Revision

1

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Downhole Sensor

Operation Manual

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Overview of DHS (Downhole Sensor)

1. Major Components

1.1. SDU Description

SDU is the electronic unit with readout at the surface which receives and displays the measurement Tool values which have been communicated via the ESP power wiring to the surface SDU unit. This unit can also communicate these values via MODBUS and RS232 to other devices of the overall ESP control system. A set of transmit and receive LED's are associated with each of these ports to indicate communication activity.

The SDU operates from nominal 120 VAC line voltage.

1.2. Fuse Block and choke Description

The three-phase choke provides an artificial Y-point at the surface for connection of the SDU and SURFACE PACK to the three-phase ESP power lines.

The Fuse Block Assembly (SURFACE PACK) provides the protective interface between the high-voltage three-phase ESP power and the SDU. It contains a fuse, inductors, capacitors, and a voltage clamping device to limit possible damaging levels of energy from being applied to the SDU in the case of a phase-to-ground fault of the three phase ESP power.

The three-phase choke and fuse block assembly are not required for testing the Tool by itself; however if connected to a motor with high Voltage applied then the three phase choke and fuse block *must* be used for proper connection and protection.

1.3. Tool Description

Tool is the measurement Tool which physically attaches to the bottom end of the ESP, measures temperatures and pressures, and communicates this information via the ESP power wiring to the surface SDU unit.

The Tool receives its power from the SDU via the ESP power wiring by connection to the ESP motor Y-point. It contains protective devices to limit possible damaging levels of energy from being applied to the Tool internal circuitry in the case of a phase-to-ground fault of the three phase ESP power. (The Tool should not be damaged by application of up to 2900 vac to the large pin.)

2. Optional Equipment

2.1. Tool Simulator Description

The Tool SIM can be used to verify correct operation of the SDU (or SRU), and can also be used to provide artificial inputs to the SDU to check operation of the rest of the ESP control system.

The Tool SIM can be directly connected to the SDU (or SRU), and via three knobs, each of the values normally coming from the Tool can be manually adjusted.

The Top knob is the internal Tool temperature, center knob is pressure reading, and bottom knob is the motor winding RTD temperature. Full CCW is the minimum (or may be below minimum) for each respective value, and CW rotation increases readings.

2.2. SRU (Surface Readout Units) Description

The SRU provides the equivalent function of the SDU, but in a portable, battery powered unit. Jumper leads are provided for connecting to the Tool or Fuse Block Assembly.

The SRU contains an ac-line powered battery charging circuit. The SRU is powered up via a mechanical timer switch which will turn it off to prevent discharging the battery in the field if inadvertently left on.

The SRU can be used to diagnose system problems with itself, the downhole instrument, the three phase choke and the connecting cable. Refer to section 8 for typical readings.

Testing the SDU Alone. Apply power to the SDU without the signal wire attached. The SDU should briefly display the firmware version (at present V 0.6); then it will display menu 1, showing the internal Tool temperature of 0 since the Tool is not connected. Below are the current SDU menus, items marked * are adjustable.

1. Tool temperature °F
2. Intake Pressure PSI
3. Winding Temperature °F
4. X Vibration (x0.01 G)
5. Y Vibration (x0.01 G)
6. Discharge Pressure PSI
7. Discharge Temperature °F
8. Spare
9. * Number of channels to read
10. * Output Voltage set point (default 3250)
11. Measured output Voltage
12. Tool current (0-1023)
13. Tool threshold (0-1023)
14. Surface unit DC Voltage
15. Decode state
16. * Cutoff filter frequency (default 40)
17. Number of data packets received
18. Number of bad data packets received

C6 * Modbus Baud rate

C7 * Modbus ID

C8 * Modbus gap time

C9 * Factory access code

The first eight menus display results from the Tool, note V0.6 supports just the first three channels.

For more detail of each menu item and typical readings, refer to section 7.0, and the diagnostics (section 8).

3. Tool Testing (On Surface)

3.1. Testing using Tool Simulator

Connect the Tool SIM to the SDU. Apply power to the SDU; wait for one to three minutes for readings on the SDU. This verifies the SDU-to-Tool communication functions. Refer to Tool SIM description for use. (Section 2.1).

3.2. Testing Tool on Surface

Inside the head of the instrument are two electrical pins. The larger pin is for the signal that comes from the motor Y-point; the smaller one is for the winding temperature transducer.

