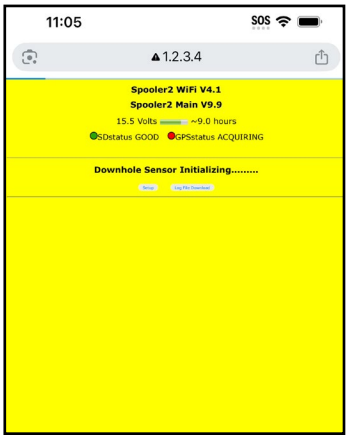


3. Once connected to the Wi-Fi network, open a browser window to access the Spooler.

   Again, different devices have different options for browsers, such as Safari for Apple products and Chrome for many Android devices.

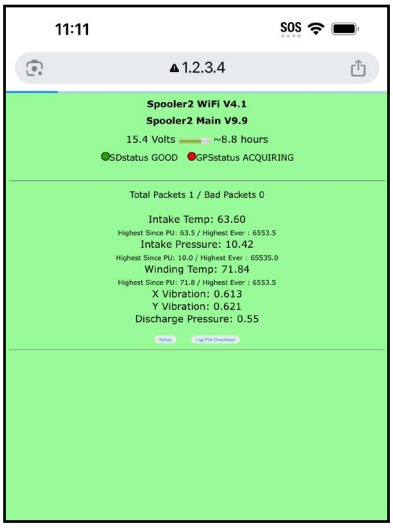
4. In the browser address bar, type the IP address of the Spooler (1.2.3.4). This is always the same for all Spoolers. The following screen should then appear, and in this case, the sensor is still initializing and the background will be yellow. Notice the IP address of 1.2.3.4 in the address bar. Updated versions of Safari may show an error message that the webpage cannot be parsed. If that occurs, simply connect using another browser, such as Google Chrome, or try another smart device.

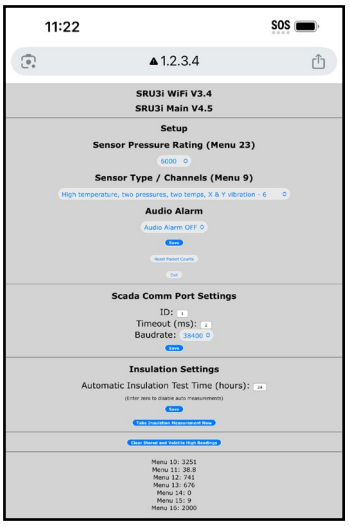




After a minute or so, the screen background color should change to green, meaning the configuration is correct and good readings are being received. Readings will be displayed from the sensor. In the example, a 5-channel sensor is connected. Each time a set of readings are received from the sensor, the total packet count will increment. This count is shown along with the total number of corrupted packets. It is normal to get a few bad packets during start up as the Spooler adjusts electrical parameters to match the sensor. The screen will automatically be refreshed every 10 seconds, slightly faster than the sensor readings are updated, so displayed readings will be current. There is just a single control on the screen labeled "Setup."

If "Setup" is clicked, another screen will appear that has the configuration adjustments and basic diagnostic information. There are just three settings that may need to be changed. The first is the pressure rating of the sensor, and it should match the sensor. The first digit of the sensor serial number indicates the pressure rating, e.g., 6 would mean its a 6000 PSI rated sensor. Clicking on it will display a drop-down menu, and a different pressure rating may be selected. If the selection is changed, the "Submit" button then has to be clicked to write the new setting. Apple products do not use a drop-down selector; typically the selections are displayed at the bottom of the screen.





In a similar way, the sensor type may be changed using the next drop-down menu; again, click "Submit" after making a change. If the wrong sensor type is selected, then the readings will not be decoded. The last setting allows the user to enable or disable the audio warning beeper located inside the Spooler. The beeper will sound if there are any error conditions, so the operator may want to silence the alarm until any errors are corrected. Once the changes are complete, select "Done," and the screen will revert to the main status screen.

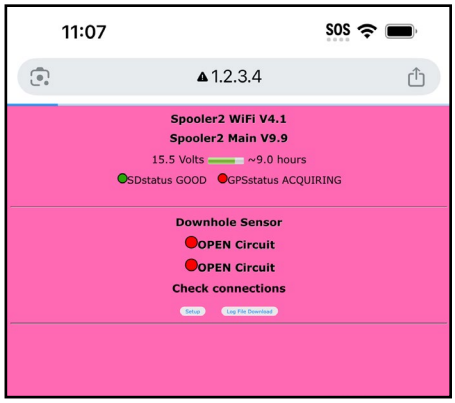
The packet count, displayed on the main status screen may be reset.

At the bottom of the Setup screen are some diagnostic displays that correspond to the indicated menu numbers on the SRU and SRU2 readouts. This enables basic diagnostics to be performed by observing these menu items. **Note:** These will update by default every 10 seconds. Some diagnostics, such as the sensor current draw (menu 12), change rapidly, so if the user keeps clicking refresh at the top of the browser window, they will be updated quickly.

Always ensure all connected users press "Done" and return to the status screen after making any changes to prevent inadvertent changes to the settings. Be aware that other users that may use their Wi-Fi devices nearby and could also change the settings.

Error Conditions

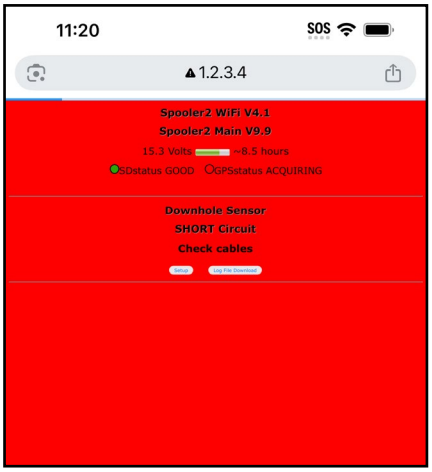
The Spooler is able to identify and display three main causes of errors. If the audible beeper is enabled, these will also cause the alarm to sound.



The first error is caused by an open circuit in the system. It may be between the Spooler and the end of the cable, or the cable may be cut either at the surface or downhole. Turn off the Spooler before trying to locate the problem.

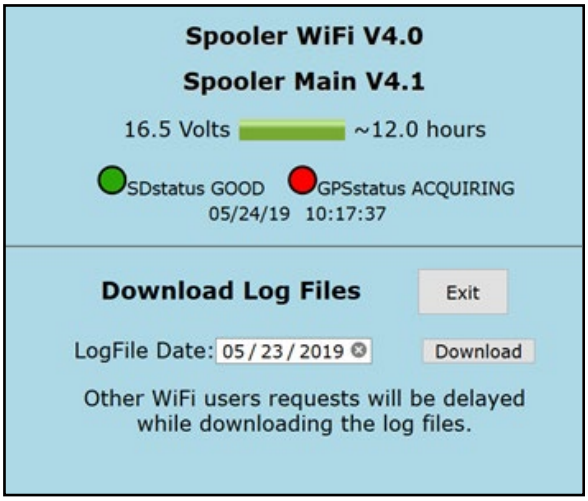
A short circuit again indicates a problem somewhere in the system, which may be at the surface or downhole. Turn off the Spooler before trying to locate the problem.

If the "Cannot decode sensor data" screen is displayed, it indicates that data is being received from the sensor; however, the Spooler cannot decode the data. This may happen briefly as the system is powered up. It may be caused by intermittent contact somewhere or by a Spooler that is not configured correctly to match the attached sensor. Verify the Spooler configuration matches the sensor on the Setup screen.



Always ensure all users connected to the Spooler network ensure they are monitoring the main status screen by clicking "Done" after making changes on the status screen. If different users are both changing items on the setup screen, the Spooler settings may flip back and forth between different users settings, thus disrupting good sensor readings.

