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USERS' MANUAL

IN-PLACE 3D INCLINOMETER CUM SETTLEMENT SYSTEM (IPIS)

FOR MONITORING LATERAL MOVEMENT AND SETTLEMENT

MODEL EAN-61MS

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1 INTRODUCTION

1.1 Purpose

The In-place 3D Inclinometer cum Settlement System **(IPIS)** is used wherever lateral movement along with settlement/heave is to be monitored in a borewell or on a structure. It finds wide application in measurement of lateral movement and settlement in soil, earthworks, slopes or structures like retaining/diaphragm walls, embankment, deep foundations or dams etc. It is also very useful in monitoring landslide areas.

An array of integrated tilt (x-y) cum settlement (z) probes are installed inside a standard grooved inclinometer casing for real-time displacement monitoring in critical applications. Continuous data logging and real-time monitoring help to provide an early warning in case of an impending danger or failure.

The Encardio-rite model EAN-61MS In-place 3D Inclinometer cum Settlement System **(IPIS)** provides a significant quantitative data on the magnitude of settlement along with the inclination or tilt of a foundation, embankment or slope and its variations with time. It also provides the pattern of deformation, zones of potential danger and effectiveness of construction control measures undertaken.

Real-time 3D (x-y-z) profile of a borehole helps in observing the behaviour of structural and ground movement during and after construction and indicates potentially dangerous conditions that may adversely affect stability of the structure.

The real advantage of **IPIS** is that it allows online monitoring of transverse movement as well as settlement using the same borehole. This was not possible until now using presently available instruments. Another advantage of the IPIS system is that it can be used as a combination of IPIS sensors (x-y-z) and IPI (x-y) where the settlement measurement is required at selected levels.

1.2 Conventions used in this manual

WARNING! Warning messages calls attention to a procedure or practice, that if not properly followed could possibly cause personal injury.

CAUTION: Caution messages calls attention to a procedure or practice, that if not properly followed may result in loss of data or damage to equipment.

NOTE: Note contains important information and is set off from regular text to draw the users' attention.

1.3 How to use this manual

This users' manual is intended to provide sufficient information for installing and making optimum use of the model EAN-61MS 3D In-place Inclinometer cum Settlement System **(IPIS)**. It covers description of the gage and installation & maintenance procedure.

To make this manual more useful, we invite your valuable comments and suggestions regarding any additions or enhancements. We also request you to please let us know of any errors that you may find while going through this manual.

NOTE: The installation personnel must have a background of good installation practices and knowledge of the fundamentals of geotechnics. Novices may find it very difficult to carry on installation work. The intricacies involved in installation are such that even if a single essential but apparently minor requirement is ignored or overlooked, the most reliable of instruments will be rendered useless.

A lot of effort has been made in preparing this instruction manual. However, the best of instruction manuals cannot provide for every condition in the field that may affect the performance of the sensor. Also, blindly following the instruction manual will not guarantee success. Invariably, installation personnel depending upon field conditions, will have to

consciously depart from the written text and use their knowledge and common sense to find solution to a particular problem.

The manual is divided into a number of sections. Each section contains a specific type of information. The list given below tells you where to look for in this manual if you need some specific information.

*For description of In-place 3D Inclinometer cum Settlement System **(IPIS)**:* See § 2 'General description'.

*For description of the **IPIS** accessories available*: See § 3 'General description'.

*For pre check installations of **IPIS**:* See § 4 '*Preparation before installation'*

*For installation of **IPIS**:* See *§* 5 'Installation'.

*For monitoring of the **IPIS**:* See § 6 'Taking readings'

*For configuration of **IPIS** with datalogger :* See § 7 'Connecting **IPIS** Sensor to Data Acquisition System'*.*

1.4 Tools and accessories required for installation

The following tools and accessories are required for proper installation of the 3D In-place Inclinometer:

1. Magnetic probe with cable reel assembly – Encardio-rite model EDS-91/2.1-IPI version
2. Sensor tilt test jig – Encardio-rite model EAN-61MS TTJ. This is a jig for approximately verifying tilt in sensor. It is not a calibration jig.
3. Dummy probe – Encardio-rite model EAN-26 DP
4. Digital Inclinometer probe – Encardio-rite model EAN-26M
5. 20 mm spacer for verifying/checking correctness of settlement readings
6. Cable ties
7. BOPP tape, insulation tape and 50 mm wide water proof sealing tape
8. Spanners 8/10 and 16/18 and 25 mm
9. Screw driver 100 mm
10. Pliers 150 mm
11. Flat file 150 mm
12. Hand saw with three 30 cm blades
13. Allen key 5 mm
14. Safety line or tension cable in case hole is very deep
15. Clean water supply to clean casing
16. Hand saw with three 30 cm blades
17. Casing collar protection if required
18. Grout tube - requisite length
19. Acetone
20. Pop rivet gun and aluminium pop rivets - four per joint plus some extra
21. Drill with a 3.15 mm spare drill bit.
22. Casing clamps - 2 sets
23. Casing cap with guy ropes (for embankment installations)
24. Casing 'U' clamps and grout bolts (For installation on concrete structures)

2 GENERAL DESCRIPTION

In-place 3D Inclinometer cum Settlement System **(IPIS)** consists of a string of in-place cum contactless magnetic sensors (model EAN-61MS/1 with SDI-12 interface) installed inside a standard inclinometer four grooved casing.

A series of four grooved ABS access tubes/casings attached to each other with couplings, are installed in a borehole or embedded in earth/rockfill or concrete structure during construction or fixed to the vertical face of a completed structure. One set of grooves is preferably aligned in the expected direction of movement and if this is not known, in the N-S direction.

NOTE: For instructions on installation of Encardio-rite inclinometer casing please refer to Users' Manual of EAN-26M Inclinometer System (Doc. # WI 6002.104).

For instructions on installing of the spider magnets on the inclinometer casing, please refer to Users' Manual of EDS-91 Vertical Inclinometer cum magnetic settlement system (Doc. # WI 6002.114)

A string of sensors is positioned inside the inclinometer casing in a continuous array to span the movement zone. These sensors measure the tilt and settlement in successive segments to accurately monitor a change in the profile (x-y-z) of the inclinometer casing. Each **IPIS** is fitted with a pair of pivoted sprung wheels and is connected to each other through gage tubes (with adjustable lengths).The **IPIS** rests inside the grooves of the inclinometer casing (Figure 1.a). Length of spacer tubing determines the distance between each sensor i.e. length of each segment over which the tilt is monitored.