CAUTION

DO NOT APPLY ANY VOLTAGE OR ATTEMPT TO MEGGER TEST THE TEMPERATURE TRANSDUCER PIN (SMALLER ONE) AS DAMAGE TO THE INSTRUMENT WILL RESULT.

BE CAREFUL TO AVOID DISCONNECTING THE MEGGER, METER OR SURFACE UNIT LEADS DURING TESTING AS THE HIGH INTERNAL INDUCTANCE WILL CAUSE LARGE DISCHARGE ARCS.

USING THE SRU WITHOUT THE THREE PHASE CHOKE / FUSE BLOCK IS ACCEPTABLE BUT BE AWARE THAT THERE WILL BE NO ARC SUPPRESSION.

THE TWO HIGH VOLTAGE, HIGH PRESSURE SIGNAL PINS ARE 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.

3.3. Tool Insulation Test (On Surface)

The Tool instrument can be safely megger tested with a 1000V maximum DC megger by attaching to the larger pin and the case of the instrument. Inside the Tool instrument, in series with the signal wire is a diode so Megger testing in one direction (case positive) should indicate open circuit (1000M Ohm or higher), and Megger testing in the opposite direction, with the leads reversed, should indicate a short circuit. ***NOTE: Megger voltage must have a slow rise-time to void triggering a protective circuit inside Tool. If megger voltage rises too fast, it will indicate a short in both directions.***

Measuring the resistance with a typical Fluke or similar digital meter may indicate an open circuit in either direction, as these meters do not output a high enough voltage when measuring resistance to overcome the internal electronics in the instrument.

If using a Simpson 260 analog type meter (which have higher output voltage when measuring resistance) the instrument should measure approximately 22Kohms on Rx10,000 range with case negative, and open circuit in the opposite direction, with the leads reversed.

3.4. Downhole Unit Functional Test (Tool on surface)

The surface test unit (SRU or an SDU) is required to test the Tool before it is run. The three phase choke / fuse block assembly is not required.

Ensure power is off to the Surface unit (SDU or SRU). First connect the black signal lead to the case of the Tool on one of the bolt holes, then connect the red test lead to the larger signal pin on the Tool. *Ensure the cables will not be pulled or the pins struck.* If available, a winding temperature test sensor may be attached to the small pin and the case of the Tool. *Ensure the cables will not be pulled or the pins struck; bending the pins will cause the ceramic to crack and the seal to fail.*

Using the rotary timer switch, turn on the SRU. The SRU should flash the firmware version then switch to menu 1. It will take one to three minutes before the first reading is displayed, since upon power up the Tool first transmits configuration data to the surface unit and the SRU will make automatic adjustments to compensate for the missing fuse block / three phase choke assembly. The temperature inside the Tool should then be displayed (Menu 1), along with the pressure (menu 2), and motor winding temperature (menu 3) if the test transducer is attached.

Note that the instrument is rated to read 0 to 5000 PSI with an accuracy of 1%, so a pressure reading of 0 to 50 is within specification at surface (air) pressure. All communications that come from the Tool are encrypted with checksums and readings are only updated if checksums match, so transmission errors or noise such as from VSD's will have no effect on readings or the Tool accuracy. If the readings are obtained the system is operating correctly and the Tool may be run downhole.

If readings are not obtained then proceed to 'System Diagnostics" (section 8) refer to SRU use in section 2.2 for menu details.

CAUTION

Connect and disconnect Tool to SRU only when SRU power is off!

4. Testing in Well with ESP OFF

4.1. Downhole Unit Insulation Test (Tool Downhole)

Disconnect the motor leads from switchboard, drive or transformer. Connect a 1000V DC maximum Megger to ground and one of the motor leads. Proceed as in the 'Downhole Unit Insulation Test (Tool on surface) description above. ***NOTE: At high well temperatures, the indicated resistance value will decrease, down to ~10 - 20 Meg ohms if the Tool is at 125 deg C.***

If using a Simpson 260 analog type meter (which have higher output voltage when measuring resistance) the instrument should measure approximately 22Kohms on Rx10,000 range with meter negative to GND (housing), and open circuit in the opposite direction, with the leads reversed.