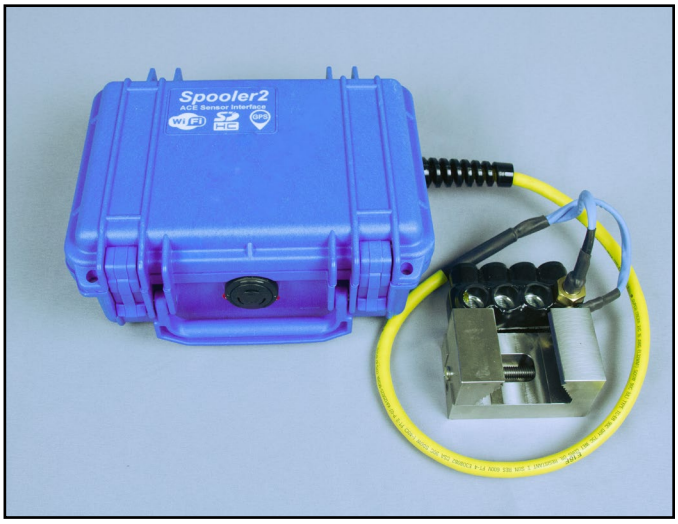
Spooler2



There is an enhanced version of the Spooler available, the Spooler2. The Spooler2 adds internal data logging of every reading ever taken. In addition, the Spooler2 has an internal GPS, which it uses to obtain the well site location as well as the date and time, which are required for data logging. The internal high performance GPS will decode signals from the 4 worldwide GPS systems currently operating (Navstar GPS USA, Glonass Russian, BeiDou Chinese, and Galileo European), so the Spooler2 will operate anywhere in the world with enhanced accuracy. Mount the Spooler2 toward the edge of the cable spool. The internal GPS antenna is on the left side of the unit (opposite side from the cable). After powering up, the Spooler2 will take a few minutes to acquire the GPS signal, and then the data logging will begin. The data log files are unique for each full day, and each file is approximately 900KB in size, so it will take a few seconds to download the file. Select a date from the pop-up calender. The appearance of the screen will vary depending on the tablet, phone, PC, etc. being used.

The start of a typical file will be as follows. The first line will be the GPS coordinates when the Spooler was first turned on. After that, each line will have the date, time, and channel readings. In the example below, the Spooler2 was connected to a 2 channel sensor. Readings are stored every 10 seconds. The data is stored on an SD card inside the Spooler2. To extend the card's life, the data is actually written to the card approximately every 3 minutes.

36° 42.73047' N 95° 56.05790' W
05/23/19,09:16:58,72.53,2.20,0.00,0.00,0.00,0.000
05/23/19,09:17:08,72.53,2.20,0.00,0.00,0.00,0.000
05/23/19,09:17:18,72.87,1.84,0.00,0.00,0.00,0.000
05/23/19,09:17:29,72.87,1.84,0.00,0.00,0.00,0.000
05/23/19,09:17:39,72.87,1.33,0.00,0.00,0.00,0.000
05/23/19,09:17:49,72.87,1.03,0.00,0.00,0.00,0.000
05/23/19,09:17:59,72.87,0.98,0.00,0.00,0.00,0.000
05/23/19,09:18:08,73.21,1.37,0.00,0.00,0.00,0.000
05/23/19,09:18:20,73.21,1.37,0.00,0.00,0.00,0.000
05/23/19 09:18:30,73.21,1.04,0.00,0.00,0.00,0.000



Power Consumption

ACE sensors consume very little power compared to other brands, one reason the ACE sensors may be powered with portable devices that are battery powered such as the Spooler. The run time before the batteries need to be exchanged with charged batteries will vary depending on many factors, such as the age of the batteries, the ambient temperature, the sensor/cable state (for example, a shorted cable causes more power consumption or an open circuit uses less power) and Wi-Fi activity.

The Wi-Fi communication back and forth to the Spooler actually consumes more power than a connected sensor would. So as more users connect to the Spooler, the power consumption increases, resulting in shorter battery run times. Although users are able to refresh their device screens as quickly as they wish, the Spooler defaults to updating each device every 10 seconds (unless prompted by a user request), since faster rates increase power consumption.

General Lithium-Ion Battery Recommendations

Lithium-ion batteries have become very popular in recent years. They are widely available and sold under many different brands. The most popular application is for operating electronic cigarette vaporizers, so many Li-ion batteries are sold for that purpose. Batteries designed for vaporizers need to have very high output current capability but generally have a limited capacity (mAh).

The Spooler is just the opposite, as it draws a very low, limited current (0.1 Amp normally, 0.25 Amp maximum). It's desirable for the Spooler to operate as long as possible without changing the batteries. So although the Spooler will operate with vaporizor batteries in an emergency, it is not recommended as the run time will be limited.

For the best run time and long-term performance, Panasonic NCR18650B 3400mAh Flat top batteries are recommended. These cells, which are provided with the Spooler, typically give a run time of approximately 12–16 hours when fully charged. **Note:** There are two versions of this battery, one with a button top and the other with a flat top. Either will work, but the flat top is preferable as its less likely to short if it is mishandled. Typically the Panasonic cells have a lifetime of at least 500 charge/discharge cycles, which would be well over a year if used every day.

There are many fakes and mislabeled batteries for sale. One recommended source for genuine replacement Panasonic cells is www.imrbatteries.com.

Warnings

CAUTION

The Spooler uses four Lithuim Ion (Li-ion) batteries. Observe the following warnings for safe operation.

Use caution as misusing or mishandling the battery may cause a FIRE or EXPLOSION which may result in personal injury or property damage. The user must have an appropriate understanding of the potential dangers of LITHIUM ION BATTERIES before purchase and usage. These batteries are manufactured and sold for the intended use in the SPOOLER only which incorporates proper protection circuitry for the batteries. These batteries are neither designed nor intended to be used with an E-CIGARETTE, a VAPORIZER, or similar devices.

- DO NOT ship via overnight or air transportation. The Spooler batteries must ship GROUND only and cannot travel by air.
- DO NOT USE with an E-Cigarette, a Vaporizer, or similar devices.
- DO NOT STORE LOOSE OR IN A POCKET, PURSE, ETC. ALWAYS USE THE PROVIDED PROTECTIVE CASES OR BOX FOR STORAGE AND TRANSPORT.
- WHEN NOT IN USE, ALWAYS STORE LITHIUM ION BATTERIES IN THE PROTECTIVE CASE/BOX IN WHICH BATTERIES WERE DELIVERED.

- Misusing or mishandling lithium ion batteries can pose a SERIOUS RISK of personal injury or property damage.
- BATTERIES MAY EXPLODE, BURN, OR CAUSE A FIRE IF MISUSED OR MISHANDLED.
- ONLY use with proper protection circuitry.
- DO NOT short circuit intentionally or unintentionally.
- KEEP AWAY from metal/conductive objects to prevent short circuiting.
- DO NOT use if PVC wrapper or terminal insulator is damaged or torn.
- DO NOT use if battery is damaged in any way.
- DO NOT over-charge or charge above the maximum voltage rating.
- DO NOT over-discharge or exceed the continuous discharge rating.
- DO NOT modify, disassemble, puncture, cut, crush, or incinerate.
- DO NOT expose to liquids or high temperatures.
- TURN OFF the Spooler before changing the batteries.
- DO NOT solder onto battery or spot weld to the battery.
- DO NOT poke or pry the battery with any kind of tool. Use the Spooler ribbon to remove batteries.
- DO NOT use force to install or install in reverse/backward.
- DO NOT charge the spare batteries close to the wellhead.
- ONLY use within manufacturer's specification.
- KEEP AWAY from pets and children.
- ALWAYS charge in or on a fire-proof surface and never leave batteries charging unattended.
- ONLY use a smart charger designed for this specific type of battery.
- DO NOT mix and match brands and models, old and new, used and unused batteries.
- STOP immediately if while charging/storing/using the battery it emits an unusual smell, feels hot, changes color or shape, or appears abnormal in any way.
- If exposed to battery electrolyte, flush with water immediately and/or immediately contact a physician or emergency services.
- DO NOT throw away in trash; contact your local jurisdiction for proper recycling or disposal.

Battery Lifetime

If properly cared for, these batteries will typically last for over 500 charge/discharge cycles. There are a few conditions that will help to preserve the long battery life. The most important is to not allow the cells to become fully discharged, as this rapidly reduces each cell's lifetime. Once the battery low warning appears on the Wi-Fi device display screen, the Spooler should be turned off, the batteries exchanged with charged ones, and the removed batteries should be charged. Do not leave the Spooler turned on with depleted batteries as this may permanently damage the batteries. When fully charged each cell has an output voltage of approximately 4.15 volts, for a total of 16.6 volts. Once the total gets down around 12.5 volts (each cell about 3.12 volts), the low battery warning will appear. Although the Spooler will continue to operate when the supply voltage is as low as 7 volts DC, by this time the batteries may be permanently damaged, so the batteries should be exchanged as soon as they become low.