- Spacer tubing length (mm) = gauge length (mm) – 921 mm

  Example: For 1.5 m gage length, the gage tube would be 0.579 m and for 2 m gage length, the gage tube would be 1.079 m long.

NOTE: Each EAN-61MS/1 settlement sensor has a displacement range of 100 mm to measure expected settlement/heave. It is marked at three locations – two ends and the middle for ease in setting.

To position the settlement sensor over the ring magnets, a coarse adjustment of 50 mm (± 25 mm) and a fine adjustment of 50 mm (± 25 mm) is provided in the gage tube. The gage tube is assembled in parts. For details refer to figure 5.

When subsurface movement in the ground occurs, it displaces the inclinometer casing, causing a change in tilt of the in-place tilt sensors. This results in a change in the output of the sensors, proportional to the tilt i.e. the angle of inclination from vertical.

Simultaneously, if any settlement/heave takes place, it is measured by the position change between the contactless magnetic sensors and the magnet rings fixed outside the inclinometer casing. Settlement/heave of all the sensors is thus determined with respect to a reference, which can be the top of the borewell or a datum magnet that can be installed at the bottom of the borewell casing.

The daisy chain of sensors are connected to a data acquisition system for real-time monitoring of lateral movement and settlement.

The lateral movement of the casing can be calculated by subtracting initial deviation from current deviation. Similarly, the displacement of the contactless magnetic sensors at different levels can be calculated by subtracting it with the reference. Provided that one end of the casing is known to be fixed in the ground, it is possible to obtain a complete profile of the access tubing by summing readings from successive sensors and settlement at the desired levels. By comparing the profiles, the lateral displacement (x-y) of the gage well along with the settlement (z) at different depths over a period of time may be determined.

The system has a SD-12 output. SDI-12 is an acronym for "Serial Data Interface at 1200 Baud". It is an asynchronous ASCII, serial communications protocol. Instruments with SDI-12 interface are typically low power (12 V); often used in remote locations, and usually, communicate with a data logger or other data acquisition device. In this master-slave configuration, the data logger or data acquisition device typically acts as the master (SDI-12 Recorder and Interrogator) to data monitoring instruments, which are the slaves (SDI-12 sensors). One master can communicate with multiple slaves; so the SDI-12 protocol requires that each device in the serial network be identified with a unique address, which is represented by a single ASCII character.

This communication is achieved by digital communication along a single serial line. The digital addressing system allows an SDI-Recorder to send out an address over a single line that is connected to sensors. Only the pre-configured sensor matching that address will respond (handshake). The other sensors on the same line will not respond until called and typically stay in "sleep mode" (low power mode), until called (often in a sequence) at a later time by the SDI-Recorder (Master).

The sensor with SDI-12 interface bears a manufacturing serial number and an identity or address can be assigned to it during the installation process. The identities are 0-9, a-z & A-Z. The sensors are provided with a pair of 3 core cable terminating at a set of male/female connectors. These connectors are waterproof and are to be handled very carefully. The connectors are provided for installation of sensors in an inclinometer casing, which may be filled with water.

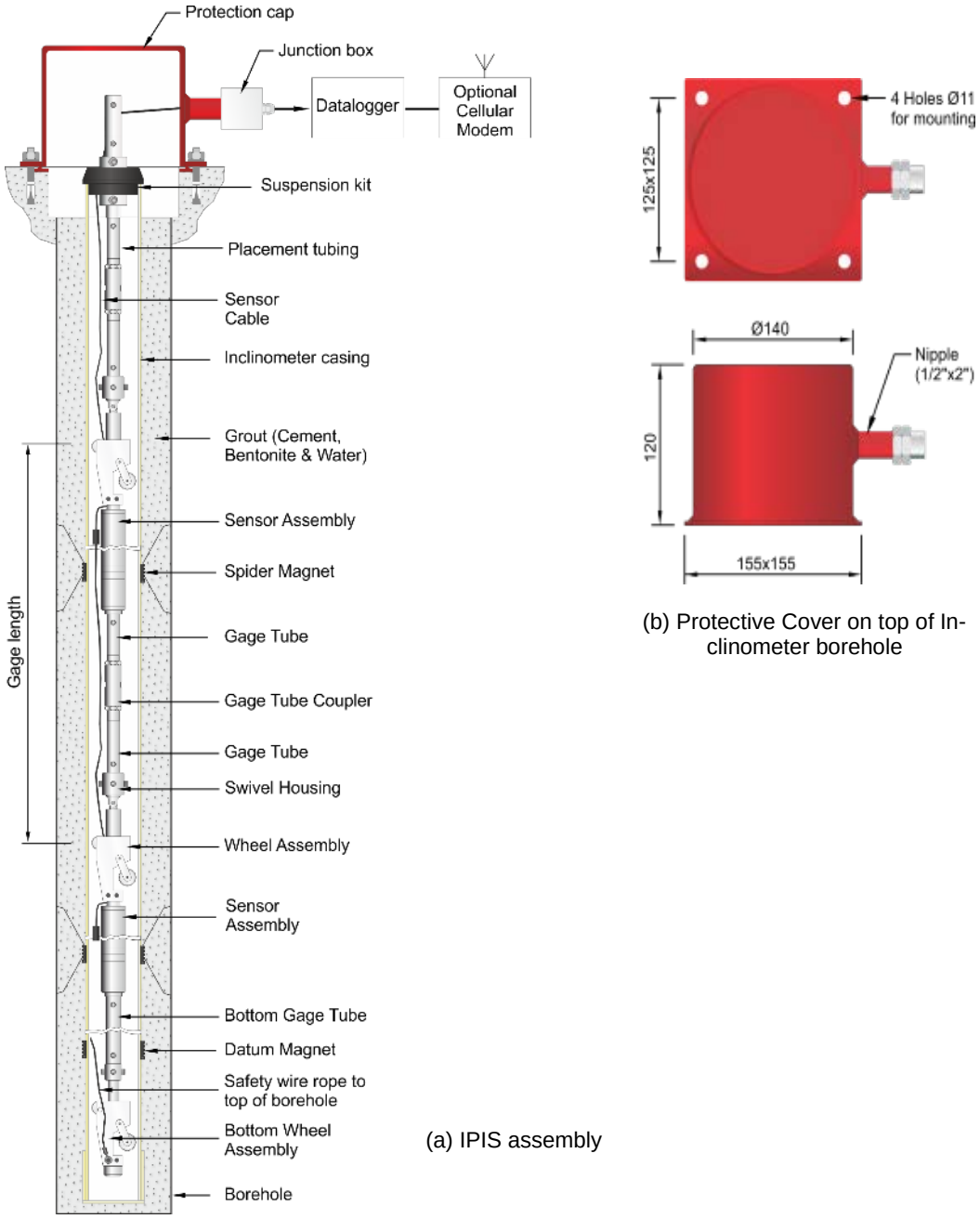
NOTE: In an in-place inclinometer, chain with SDI interface connected to one port of a datalogger IDs of the sensors cannot be repeated.