4.2. Downhole Unit Functional Test (ESP Power OFF)

The three phase choke / fuse block assembly is not required, but may be left in circuit if already installed. Remove any connection to the VSD, switchboard or transformer. Ensure power is off to the surface test unit. If the fuse block / three phase choke is in circuit connect the SRU signal wire and ground to the fuse block 2 pin connector. If the Fuse Block is not connected, connect the SRU signal wire to a motor lead and ground lead to ground. Power up the SRU and readings should be shown within a couple of minutes.

If readings are not obtained then proceed to 'System Diagnostics" (section 8). Refer to SRU use in section 2.2 for menu details.

5. Testing in Well with ESP Running

5.1. Downhole Unit Functional Test (With ESP Running).

The three phase choke / fuse block assembly must have been installed on the VSD, switchboard or transformer before the motor was started. Connect the SRU signal wire and ground to the fuse block 2 pin connector (GND to GND, SIG to SIG). (Remove any connection to an SDU).

Power up the SRU and readings should be shown within a couple of minutes. If they are not, proceed to 'System Diagnostics" (section 8). Refer to SRU use in section 2.2 for menu details.

6. Fuse Block and Surface Choke

The following tests should be performed only with power removed to the switchboard / VSD. Testing of the SURFACE PACK board items and choke is recommended anytime an event occurs which requires replacing the fuse. (phase-to-ground short etc.)

CAUTION

Insure ESP power is off and leads are disconnected from choke and/or Fuse Block Assembly!

6.1. Three-phase Choke

If necessary, disconnect H1, H2, & H3 choke leads from ESP power lines. The H0 leads can be left connected to the SURFACE PACK Y- POINT terminals.

The resistance from the Y Point to each individual three phase choke lead should be ~475-500 ohms (requires access to connection points of three-phase choke leads).

NOTE: many auto-ranging digital meters will not measure this unless the meter can be placed in a manual resistance range. Otherwise, the large inductance prevents the meter from ever finding the right range. If the meter is not auto-ranging, or can be placed on a manual range, it will usually work. If using a Simpson 260 analog type meter, the choke resistance can be measured, typically on the x100 range.

6.2. SURFACE PACK

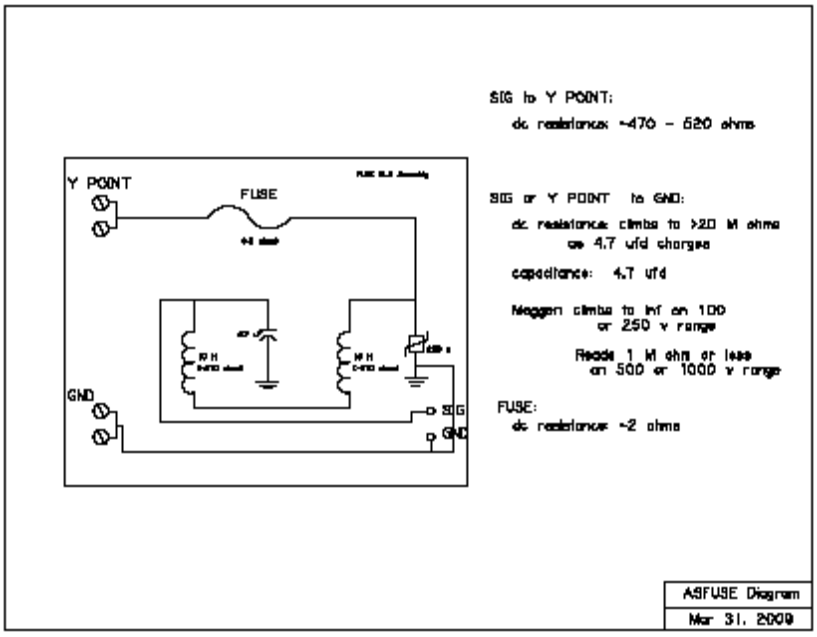


Diagram of SURFACE PACK showing connections of parts as arranged on board
Also typical measurement values

Fuse: Check that the 1 Amp high Voltage fuse is not open by measuring resistance between the fuse ends. A good fuse will measure about 2 ohms.

Voltage clamp device: With the SRU or SDU disconnected, the resistance between the SIG terminal (or Y POINT) and ground should be open circuit. ***Note: Due to the 4.7 ufd capacitor, some meters may take minutes to charge it and measure the high resistance.***

Series chokes: Resistance from Signal pin to fuse (or Y POINT if fuse is good) should be ~470 - 540 ohms.