Charging Notes

The charger supplied with the Spooler will operate from standard 120 VAC or from 12 VDC (car cigarette charger adapter) power. It will charge at the same rate when powered from either source. Typically with cells that have

been removed when the "Replace Batteries" warning first appears, it will take approximately 3-4 hours to fully charge them. Cells completely discharged may take 5 hours or longer to charge. The charger will start charging at a high rate and slowly reduce the charge current as the cells fill; this increases the cell life. Each cell is individually charged and monitored, so it is safe to mix cells of various states of charge in the charger. The state of each cell may be monitored, and the charger is also capable of testing the battery condition and capacity. Consult the manual supplied with the charger for further details. Do not attempt to quick charge at an accelerated rate using a charger or power supply not designed for these cells.

Field Test Box

The ACE field test box consists of a robust, portable case containing a built in SRU2i and additional components to simulate the HVI. An external charger is included with the case to allow you to recharge batteries.

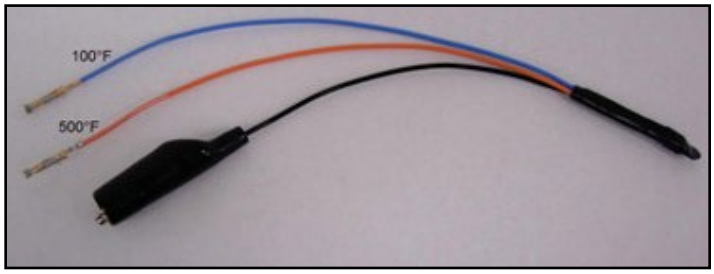
The Field Test Box is ideal for testing a system during equipment run in as it may be quickly connected directly to the motor power cable to verify cable and instrument integrity and operation without requiring AC power at the well head or the spooler.

miniSIM Signal Simulator

The miniSIM simulates a sensor to allow quick and easy verification of all surface equipment. Once the motor is shut off the miniSIM may be connected at the junction box and if good readings appear at the SRU the surface equipment is verified. The miniSIM may also be plugged directly into a surface readout to verify correct operation. The miniSIM always generates three fixed values, an intake temperature of 250°F, a pressure half of the full scale readout setpoint and a winding temperature of 500°F.

NOTE: Menu 9 (tool type) on SRU must be set to 3 for miniSIM to function correctly.

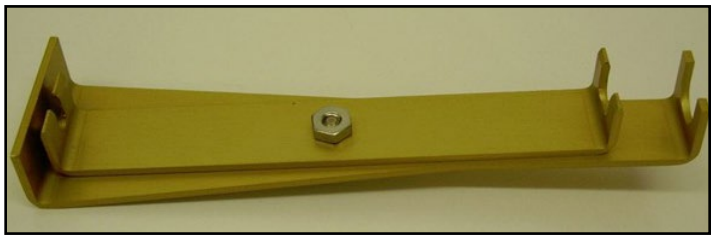
Temperature Simulator (Test RTD)



The winding/oil temperature simulator allows quick and easy verification of the system with a winding temperature transducer. This allows simulating two fixed temperatures (100°F and 500°F) to quickly verify accurate, positive operation of the sensor. If a temperature transducer has already been installed in a motor to be run, but the motor is not convenient to the instrument, this simulator may be used. Connect the orange

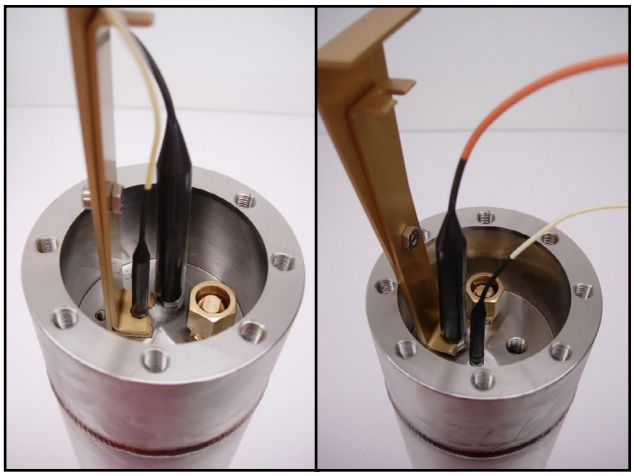
wire to the small motor temperature transducer pin on the instrument and the black wire with alligator clip to one of the threaded bolt holes to simulate 500°F. Alternately connect the blue wire to the small motor temperature transducer pin on the instrument to simulate 100°F. The simulated temperatures will be visible on the SRU, typically within +/- 2°F.

Boot Removal Tool



After having the sensor be downhole under high pressure and temperature, it may be difficult to remove the connecting boots from the signal lead and temperature sensor. Pulling at the top of the boots or by the wire causes the boots to grip tighter and may cause damage. The boot removal tool allows easy removal by applying lifting force underneath the boots, where fingers and other tools will not reach. This allows the boots to be removed without damage to the boot or the pins; the sensor may then be re-run without requiring any service. The tool has a thin grooved and wide grooved pulling tongue, so the same tool may be used to remove the large and the small boots.

Boot Removal Instructions



For the small pin, locate the tool with the small grooved puller below the boot. It may take some pressure to slide it under the boot if the boot has hardened, which may occur if the boot has been exposed to certain well fluids and chemicals. Once the tool is located simply pull up on the sliding part, which will cause the boot to pop off the pin.

For the larger pin turn the slide around, so the large groove is to be located beneath the boot. It may be necessary to remove the temperature transducer grounding screw first as it may block access for the tool to reach under the boot. Repeat the sliding process to remove the large boot.

Diagnostic

System Diagnostics

If the system does not provide valid readings, the SRU can display diagnostic information to help try to identify the problem. First, verify that menu 14 on the SRU is approximately 22–24 if operating on AC power or approximately 12 if using a battery-powered field test box. These two values will change depending on the supply voltage.

Next use menus 11 and 12 to observe readings then use the following table to try and isolate the problem.

Menu 11 SRU DC Volts	Menu 12 SRU DC Current	Comments
38–42	180–220	Signal lead appears open circuit. Check HV fuse, verify signal lead and ground wire. Measure DC Voltage at SRU signal lead to ground, should be about 40VDC. Verify menu 10 is 3250. Check signal/ ground leads are not reversed.
Less than 35	180–220	SRU output may be damaged. Power down SRU, remove signal lead, power SRU back up. If condition still exists replace SRU.
38–42	450–600 changes less than about 25	Tool does not appear to be transmitting/system impedance may be too high. Try changing menu 10 to 3750 and cycling power to the SRU. Verify 3 phase choke is a genuine Automation Solutions OEM unit.
38–42	450–712 changes greater than 100	Should be normal operation. Check pressure and 2 temperature readings. If at least 1 of the 3 is correct, then the other channels may have failed in the sensor. If menu 12 is changing but no readings after a couple of minutes, verify menu 9, number of channels, is set to match the type of sensor attached. Refer to System Integrity Test for further details with the chart of sensor types and settings.
Less than 2	760–800 varies less than 25	SRU output voltage is shorted out before the signal goes through the three phase choke. Power down SRU, remove signal lead. Power up SRU. If condition continues, replace SRU. If fault clears with signal lead removed problem may be MOV on fuse block assembly shorted which may occur if 1 motor leg is shorted to ground or three phase choke failure.
15–25	760–800 varies less than 25	Verify SRU as above by trying without signal lead connected. This condition is probably a short at the motor winding/ tool connection point or possibly a phase to ground short.
25–42	750–780 varies less than 25	Verify SRU as above by trying without signal lead connected. This condition is probably a short to ground inside the Downhole Tool.

Note: Base current values bellow 712 is a sign of normal operation. When the gauge is transmitting data, it is common to see current spikes above 712. A consistent base current above 750 is an indication of a faulty gauge (see above for diagnostics).