3 IN-PLACE 3D INCLINOMETER CUM SETTLEMENT SENSOR COMPONENTS

Figure 3-1.a shows an in-place inclinometer string assembly, and Figure 3-1.b shows the protective cover details. Please note the following:

- The depth at which first in-place sensor is to be placed from top of the borehole determines the length of the placement tube.
- The depth of borehole, number of sensors per borehole and the gage length at which sensors are to be placed is specified by the user.

  Encardio-rite stocks **IPIS** with a gage length of 1.5 m and 2 m. Gage length is the spacing between two wheel assemblies as shown in figure 1.a. Other gage lengths are also available on request.



(a) IPIS assembly

(b) Protective Cover on top of In-clinometer borehole

Figure 3-1: In-place 3D Inclinometer cum Settlement assembly and Protective cover

NOTE: Sensor used in this system is model EAN-61MS/1 with a SDI-12 interface

4 GUIDELINES FOR SUCCESSFUL INSTALLATION

NOTE: These guidelines are very important to follow. It is recommended that they be read repeatedly and definitely always before a new installation.

4.1 Civil works (installation of casings and magnets)

- Install ABS casings as per Users' Manual - EAN-26M Inclinometer System - doc. # WI 6002.104 in a 150 mm diameter borehole. For installation of datum magnet and spider ring magnets at different levels of the casing, please refer to Users' Manual EDS-91 Vertical Inclinometer cum magnetic settlement system (Doc. # WI 6002.114).

Note: 'BOTTOM' embossed on the magnet should face downwards while installing on the ABS casing (Refer to figure 4-1.a).

- Fix the datum magnet assembly (refer to figure 4-1.b) firmly to the bottom most access tubing with the screws provided, around 0.5 m above the bottom of the plug. Since in most cases the bottom of inclinometer access tubing is located in solid ground (fixed), the datum magnet provides a good benchmark. All the other settlement (z) readings are referred to this datum magnet to get their respective absolute settlement relative to the benchmark.

Note: The gage tube connecting bottom wheel to sensor will have fixed length (80 mm).

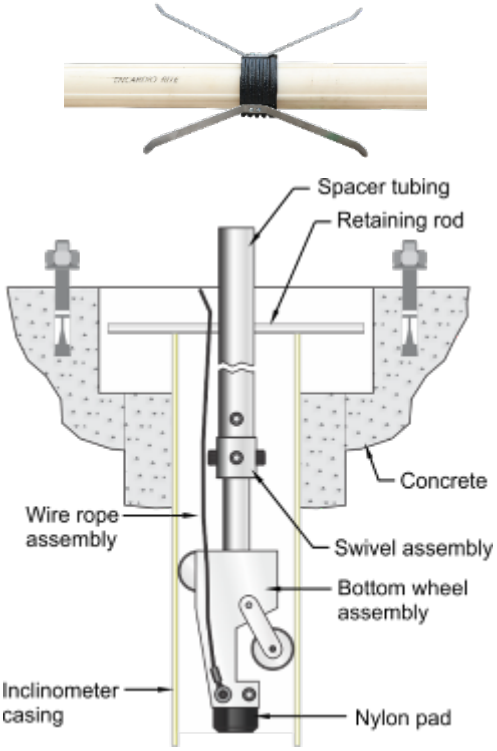
- Fix the other magnet rings on the surface of the ABS casing at the desired levels, as it is installed.
- With the casing and magnets lowered down in position, release the spider magnet springs to grip the surrounding soil at locations where displacement is to be monitored and grout the borehole as detailed in instruction manuals WI 6002.104 and WI 6002.114.

NOTE: Ensure quality of grouting such that all area around the ABS casing and magnet rings are filled and magnets are not displaced during lowering or grouting.

- Make a concrete platform (refer to figure 4-1.c) such that mouth of inclinometer casing is around 50 mm below the top of the concrete platform. Mandatory checks before installation of IPIS in bore

(a) Datum Magnet

(b) Spider Magnet



(c) Concrete platform for protection

Figure 4-1 : Datum magnet, Spider magnet, Concrete platform for protection

4.1.1 With Encardio-rite model EAN-26 DP dummy pro...

Lower dummy probe inside the inclinometer casing, first in grooves in one direction and then in the perpendicular direction to verify that the grooves are smooth with no concrete or foreign material stuck in them, clean if necessary.

NOTE: The model EAN-26DP dummy probe is not a part of the supply and has to be ordered separately.

4.1.2 With Encardio-rite model EAN-26M inclinometer probe

Take initial reading of x-y profile of borehole with model EAN-26M inclinometer probe and store the data for future reference. This step is very important and should never be missed. The inclinometer probe gives the true x-y profile of the borewell with a gage length of 0.5 m. In case of any abnormal movement observed from the installed **IPIS**, the borehole profile can be verified by removing the **IPIS** and taking a fresh set of readings with the model EAN-26M inclinometer probe.

Figure 4-2 Digital Inclinometer – EAN-26M

NOTE: The model EAN-26M inclinometer probe is not a part of the supply and has to be ordered separately.