7. SRU (Surface Readout Unit) Testing

The SRU can be used to diagnose system problems with itself, the downhole instrument, the three phase choke and the connecting cable.

CAUTION

DO NOT CONNECT OR DISCONNECT THE SIGNAL WIRE FROM THE SRU WHEN POWER IS APPLIED. THERE ARE VERY HIGH INDUCTANCES IN THE SYSTEM, AND CONNECTING OR DISCONECTING THE SIGNAL WIRE WITH POWER APPLIED WILL RESULT IN LARGE ARCS THAT MAY DAMAGE THE EQUIPMENT.

7.1. Testing the SRU Alone

Apply power to the SRU without the signal wire attached. The SRU should briefly display the firmware version (at present V 0.6); then it will display menu 1, showing the internal Tool temperature of 0 since the Tool is not connected.

Summary - Quick Standalone SRU Test:

1. Power down unit.
2. Remove signal connector.
3. Power up unit, should flash V0.6.
4. Menu 9 should be 3.
5. Menu 10 should be 3250.
6. Menu 11 should display 38 to 42 Volts. (May also be measured with a multimeter).
7. Menu 12 should be 180 to 220.
8. Menu 16 should be 40.
9. Power down the SRU.
10. Short out the signal (connect the 2 pins on the 2 pin connector together).
11. Power up the unit.
12. Menu 11 should be about 1 to 2 Volts, Menu 12 should be about 770 – 800.
13. Power down the unit, remove signal short.

For more detail, and for using the SRU to test the Tool, refer to the following, and to the diagnostics (section 8) information.

7.2. Testing SRU With Tool

For using the SRU to test other parts of system, refer to the following, the Tool testing sections above, and the diagnostics (section 8).

Below are the current SRU menus, items marked * are adjustable.

1. Tool temperature °F
2. Intake Pressure PSI
3. Winding Temperature °F
4. 4 X Vibration (x0.01 G)
5. Y Vibration (x0.01 G)
6. Discharge Pressure PSI

7. Discharge Temperature °F
8. Spare
9. Number of channels to read
10. Output Voltage set point (default 3250)
11. Measured output Voltage
12. Tool current (0-1023)
13. Tool threshold (0-1023)
14. Surface unit DC Voltage
15. Decode state
16. Cutoff filter frequency (default 40)
17. Number of data packets received
18. Number of bad data packets received

C6 * Modbus Baud rate

C7 * Modbus ID

C8 * Modbus gap time

C9 * Factory access code

The first eight menus display results from the Tool, note V0.6 supports just the first three channels.

Menu 9 should be set to match the number of channels being read, presently three. In the future the SRU will automatically read the number of channels enabled from the Tool as it powers up; at present it must be manually set in the SDU and SRU.

Menu 10 sets the SRU output Voltage, and Menu 11 displays the measured output Voltage. The SRU contains an adjustable DC Voltage supply, and it is able to measure and display both the output Voltage and current. Menu 10 allows the output Voltage to be adjusted from approximately 1 Volt DC to 50 Volts, by setting the menu 10 value from 0 to 4095. Menu 11 will display the actual measured Voltage. The setting in menu 10 should not normally need to be changed; the default value is 3250, which should correspond with an output Voltage of approximately 40 Volts with no load connected. If it is greater than 42 Volts or less than 38 volts when menu 10 is set to 3250 the SRU may be damaged.

Menu 12 displays the measured Tool current on a scale of approximately 200 to 1023. When the signal wire is disconnected (remove power to the display *before* unplugging the signal cable) the display should be approximately 200; verify that it is between 180 and 220. If it outside this range the SRU may be damaged. If the signal is shorted directly to ground the current reading will be 780 – 800 (the output current is limited internally, and this will not damage the SRU). In normal operation, these readings will vary from ~500 to 700 as data is transmitted. Menu 13 displays the automatically generated data threshold; the reading is not valid unless a Tool is connected. With a Tool connected, it should be ~560 - 670.

Menu 14 displays the SDU or SRU internal DC power supply Voltage. For the SDU connected to an AC power source it typically displays around 22 - 24 Volts. For the battery powered SRU test box it should display about 12 Volts, which will rise to about 13.5 Volts when charging form AC power.

Menu 15 displays the decode state; when not connected to a Tool it is not valid, and will probably display 3499. When connected and communicating to a Tool, it counts down rapidly during the packet gap, and then counts up slowly as each packet byte is received.