Some Faults and Possible Causes

1. **The HVI Fuse blown/blows when replaced, typically caused by phase to ground or partial phase to ground shorts in the motor cable, motor, or well head.** To isolate the cause, power down and disconnect the motor from high Voltage system and Megger test the cable/motor/sensor. If the system runs and then a fuse blows after some time, this may be due to fluid moving in to a damaged area of the cable. To verify this, power down and disconnect the motor cable from the high voltage system, transformer, and HVI. Use DVM to measure DC voltage between the three motor leads. DC voltage should be around 0.0 VDC; if there is a difference (or a voltage that is slowly increasing/decreasing as the well fluid rises or falls), this may be due to cable damage and electrolytic reaction between the cable conductors.

2. **A brand new HVI fuse is open or opens after a short time.** (When replaced, the system runs normally.) The HVI fuses are rated for very high voltage but very low current. As a result, they have a long, very thin internal conductor, which will fail open circuit if there is excessive vibration. New fuses left in vehicles should be wrapped in cloth, bubble wrap, or similar shock absorbing material to protect the internal fusible element. A fuse bouncing around in a pickup truck glove box will be open circuit after a few weeks. Ensure the HVI enclosure is not subject to excessive vibration from attached equipment such as VSDs or cooling fans.

3. **In the 440/460/480 VAC VSD system, the sensor runs until the VSD is started.** Ensure an isolated (not auto) three-phase transformer is installed between the VSD and the motor cable/HVI. The VSD is electrically connected to the incoming three phase, which is grounded at some point, so the sensor requires an isolation transformer.

4. **The electrical test box does not stay charged.** The test box contains a 9AH SLA battery, which should stay charged for many hours of operation and for several months of no operation. To charge the unit, plug it into AC power and switch the on/off toggle to the "|" symbol. The unit will not be charged if it is set to "O." An audible click may be heard a second or two after turning on the toggle switch. It does not matter if the clockwork timer is on or off. The test box can remain plugged into the AC power and left turned on, indefinitely charging if needed as the internal battery charger will switch to trickle-charge mode once the battery is fully charged. Note that the SRU displays the state of charge (internal DC voltage) on menu 14. On normal, the charged battery operation the voltage will typically be 11.8 to 12.5 VDC. While charging, the voltage will slowly rise to about 13.5 VDC. Readings below about 11.3 VDC indicate a discharged battery; if the voltage does not come back up after charging overnight, then the battery should be replaced.

5. **The winding temperature reading is missing. (SRU1 or SRU3)** If the winding temperature is incorrect, then the reading can help isolate the problem. The winding temperature will be displayed as 0.0 °F if the winding transducer is shorted out. If it displays 1.0 °F, the winding transducer is completely open circuit. This is because either it is not plugged in or the transducer wires may be cut. If 2.0°F is shown, the winding transducer is partially, but not fully, open circuit. This may occur if the transducer is unplugged or there is a wire cut and there is water or saltwater in the motor. If the temperature is below 32°F, the readout will display 31°F; temperatures below 10°F will display 0.0 °F. (The normal winding transducer range is from 32 °F to 600°F.) The sensor should be heated to temperatures above 32 °F to ensure the winding transducer functions correctly. **(SRU2)** If the winding temperature is missing and menu 3 readings fluctuate, the winding transducer can be considered faulty.

6. **There is a 0 Pressure Reading. Important**: If intake temperature is similar to your ambient temperature the transducer is good. A 0.0 psi intake pressure reading might occur due to transducer tolerances. To ensure the gauge is not faulty, pressure should be applied to the gauge, which will begin to read correctly. This is due to transducer accuracy: for example, an 8,000 psi transducer with a 0.25% accuracy has a 20 psi pressure window (8000 psi x 0.0025 accuracy = 20 psi). At sea level, the standard pressure is 14.7 psi, and the transducer might read 0.0 psi due to transducer tolerances. Temperatures below 40 °F will compound this phenomenon due to elastomers hardening at lower temperatures.

Surface Testing

Instrument Motor and Adapter Testing

The assembly and connection of these components may vary slightly depending on the manufacturer's motor configuration. The motor adapter and instrument may be coupled together before reaching the wellhead, and then the assembly can be attached to the motor. Alternately, the instrument may be installed at the wellhead by attaching it to a motor adapter that is already mounted onto a motor.

The complete adapter and instrument may also be attached to the motor before it is shipped to the wellhead; this gives a controlled environment for assembly. However, care must be taken during transit to prevent shipping damage from occurring.

DANGER

Ensure the motor is disconected from any high voltage while attempting these procedures.

CAUTION

Do not apply any voltage or attempt to megger test the temperature transducer pin (smaller one) as damage to the instrument will result.

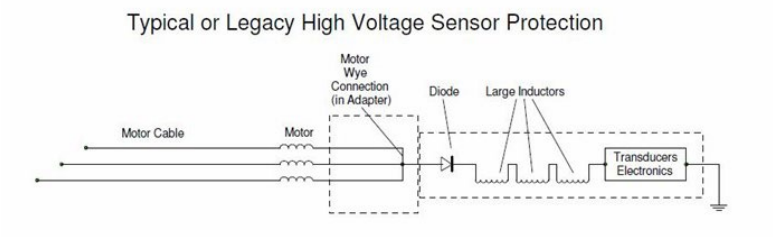
The instrument coupled to the motor and adapter may be tested on the surface before it is run into the well.

Typically, the Field Test Box will be used; however, it is possible to use the SRU or SRU2 directly.

Insulation Resistance Testing

Background

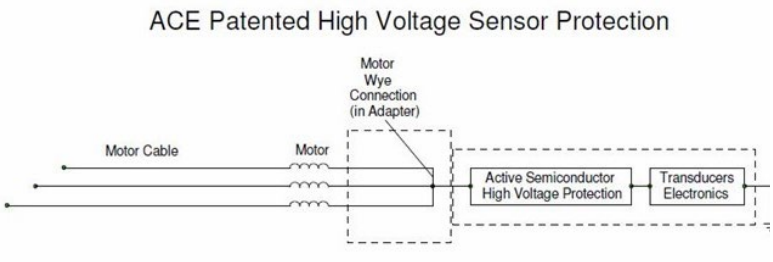
For decades, downhole sensors have typically all used the same method for phase-to-ground failure protection, which causes a large AC voltage relative to ground to be impressed upon the common motor wye point. This protection typically consists of very large chokes (inductors) wired in series in an attempt to block the AC voltage from destroying the sensor.



To allow the capability of DC HiPot or Megger testing, a diode is typically inserted in series with the chokes (see following image). This simple method does have drawbacks. The chokes tend to electrically saturate and lose their protection when DC currents are passed through them. The chokes have to be very large, often physically too large for 3.75-inch diameter systems and are also prone to failure from electrical breakdown during the electrical phase to ground cable and motor faults.

With some brands of sensors, the diode is blown open circuit during a phase to ground short, so ending the life of the sensor, which of course may remain downhole not working for years, even though the phase to ground short could have been repaired.

The ACE sensor incorporates an active safety circuit to protect itself during a phase-to-ground event. It is capable of withstanding over 2700 VAC (this is the voltage if a 4160 volt motor had a phase-to-ground short) indefinitely at the wye point without any damage. Voltages this high typically destroy most other brands of sensor. Once conditions return to normal, the ACE sensor will continue to operate.



As part of the protection scheme, the circuit will automatically turn on to protect the sensor when the applied DC voltage at the wye point exceeds approximately 1500 volts, and it will also turn on to protect the sensor if the applied voltage has a very fast rise time, typically seen during catastrophic motor/cable phase to ground shorts.

Resistance Testing

To measure insulation resistance of the sensor or system, use an insulation tester rated for 1000 volts DC maximum, preferably one that limit rise time for the applied DC test voltage. Testing above 1000V may cause damage or lead to poor test results.

To prevent the safety circuit from falsely engaging while testing, it is recommended to use the ACE test cable, P/N 1170576. The ACE test cable set incorporates a current-limiting resistor to limit the voltage rise time to an acceptable level.

The recommended test instrument is the Fluke 1507 insulation tester; however, many other brands will perform the same function. The series resistor shown in the picture is only required if the sensor is tested on the surface without a motor cable, since a motor cable would have enough capacitance by itself to slow the Voltage rise time allow testing.

The instrument should be tested with a –Ve polarity, so the test leads should be connected as shown with the "common" connection going to the large pin. If connected backward, the instrument will not be damaged, but the Megger test reading will be zero.

Do not connect any voltage to the small pin, which is used for winding temperature measurement. Applying voltage to the small pin may damage the instrument.