CAUTION: The initial x-y profile taken with the model EAN-26M inclinometer probe is a reference for future use. It should be carefully stored and never be lost till the borewell is used for monitoring

4.1.3 X-Y coordinates with Prism target

Determine initial Northing (X) and Easting (Y) positions of casing top by surveying after the casing is set. For this purpose use a prism assembly with holder pin and suspension bracket (to be ordered separately) for inclinometer casing EAN-AT-70. ERT-10P2 prism target can be directly mounted on the suspension bracket (which is an integral part of the IPIS). Readings should be taken with an accurate and precise total station. This data should be treated as a reference during verification of deflection at a later date.

Note: This step can be taken before IPIS chain installation or just after the IPIS chain is installed. In former case, place only the suspension bracket over the casing for mounting prism target.

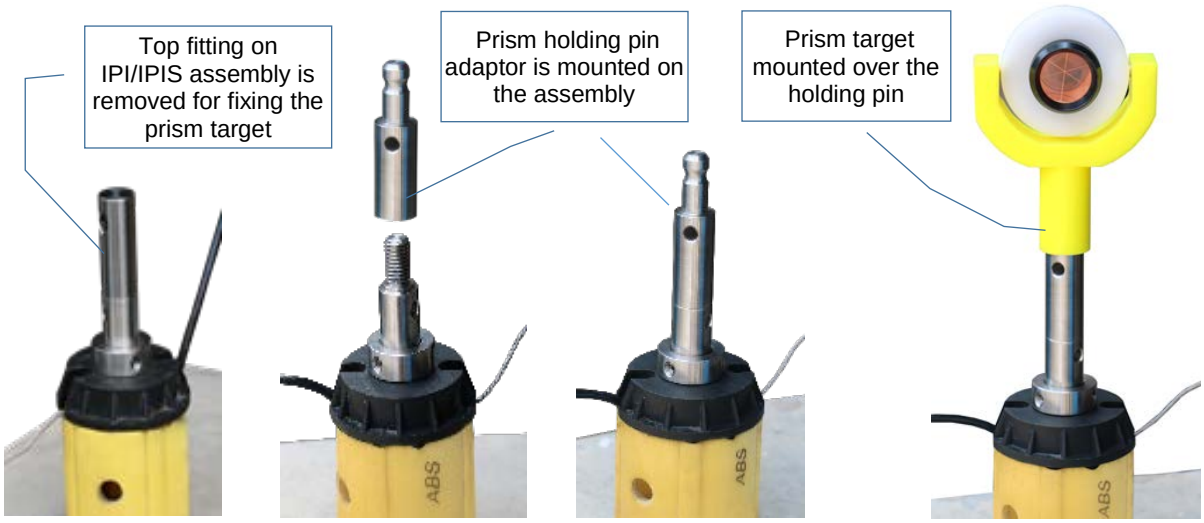


Figure 4-3 Prism target mounting accessories suitable for taking X-Y coordinates for IPIS

4.1.4 Elevation by settlement point

Additionally, determine the elevation of the pipe top using a precision digital level. For this purpose, a settlement marker should be provided adjacent to top of inclinometer casing that will serve as survey reference point. (Refer to figure 4-4)

This will allow inclinometer as well as settlement profile to be referenced to an absolute reference (elevation above sea level) should datum reference at the bottom be required to be verified due to any reason.

NOTE: The prism target assembly and suspension bracket are not a part of the supply and have to be ordered separately.

CAUTION: The Northing (X), Easting (Y) and Elevation (Z) of the casing top taken by the precision total station and digital level is a reference for future use. It should be carefully stored and never be lost till the borewell is used for monitoring.

Figure 4-4
Survey target to be mounted on top concrete platform to determine elevation of casing top

4.1.5 With Encardio-rite model EDS-91/2.1 – IPI version magnetic extensometer probe

The position of the datum magnet and the other magnetic rings needs to be verified after the inclinometer casing is installed and grouted in the borehole. For verifying the position always use Encardio-rite model EDS-91/2.1 – IPI version magnetic extensometer probe. The IPI version probe has a nylon disc of 54 mm diameter for centering the probe inside the inclinometer casing. (Refer to figure 4-5)

The magnetic extensometer probe has a reed switch encapsulated inside it at a distance of around 60 mm from the end. It is made to travel within the access tube to sense the position of magnets outside the access tube. The reed switch closes on entering a magnetic field and activates a buzzer and an indicator light in the signal receiving instrument. The flat 10 mm wide x 2 mm thick cable tape of the probe is marked at suitable intervals for measuring the location of each magnet from the top of the access casing.

Figure 4-5 Magnetic Probe with nylon disc

For verifying the position of the ring magnets outside the access casing, always take the depth reading of each magnet at the beginning of first buzz while lowering the probe into the casing. The buzz will be long and there may be more than one buzz at every location of the magnet. **It is repeated that the beginning of the first buzz is always to be taken to determine the depth of the magnetic ring.**

The position of the reed relay in the Encardio-rite model EDS-91/2.1 – IPI version magnetic extensometer probe is set in a manner that subtracting 5 mm from the reading will give the position of the ring magnet to an accuracy of ± 10 mm. For example, if the reading on the tape is 3.010, the depth of the magnet from the top should be taken as 3.005 m.

The datum magnet is installed 50 cm from the bottom of the borewell. The position of the datum magnet can therefore only be taken with the magnetic extensometer probe.

NOTE: For verifying the position of the ring magnets outside the access casing, always take the depth reading of each magnet at the beginning of first buzz while lowering the probe into the casing.

Always use Encardio-rite model EDS-91/2.1 – IPI version magnetic extensometer probe to take the reading. The extensometer is not a part of the supply and has to be ordered separately.

4.2 Pre-assembly

4.2.1 Bottom assembly

- The supplied wire rope assembly has two loops. Fix the smaller loop of the wire rope assembly to the lower end of the bottom wheel assembly as shown in figure 4-9 and figure 4-8.(a). Other end of wire loop is fixed to any secure structure at the top of the borehole to prevent the whole assembly from dropping down accidentally into the borehole during installation/removal.
- Assemble the lower end of the spacer tubing to the bottom wheel assembly as shown in figure 4-8.(a) and figure 4-9.