Menu 16 shows an adjustable filter cutoff setting, it should be set at 40 and not changed.

Menu 17 and 18 show a count of data packets received; should be zero if no Tool is connected. If a Tool is connected, menu 17 indicates the total number of packets received, and menu 18 indicates the number of bad packets received. Both these counts are reset to zero when the SDU is powered up. Note: at power up, the first 1 – 3 packets are typically bad as the threshold is being automatically adjusted.

Menus C6, C7 and C8 are for changing Modbus settings; they have no effect on SRU operation and are only used for remote access of readings.

Menu C9 is for factory diagnostic use, for example entering a code of 1 will test all the LED display segments (press enter again to set it back to normal).

8. System Diagnostics

If the system does not provide valid readings the SRU or SDU can display diagnostic information. First verify that menu 14 is approximately 22 - 24 for the SDU, and ~12 if using battery powered test SRU; these two values will change depending on supply voltage.

Use menus 11, 12 and the following table to try and isolate the problem.

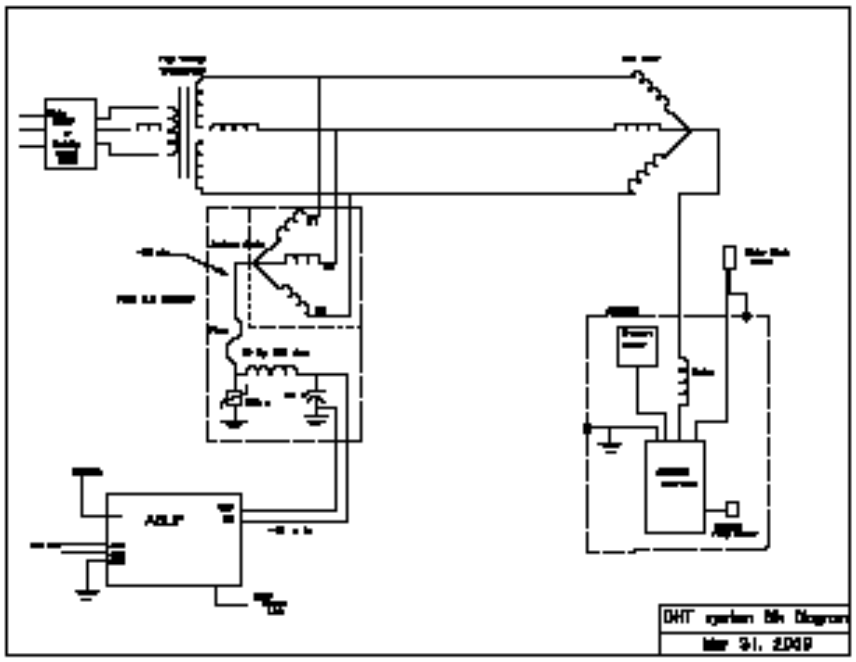
Menu 11 SRU dc Volts	Menu 12 SRU dc Current	Comments
38 to 42	180-220	Signal lead appears open circuit. Check HV fuse, verify signal lead and ground wire. Measure DC Voltage at SDU signal lead / ground, should be ~40VDC. Verify menu 10 is 3250. Check signal / ground leads are not reversed
Less than 35	180-220	SRU output may be damaged. Power down SRU, remove signal lead, power SRU back up. If condition still exists replace SRU.
38 to 42	450 to 600 changes less than ~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 new larger style.
38 to 42	450 to 650 changes greater than 100.	Should be normal operation. Check pressure and 2 temperature readings, if at least 1 of the three is correct then the other channels may have failed in the Tool. The winding temperature will be displayed as 0.0 °F if the winding transducer is shorted out, 1.0 °F if the winding transducer is open circuit and 31°F if below 32°F (normal range 32 °F to 500°F)
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 1motor leg is shorted to ground or three phase choke failure.
Between 15 and 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 to 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.

If the SRU menus keeps scrolling , the problem is caused by a stuck key, verify one of the keypad keys is not jammed down causing the menus to keep scrolling by.

If measuring dc current in SIG lead with meter, should be 10 – 14 mA.

Motor winding RTD: Reading should be ~127 F if substitute a 1200 ohm resistor, or 267 F if using a 1500 ohm.

9. System Interconnection Diagram



Interconnect Diagram of System