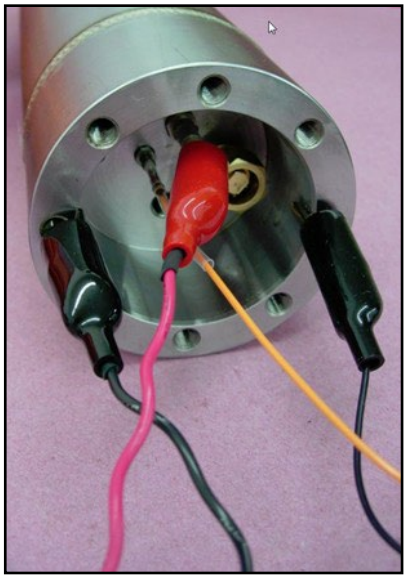
Press and hold the test button on the insulation tester; the test voltage should go up to around 1000VDC and the insulation resistance slowly climb up to several Gig Ohms. Note that temperature, cable condition, cable type, ambient humidity and other factors will influence the system. The sensor by itself, at room temperature, typically has an insulation resistance exceeding 4 Gig Ohms (>4000 Meg Ohms). However, once the sensor is downhole

combined with the motor and motor cable the insulation resistance reading may be down to well below 20 Meg Ohms, mainly due to the motor cable.

The insulation tester may be directly connected to the end of the motor cable while it is still on the spool or as it is being lowered into the well. As explained above, the insulation resistance readings will probably be substantially less compared to readings taken directly from the instrument on the surface; this is due to the effect of the motor and cable leakage resistances.

System Integrity Test

Ensure that power is off to the surface test unit. If the sensor is being tested alone, connect the signal wire to the large (signal) pin and the black (ground) lead to one of the sensor bolt holes. If available, attach the winding temperature simulator black wire to another of the sensor bolt holes. Attach one of the winding temperature simulator leads (orange to simulate for 500°F as shown in the picture or blue to simulate 100°F) to the small temperature transducer pin. Turn on the electrical test unit. Within a couple of minutes, readings should appear; if not, verify menu 9 is set correctly; see the next page for further details.



If a complete system with a sensor is being tested, attach the sensor to the adapter and connect the signal ground lead from the SRU to the motor adapter metal. The bolt holes may provide a suitable place to connect. Connect the signal wire to one of the motor adapter wye lead connections or, if the adapter is attached to the motor, one of the motor leads. Apply power to the SRU , which will briefly display the firmware version and then it will display menu 1, which will show the instrument internal temperature once communications with the sensor have been established.

There are many different versions of sensor available. The SRU/SRU2 must be set to communicate with the correct sensor; otherwise, no readings will be obtained. Menu 9 is set to match the number of channels of data that the sensor is transmitting. Verify it matches the sensor as shown:

Sensor Type	**Operation**	**Menu 9 Setting**
2 Channel (Wireline "slim" models)	Legacy	2
2 Channel Highspeed (wireline PCP model)	Legacy	2F
3 Channel (most common, 1 pressure, 2 temperatures)	Legacy	3
4 Channel (discharge capable version; 2 pressures, 2 temperatures)	Legacy	4
5 Channel standard and high temp (1 pressure, 2 Temperatures, 2 vibrations)	Legacy	5
5 Channel Extreme Temperature (1 pressure, 2 temperatures, 2 vibrations)	Active	5X
6 Channel High Temperature (2 Pressure, 2 temperatures, 2 vibrations)	Legacy	6
6 Channel Extreme Temperature (2 pressure, 2 temperatures, 2 vibrations)	Active	6
Future version		7
Future version		8

The Menu 9 setting can be derived from the units serial number and chart above; menu 23 (pressure range) from the first digit of the unit's serial number.

RGA

Warranty Repair Instructions

You are responsible for all expenses incurred when returning ACE sensors. ACE pays return-to-customer shipping costs only on warranty-repaired units. Although we do not require an RMA number, please notify us of a pending return.

Please mark the invoice and the Airway Bill with the following information:

- **Description:** "Units for Repair"
- **Country of Origin:** USA
- **Duties and Taxes:** Bill Sender
- **Shipping Costs:** Bill Sender
- ATTN: Repairs ACE Downhole
  4334 West Links Drive
  Salt Lake City, UT 84120
  USA

Marking the package correctly is the best way to avoid unnecessary duties/taxes. We will bill your company for any unnecessary charges incurred.

NOTE: Before returning the unit to ACE, please make sure it is clean and free of debris. If the unit has been exposed to any media, ACE Downhole requires a copy of the pertinent MSDS or written statement certifying that the unit was not exposed to any media covered by a MSDS. This information is required prior to the unit being returned to ACE.

Product Failure Details

ACE will deliver a returned sensor summary report to the email below once a unit has been evaluated.

To help us ensure that we address the problems with your transducer, and return the unit to you as quickly aspossible please provide the following:

Company Name:		Ship to Address:	
Telephone #:		Part Description:	Sensor / Surface Redout / Spooler, etc.
Contact Person:		Part Model:	
E-mail:		Part S/N:	

Please provide a description of the problem:

Where did the problem occur?

_____Incoming Inspection **_____In-Process** **_____Field** **_____Run-in-Hole** **_____Other**

Please fill provide information below where applicable

Pressure and temperature conditions present when the failure occurred:

_____psi **_____ °F**

What is the temperature on the temperature strip in the sensor head _____ **°F** (for sensor issues only)

Approximately how many days was the unit at this temperature?

_____days

Last readings displayed in surface readout unit

Pint _____psi
Pdis_____psi (enter N/A for a single pressure sensor)
Tint_____ °F
Tmotor_____ °F
Vib X _____G
Vib Y _____G
Insulation Resistance (SRU2i)_____kOhm
Insulation Resistance (SRU3i)_____MegOhm

Last readings of diagnostic menus in the SRU

Menu 10_____
Menu 11_____
Menu 12_____
The range of value fluctuation in Menu 12_____

Electric tests (for sensor issues only)

Megger Test Result (with ESP cable_____MOhms
Phase to Phase (with ESP cable)_____A-B____BC____AC____Ohm
Megger Test Result (motor and sensor) ___ GOhms
Megger Test Result (sensor only) ___GOhms
What device was used for Megger testing?) _____

Is Fuse in the High Voltage Interface good?

Yes / No

Motor temperature probe (for motor temperature issues only)

How is your motor probe was installed?

ACE RTD probe inserted into motor base in a shop_____
ACE RTD probe installed in motor winding during motor manufacturing_____
3rd party RTD probe inserted into motor base in a shop_____
3rd party RTD probe installed in motor winding during motor manufacturing _____

Should we wait for approval before beginning therepair? (This may cause additional delays)