4.2.2 Sensor assembly

- Note down the sequence of sensors to be installed from bottom to top and assign individual ID to each sensor
- All the sensors are provided with wheel assembly fixed to it.
- Attach the bottom-most sensor to a wheel assembly as shown in figure 4-8.(a).
- Fix a gage coupler tubing to other end of wheel assembly as shown in figure 4-8.(b) and figure 5-1.(b).
- Prepare such assemblies for all the sensors.
- Gage coupler tubing connected to the sensors as shown in figure 4-6. These gage couple tubing have ± 25 mm chuck nuts in clockwise and anticlockwise direction to tweak the marked mid level of the sensor which should coincide with the spider magnet.
- The gage coupler tubing supplied as a standard length (Refer to figure 4-6.(a)).
- The gage with -25 mm coarse adjustment (refer to figure 4-6.(b))
- The gage with +25 mm coarse adjustment (refer to figure 4-6.(c))

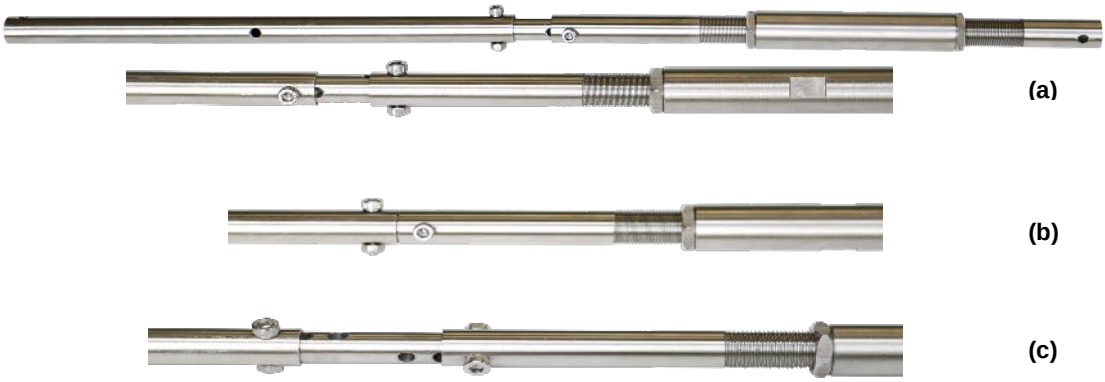


Figure 4-6 Gage coupler tubing with coarse adjustments of ±12.5 and ±25 mm through extension pin with six holes (left) and spacer tube and fine adjustments of ± 25 mm with chuck nut with right and left hand threads (right).

- At the time of supply, both coarse and fine adjustments are set in the middle position to provide the specified gage length.
- To adjust coarse length of ±12.5 mm, adjust one end of gage tube by shifting it to one hole on the extension pin.
- To adjust coarse length of ±25 mm, adjust both end of gage tube by shifting it to one hole on either side of the extension pin.

4.2.3 Top assembly/Suspension bracket:

- Attach a wheel assembly to the top most sensor as shown in figure 4-7.
- To the other end of the wheel assembly, fix the placement tube as shown in figure 4-8. (c).
- Attach suspension kit to the other end of the placement tube as shown in figure 4-8 (c).
- Measure and adjust the required distance between centre line marking to the collar of plastic component of the top suspension kit.

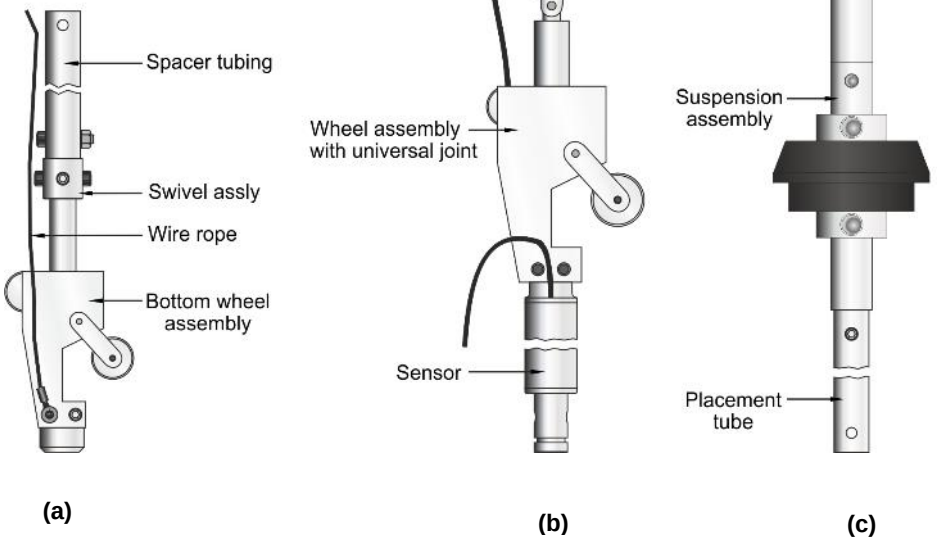


Figure 4-7 Sensor assembly

NOTE: Required fasteners are supplied mounted on the assemblies except those used for fixing the IPI sensors to the gage tubing. These fasteners with some spares are packed separately.

CAUTION: Please refer to section 4.1 for mandatory checks to be performed before lowering of the IPIS chain in the gage well.

4.3 Pre-assembling IPIS for installing in borewell

- In preparing the IPIS sub-assemblies for installation in the borewell, use position of the ring magnets as obtained with the model EDS-91/2.1 – IPI version magnetic extensometer probe as mentioned in Section 4.2.4.

NOTE: These positions may be slightly different from those initially specified but should be used for making the best and most efficient use of the IPIS system.

Figure 4-8 In-place assembly showing sensor and gage coupler tubing

- Use the table below (Table 1) and calculate difference in consecutive magnets
- Identify the sensors to be lowered in order (lower most sensor to be numbered as sensor 1) and note down their serial number. Assign ID or address (0-9, a-z or A-Z) to each sensor. Ensure that no sensor in the chain has the same ID.
- Attach the bottom-most sensor to a bottom wheel assembly as shown in figure 4-8. (a).
- Fix a gage coupler tubing to other end of wheel assembly as shown in figure 4-8. (b) and figure 4-7.