Yes / No

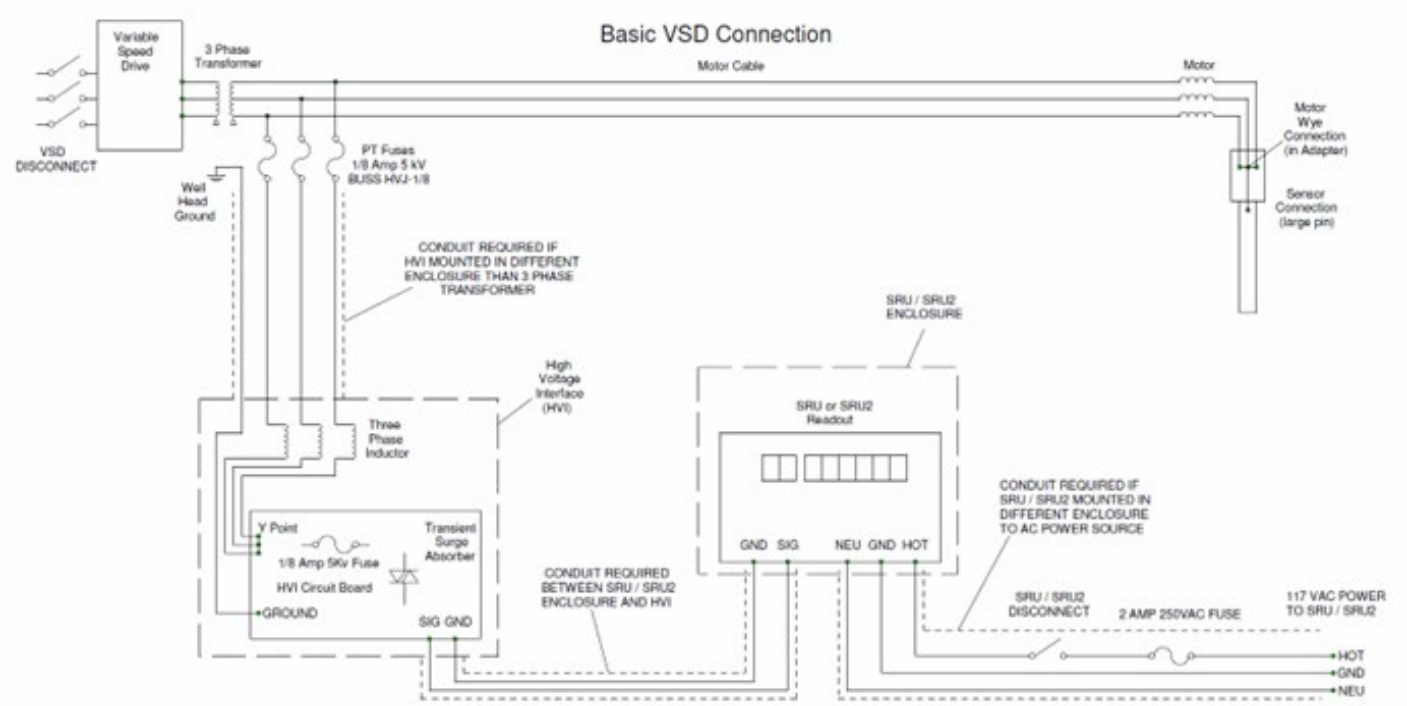
Have you provided your Ship to, and Bill to addresses to ACE?

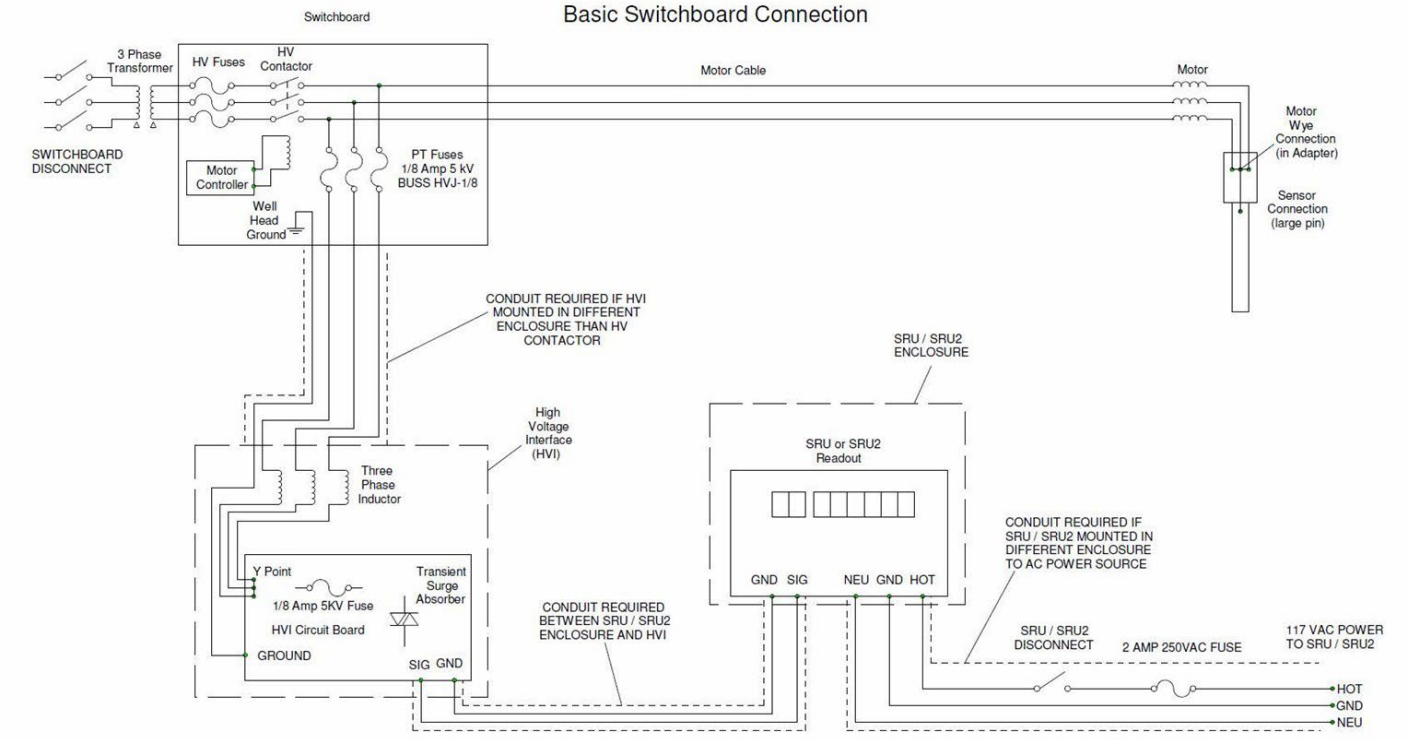
Yes / No

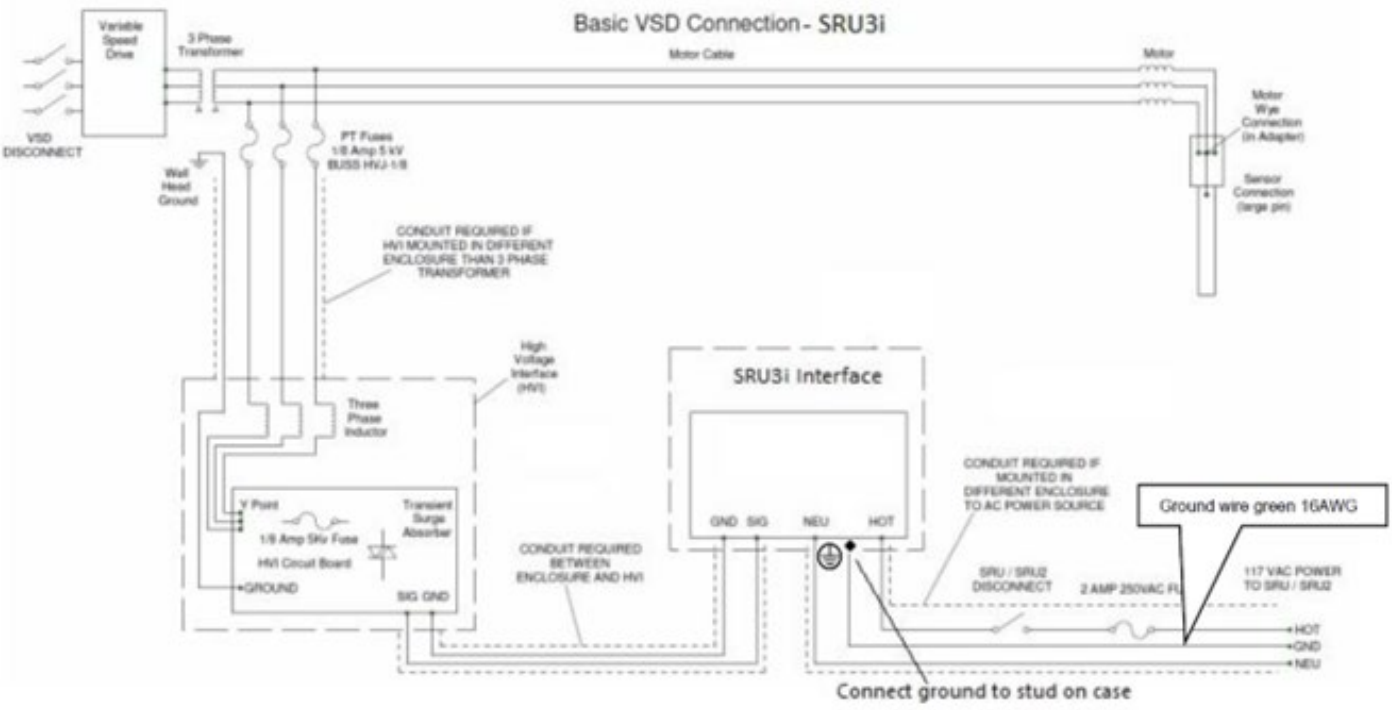
Other observations:
Please attach all additional information related to this return, such as but not limited to, test results,graphs/charts, inspection results, screenshots, etc.

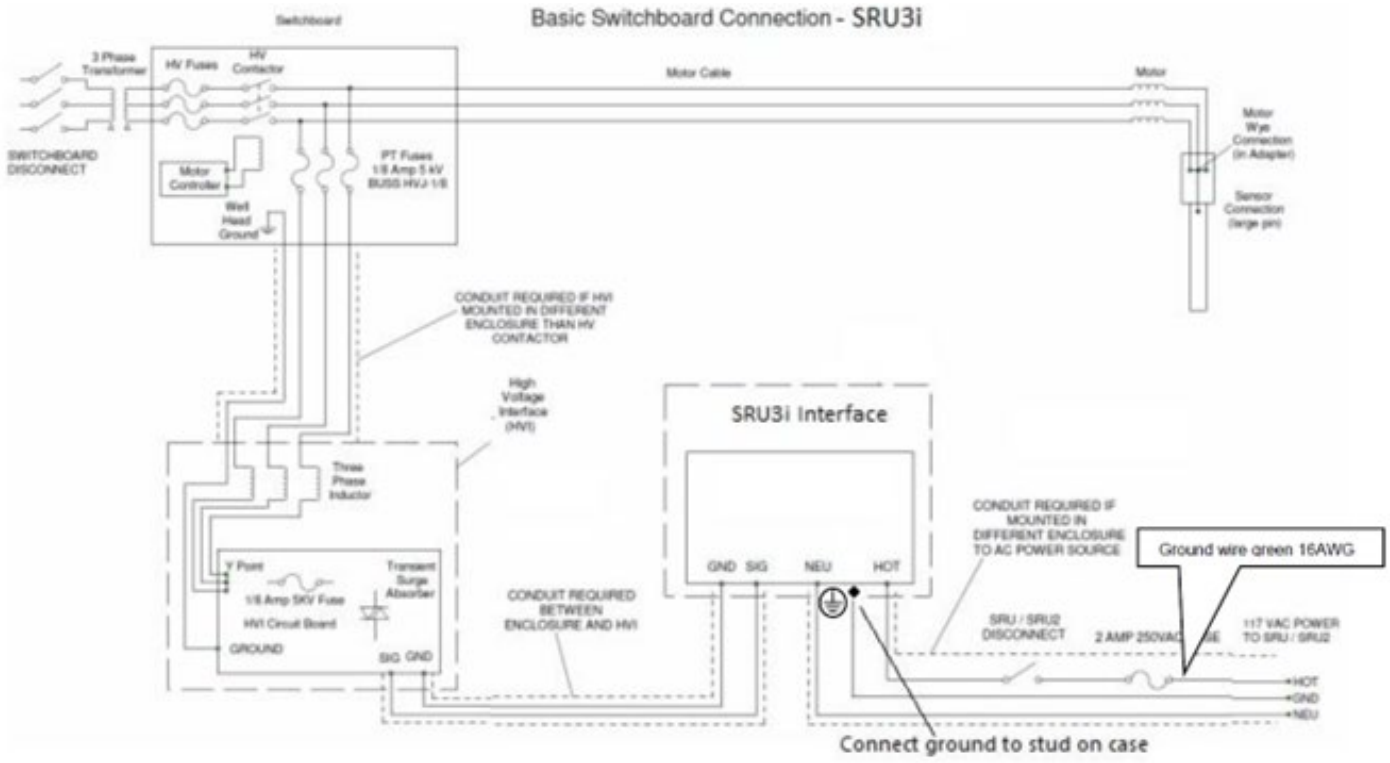
Appendix A

System Interconnection Diagrams






Basic VSD Connection- SRU3i
Variable Speed Drive
3 Phase Transformer
Motor Cable
Motor
VSD DISCONNECT
Motor Wye Connection (in Adapter)
Sensor Connection (large pin)
PT Fuses 1/8 Amp 5 kV BUSS HVJ-1/8
Well Head Ground
CONDUIT REQUIRED IF HVI MOUNTED IN DIFFERENT ENCLOSURE THAN 3 PHASE TRANSFORMER
High Voltage Interface (HVI)
SRU3i Interface
Three Phase Inductor
Y Point
1/8 Amp SKV Fuse
Transient Surge Absorber
HVI Circuit Board
GROUND
SIG. GND
CONDUIT REQUIRED BETWEEN ENCLOSURE AND HVI
GND SIG NEU HOT
CONDUIT REQUIRED IF MOUNTED IN DIFFERENT ENCLOSURE TO AC POWER SOURCE
Ground wire green 16AWG
SRU / SRU2 DISCONNECT
2 AMP 250VAC FU
117 VAC POWER TO SRU / SRU2
HOT
GND
NEU
Connect ground to stud on case


Switchboard
Basic Switchboard Connection - SRU3i
3 Phase Transformer
HV Fuses
HV Contactor
Motor Cable
Motor
SWITCHBOARD DISCONNECT
Motor Wye Connection (in Adapter)
Sensor Connection (large pin)
Motor Controller
PT Fuses 1/8 Amp 5 kV BUSS HVJ-1/8
Well Head Ground
CONDUIT REQUIRED IF HVI MOUNTED IN DIFFERENT ENCLOSURE THAN HV CONTACTOR
High Voltage Interface (HVI)
SRU3i Interface
Three Phase Inductor
Y Point
1/8 Amp SKV Fuse
Transient Surge Absorber
HVI Circuit Board
GROUND
SIG. GND
CONDUIT REQUIRED BETWEEN ENCLOSURE AND HVI
GND SIG NEU HOT
CONDUIT REQUIRED IF MOUNTED IN DIFFERENT ENCLOSURE TO AC POWER SOURCE
Ground wire green 16AWG
SRU / SRU2 DISCONNECT
2 AMP 250VAC
117 VAC POWER TO SRU / SRU2
HOT
GND
NEU
Connect ground to stud on case

Appendix B

Modbus Map

0	Intake temperature
1	Intake Pressure
2	Winding temperature
3	Vibration X
4	Vibration Y
5	Discharge Pressure
6	Spare
7	Spare
8	Number of channels
9	Set Voltage (0 to 4095)
10	Output Voltage measured (0 to 50 VDC, e.g. 407 = 40.7 VDC)
11	Output Current Measured (0-1023)
12	Threshold level (0-1023)
13	Internal bus DC Voltage (typically 23.0 Volts, or 12.0 VDC on battery powered tester); high-register packet count for SRU2/3
14	Digital data decode state
15	Low pass cut off frequency
16	Total downhole data packets received since power up
17	Total bad downhole data packets received since power up
28	SRU model (2 = SRU2)
38	Intake temperature highest value recorded since power up
39	Intake pressure highest value recorded since power up
40	Winding temperature highest value recorded since power up
41	Vibration X highest value recorded since power up
42	Vibration Y highest value recorded since power up
43	Discharge pressure highest value recorded since power up
44	Discharge temperature highest value recorded since power up
45	Spare highest value recorded since power up
76	Analog out 1 present calculated output value
77	Analog out 2 present calculated output value
78	Analog out 3 present calculated output value
79	Analog out 4 present calculated output value
82	Special factory code register
83	Read Real time clock year (0-99) Read only, see RTC write regs below to set RTC
84	Read Real time clock month. (1-12) Read only, see RTC write regs below to set RTC