- After assembling the bottom sensor wheel assembly, keep it on the ground. Fix the appropriate gage tube to it and fix the next sensor at the other end.
- Measure distance between centre line (settlement monitoring region) of the sensor. While measuring the distance between IPIS sensors make sure that they are in a straight line. The sensor should be nearest to the measurements obtained by EDS-91/2.1. (Difference between the readings of these two magnet location). This can be set by coarse and fine adjustment of gage coupler.
- Plug in the male seacon connector to the female connector (refer to figure 5-1. (f)) of the upper sensor and roll the extra length of cable on the gage tube. Tie with cable ties.

Note: Avoid any sharp looping of the cable.

- Tighten all the fasteners (allen nuts and bolts) properly.
- Verify the distance again (correct it, if required). Unplug the cable connector and then remove the upper sensor.
- Keep aside the assembly and mark accordingly (location in borehole).
- Now fix another gage tube on the removed sensor assembly and then fix next sensor.
- Repeat the processes for every subsequent sensor till the top most sensor is connected.
- Remove the top most sensor from this assembly and fix the placement tube and then suspension assembly.
- Measure and adjust the required distance between centre line marking on the sensor to the collar of plastic component of Top suspension kit.
- Place all the sensor assemblies nearby to the borehole in sequential manner of lowering them.

Readings of magnet location by EDS-91/2.1		
Magnet Top	**Reading from top**	**Relative difference between magnets**
15		
14		
13		
12		
11		
10		
9		
8		
7		
6		
5		
4		
3		
2		
1		0
bottom	---------	---------

Table-1

Encardio-rite stocks systems with a gage length of 1.5 m and 2 m. We recommend use of these gage lengths. However, different gage length to these can be made available and can be directly ordered from the factory. The lesser the gage length, the better the system.

The gage length can be changed by changing the length of the gage tube. A gage tube assembly is shown below:

To adjust the gage length to match the position of the ring magnets outside the inclinometer casing, a coarse adjustment of ± 25 mm and a fine adjustments of ± 25 mm each is available on the gage tube (refer to figure 9).

Please refer to figure 11 below:

- Check for any damage to cable/connector of each sensor.
- Each sensor bears a serial number and has two cables coming out of it.

NOTE: The bottom wheel assembly is to be considered as the reference point while analysing the monitored data.

- One end of the cable from the topmost sensor is directly terminated in a junction box at the top of the borehole. The other end has a connector, which is mated with cable connector from the lower sensor.
- Locate A+ side i.e. the top wheel on all the sensors and it should be towards the expected direction of movement (refer to figure 4-10).

NOTE: Failure to place A+ side of each sensor of an IPI chain towards the expected direction of movement can result in misinterpretation of the data. This may have serious consequences.

NOTE: Before starting with the installation of 3D In-Place sensor daisy chain, the position of the magnetic rings after casing installation shall be verified using the Encardio-rite model EDS-91/2.1 magnetic probe with cable reel assembly.

Figure 4-9 Bottom wheel assembly

Figure 4-10 Top wheel

5 INSTALLATION

- Place assemblies and the necessary tools (retaining rod, allen key, spanners, cutter etc.) in side by side in the order of installation.
- Lower the bottom assembly in inclinometer casing, holding the safety wire rope such that assembly does not accidentally slip down into the casing. Ensure that the bottom sensor assembly female seacon connector is plugged before lowering in the borehole and make sure the male seacon connector is out of the borehole.

NOTE: Align wheels in casing grooves such that top/fixed wheel points towards the expected direction of movement.

- Insert a retaining rod in the hole at the top end of the spacer tubing and rest assembly on the casing's top with the help of the retaining rod (figure 5-1.a).
- Fix first (bottom-most) sensor assembly to the lower most gage coupler tube (refer to figure 5-1.b) with the allen bolts and nuts and spring washers and tighten it with the spanner and allen key.
- Lower the assembly down, till the hole of gage tube coincides the top of hole (figure 5-1e) and instert the retaining rod to hold the assembly on top of the inclinometer casing.
- Use cable ties to tie the signal cable of sensor and wire rope neatly to the spacer tubing.
- Remove retaining rod, lower assembly into borehole, fix next 3D IPIS sensor assembly to the lower most sensor's gage.
- Repeat the adjustment of the next expandable gage as per the expected movement.
- Fix the connector of the lower sensor to the next one tightly using the hands only (refer to figure 5-1.e) and insert retaining rod in hole of next spacer tubing.

NOTE: Care should be taken during fixing of the connectors.

(a) Inserting retaining rod in the spacer tubing

(b) Connecting the spacer tubing with the sensor

(c) Fixing sensor to gage coupler tubing

(d) Lowering of assembly

Figure 5-1 Installation steps for the IPIS sensors assembly

- Repeat above procedure for all sensors taking care of orientation of wheels as mentioned above (refer figure 5-1.d) till suspension kit of the top assembly rests on the mouth of the inclinometer casing.

NOTE: 1. While lowering assemblies make sure to use the retaining rod in every expandable gage tube to prevent assemblies accidentally falling in to the borehole.

2. Take care of the sequence of sensors from bottom to top. Note the manufacturing serial and address of the sensors during assembly.

3. Prevent twisting of installed sensors during tightening of fasteners as this can damage the wheels and push them out of the grooves of inclinometer casing.

- Take the readings by connecting datalogger (refer to section 6) of all sensors for its magnet location.
- Reading should be 50 (± 10). The common variation can be adjusted by adjustment in placement tube (using coarse and fine adjustment).

6 TAKING READINGS

6.1 Wiring details

Colour coding of the cable coming out from the top most IPI sensor is given below:

Colour	Description
Red	+ 12V DC
Black	0 V
Green	Output

The SDI-12 sensors are connected in a bus chain through waterproof connectors.

For extending cable from the top of an IPI chain, a junction box is required. Mounting details of the standard junction box from Encardio-rite are provided in figure 6-1. If it is required to connect IPI sensor chains installed in two or more boreholes, a special junction box is required as shown in figure 6-1 (right).