85	Read Real time clock date. (1-31) Read only, see RTC write regs below to set RTC
86	Read Real time clock hour (0-23) Read only, see RTC write regs below to set RTC
87	Read Real time clock minute (0-59) Read only, see RTC write regs below to set RTC
88	Read Real time clock second (0-59) Read only, see RTC write regs below to set RTC
89	* RTC Year write
90	* RTC Month write
91	* RTC Day write
92	* RTC Hour write
93	* RTC Minute write
94	* RTC Second write
95	* RTC Write Command. After presetting RTC write regs write 54321 to update clock
97	D/H status. 0 = OK. 1 = Connecting. 2 = Open circuit. 3 = Shorted. 4 = Cannot decode
99	* Test values enable. Write 1 to enable test values
100	Test value 1
101	Test value 2
102	Test value 3
103	Test value 4
104	Test value 5
105	Test value 6
106	Test value 7
107	Test value 8
110	* User volatile register 1 (resets to 0 upon power fail)
111	* User volatile register 2 (resets to 0 upon power fail)
112	* User volatile register 3 (resets to 0 upon power fail)
113	* User volatile register 4 (resets to 0 upon power fail)
114	* User volatile register 5 (resets to 0 upon power fail)
115	* User volatile register 6 (resets to 0 upon power fail)
116	* User volatile register 7 (resets to 0 upon power fail)
117	* User volatile register 8 (resets to 0 upon power fail)
120	High precision downhole intake temperature, LSW of 32-bit
121	High precision downhole intake temperature, MSW of 32-bit
122	High precision downhole pressure, LSW of 32-bit
123	High precision downhole pressure, MSW of 32-bit
124	High precision downhole winding temperature, LSW of 32-bit
125	High precision downhole winding temperature, MSW of 32-bit
126	High precision X vibration, LSW of 32-bit
127	High precision X vibration, MSW of 32-bit
128	High precision Y vibration, LSW of 32-bit
129	High precision Y vibration, MSW of 32-bit
130	High precision downhole discharge pressure, MSW of 32-bit
131	High precision downhole discharge pressure, LSW of 32-bit
132	Spare
133	Spare

134	High precision spare, LSW of 32-bit
135	High precision spare, MSW of 32-bit
140	Metric intake temperature, °C Eg 234 23.4°C
141	Metric intake pressure, kPA. Eg 1234 = 1234 kPA
142	Metric winding temperature, °C Eg 234 23.4°C
143	Metric X vibration, m/s2. Eg 321 = 0.321 m/s2
144	Metric Y vibration, m/s2. Eg 321 = 0.321 m/s2
145	Metric discharge pressure, kPA. Eg 1234 = 1234 kPA
200	Software Version (main SRU2/3 board)
201	Serial number
202	Software Version (Display / SD Datalogging board)
203	Site name – first letter
204	Site name – second letter
205	Site name – third letter
206	Site name – forth letter
211	State of insulation measurement sampling 1 to 11; 0 when not taking a reading (write 1 to force a reading via Modbus. Wait until the state reverts to 0 to get result).
214	Calibrated last insulation measurement result, in KOhms.
219	Register that will be written to BH GCS/Advantage VSD Dev 1 Tag 1 (SRU3i / ADCM)
220	Register that will be written to BH GCS/Advantage VSD Dev 1 Tag 2 (SRU3i / ADCM)
254	Register that will be written to BH GCS/Advantage VSD Dev 3 Tag 12 (SRU3i / ADCM)
304	Intake pressure in PSI (BH Centinel compatible)
305	Intake temperature °C x10 (BH Centinel compatible)
306	Motor winding temperature °C x10 (BH Centinel compatible)
440	Vibration X x100 (BH Centinel compatible)
441	Vibration Y x100 (BH Centinel compatible)
468	Discharge pressure in PSI (BH Centinel compatible)
Registers 1000 and above are non-volatile; i.e. the values will be remain the same after power cycle. The ones marked # cannot be written to.	
1000	# Serial number
1002	Set Voltage (0-4095)
1003	Tool type; i.e. number of channels
1005	PSI rating, e.g. 3 = 3000 PSI
1007	Intake pressure highest value recorded
1008	Winding temperature highest value recorded
1009	Vibration X highest value recorded

1010	Vibration Y highest value recorded
1011	Discharge pressure highest value recorded
1012	Spare highest value recorded.
1013	Spare highest value recorded
1014	Runtime (hours)
1015	Modbus ID, 1 to 254. The controller will also always respond to Modbus address 234
1016	Modbus silent time in mS. Adjusts for breaks in packets caused by modems, etc.
1017	Modbus baud rate in baud, e.g. 19200 = 19200 baud.
1018	Ethernet Enable. 1= Enable IP comms, 0 = disable IP comms
1019	First part of IP address
1020	Second part of IP address
1021	Third part of IP address
1022	Fourth part of IP address
1023	First part of IP netmask
1024	Second part of IP netmask
1025	Third part of IP netmask
1026	Fourth part of IP netmask
1027	IP Port, RTU Protocol. (See 1063 for TCP/IP Protocol)
1028	Write 22 to reset all EE values to defaults. Use with caution!
1029	Relay 1 source register
1030	Relay 1 on setpoint
1031	Relay 1 off setpoint
1032	Relay 2 source register
1033	Relay 2 on setpoint
1034	Relay 2 off setpoint
1035	Analog out 1 source register
1036	Analog out 1 process value 1
1037	Analog out 1 process value 2
1038	Analog out 1 output value 1
1039	Analog out 1 output value 2
1040	Analog out 2 source register
1041	Analog out 2 process value 1
1042	Analog out 2 process value 2
1043	Analog out 2 output value 1
1044	Analog out 2 output value 2
1045	Analog out 3 source register
1046	Analog out 3 process value 1
1047	Analog out 3 process value 2
1048	Analog out 3 output value 1
1049	Analog out 3 output value 2
1050	Analog out 4 source register
1051	Analog out 4 process value 1
1052	Analog out 4 process value 2

1053	Analog out 4 output value 1
1054	Analog out 4 output value 2
1057	Site name, first character in ASCII. Eg 65 decimal, 0x41 hex = “A”
1058	Site name, second character in ASCII. Eg 66 decimal, 0x42 hex =“B”
1059	Site name, third character in ASCII. Eg 67 decimal, 0x43 hex = “C”
1060	Site name, forth character in ASCII. Eg 68 decimal, 0x44 hex = “D”
1062	SRU2 Hardware version
1063	IP Port, TCP/IP Protocol. (See 1027 for RTU Protocol)
1065	Hours between automatic insulation measurements (SRU2i and SRU3i). 0 = disable
1066	0xDAB for Borets emulation. 0xBAD for Apollo emulation. Anything else normal
1070	Address of Modbus register to become CITIbus Device 1 Tag 1 (SRU3i / ADCM)
1071	Address of Modbus register to become CITIbus Device 1 Tag 2 (SRU3i / ADCM)
1070	Address of Modbus register to become CITIbus Device 1 Tag 3 (SRU3i / ADCM)
	Etc. For Device 1, 2, 3 Tags 1–12
1105	Address of Modbus register to become CITIbus Device 3 Tag 12 (SRU3i / ADCM)
1106	ID of Modbus device to poll for CITIbus transmission (SRU3i / ADCM)
1107	Write 0x1234 to enables Modbus device polling for CITIbus transmission (SRU3i)
1110	User static register 1 (retains values after power cycles)
1111	User static register 2 (retains values after power cycles)
1112	User static register 3 (retains values after power cycles)
1113	User static register 4 (retains values after power cycles)
1114	User static register 5 (retains values after power cycles)
1115	User static register 6 (retains values after power cycles)
1116	User static register 7 (retains values after power cycles)
1117	User static register 8 (retains values after power cycles)

Appendix C

ACE End of Line Acceptance Criteria

Example of acceptance criteria and values of the ACE end of line test. This checklist can be used to evaluate an ACE gauge that has been used to ensure the sensor still operates correctly.

ACE DOWNHOLE

Sensor Standalone Test **Serial:** Test Date:

Resistance Test	Criteria	Values
Insulation Resistance (1kV Megger)	>4.0GΩ	

Functional Test	Criteria	Values at Ambient
Menu 1 Intake Temp	±5F Ambient	
Menu 2 Intake Pressure measured at 4,300 ft elevation	5k(0 to 62), 6K(0 to 27), 8k(0 to 32) psi	
Menu 3 Winding Temp	100, 500 F	
Menu 4 X-Vibration	Rolling 1.75 - 2 Stationary < 0.2	
Menu 5 Y-Vibration	Rolling 1.75 - 2.7 Stationary < 0.2	
Menu 6 Discharge Pressure measured at 4,300 ft elevation	6K(0 to 27), 8k(0 to 32) psi	
Menu 9 Number of channels to read	3, 5, 5X 6	
Menu 10 Output Voltage set point	Must be set to 3250	
Menu 11 Measured Output Voltage	39.7 V	
Menu 13 Avg DC Current	Range based on SN scheme	

Accepted By:	