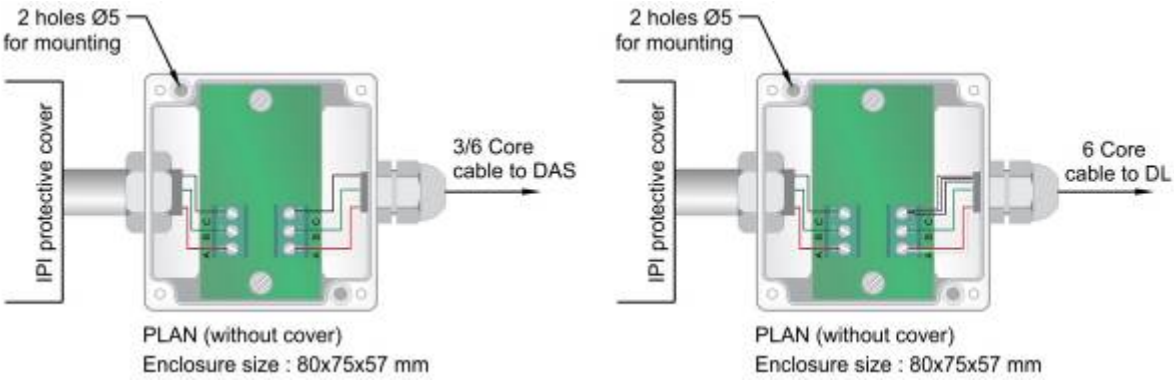


Figure 6-1 Junction box

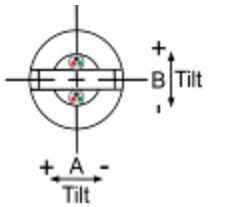
From IPI 3 core cable	Description	JB terminal	Output 6-core cable (Encardio-rite CS-0703)
Red	+12 V	A	Red, White
Green	Output	B	Green
Black	0 V	C	Black, Blue, Brown and Shield

6.2 Powering up the 3D IPI daisy chain assembly

1. After completion of the whole assembly of daisy chain, a single 3 core cable coming out of the top of borehole will then be connected to our Encardio-rite model ESDL-30 datalogger for datalogging.
2. ESDL-30 datalogger will be powered with battery pack supply of 15V. The battery pack is an integral part of dispatch of the complete assembly kit.

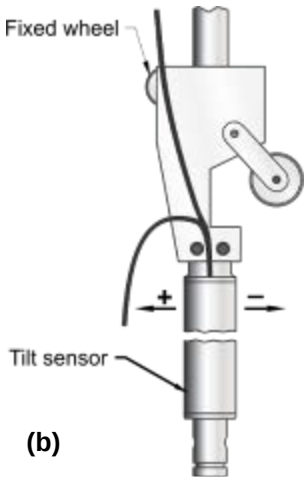
6.3 Sign convention

- Carefully orient the sensor during installation. Make a note of the orientation. A "+" is marked on each sensor along the A-axis.
- A-axis measures tilt in the plane of wheels. B-axis is at 90 degrees to A-axis. Uniaxial sensor measures tilt only along axis 'A'.



End view of tilt sensor

(a)



(b)

Figure 6-2 Sign convention

Figure 6-2(a) shows a view from top and also convention used for assessing direction of movement for data interpretation.

- Generally we install the sensors with A+ orienting towards the expected movement side / excavation direction. If the expected movement is uncertain, we orient the sensor's A+ towards the geographic North. (Figure 6-2 (b))

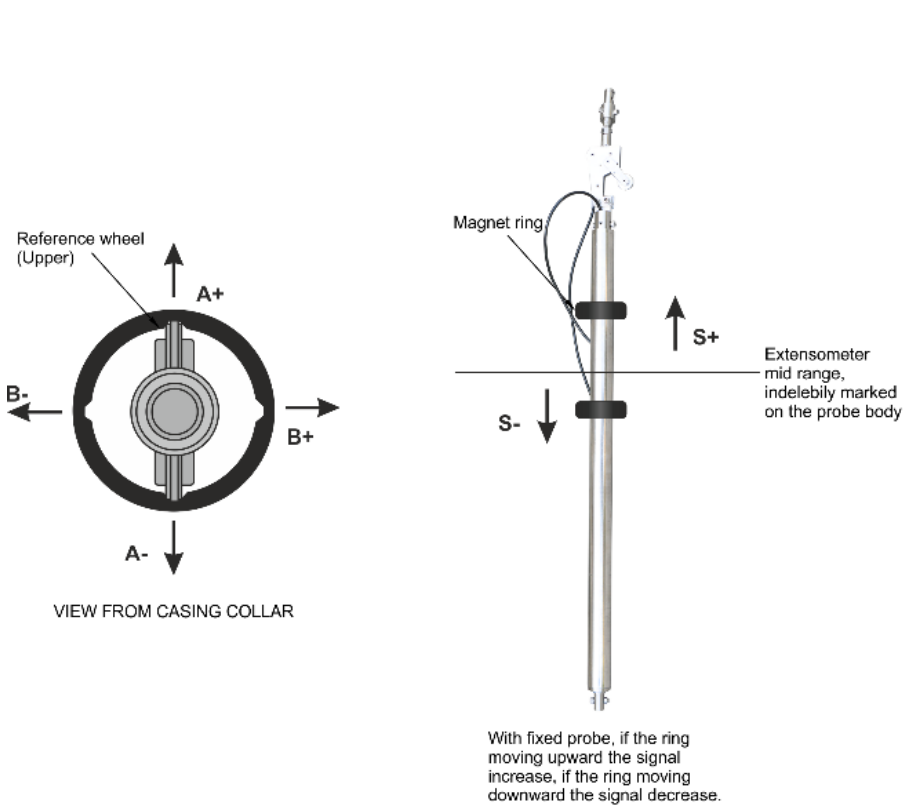


Figure 6-3 Displacement and Settlement Direction

- For settlement or heave the expandable gage /gage couple tubing (joint between the subsequent sensors) will need to be adjusted depeding on the expected movement

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6.4 Lowering of 3D IPI sensors

- **SENSOR MARKING** Once the exact levels of the magnetic readings are noted, the 3D IPI sensors connected with the gage coupler tubing is adjusted according to the centre of the spider magnet.
- The centre of the three-marked location for sensing the settlement is adjusted with the centre of the spider magnet. (Refer to figure 6-4)
- The coarse and fine adjustments of the 3D IPI sensor is done by the ±25 mm slots and chuck nuts provided on the either side of the gage coupler tube. (For details refer to section 4.2.2)

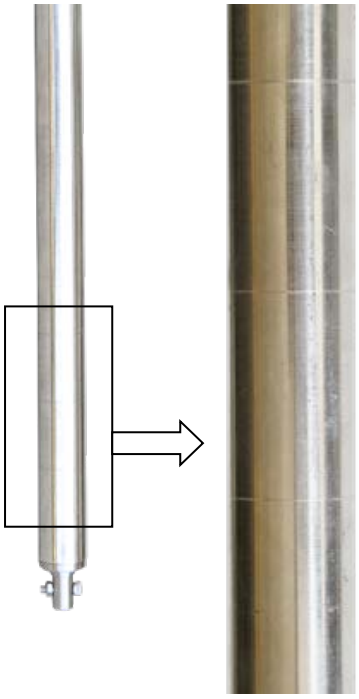


Figure 6-4

Sensor marking 100 mm for settlement measurement

6.5 Maintenance of 3D IPI Sensors

The 3D In-place inclinometer requires careful maintenance after dismantling if the whole set needs to be reused in another borehole in the future. Please implement the following maintenance steps:

- Wheel assemblies, springs, pivots and axles should be cleaned and dried after dismantling the IPIS and IPI chain using compressed air.
- Oiling of the wheels, springs, pivots and axles to be performed subsequently.
- Connectors should be cleaned and dried. These should be free of any cuts.
- As the dismantled IPIS and IPI sensors were in use, there would be a zero offset for each sensor. It should be removed before reusing. It is recommended that the sensors should be sent back to the factory for recalibration.

7 CONNECTING SENSOR TO DATA ACQUISITION SYSTEM

7.1 Encardio-rite model ESDL-30 datalogger overview

ESDL-30 datalogger is designed to record data from the sensors connected to SDI-12 bus. The datalogger is having 3 SDI-12 ports (channels). Sensors having SDI-12 interface can be connected on a common SDI-12 bus. This bus can be connected to any SDI-12 port of the datalogger. Each reading is stamped with date and time at which the measurement was taken. It has a non-volatile flash memory to store up to 2 million data points.

Model ESDL-30 datalogger

These data files can be downloaded to PC using Configuration Manager software by connecting logger with data cable or Bluetooth. The downloaded readings get stored in the PC's Home Directory in CSV format. The downloaded files can be transferred to FTP server using internet connection. It can be processed on any commonly available spreadsheet like Microsoft-Excel.

ESDL-30 with built in GSM/GPRS modem has capability to upload data records directly to remote FTP server. Upload schedule can be programmed in the datalogger using the software for automatic data upload to FTP server. Schedule can be set as fast as 5 minutes.

SDI-12 inputs should have a unique ID (0-9, a-z or A-Z). So one needs to set ID of sensors having SDI-12 output. Each of the 3 channels of the datalogger can have 61 sensors with ID 1-9 (ID 0 is used for factory purposes, hence not available for use), a-z or A-Z. For a given channel each sensor should have a different ID.

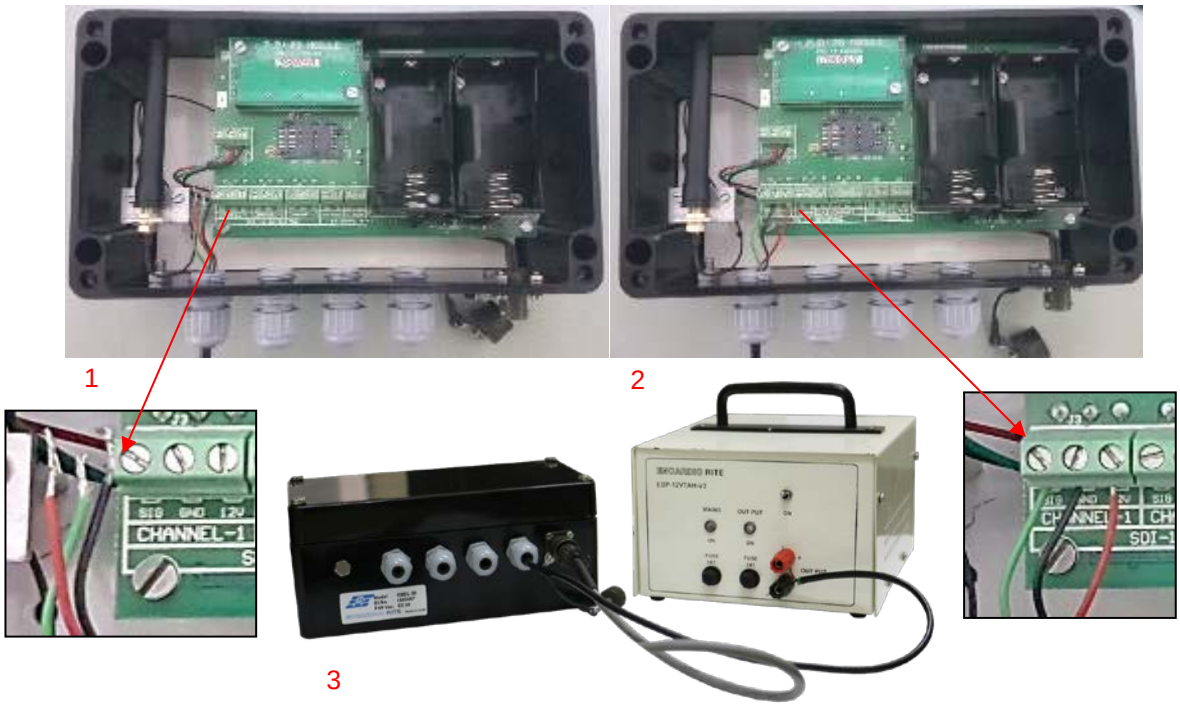


Figure 7-1 Connection of IPIS with ESDL-30 Datalogger:

1- **Datalogger shown without the 3D IPI connection**
2- **Datalogger shown with the IPI connection without internal batteries**
3- **15 V Supply connected with the datalogger and 3D IPIS connection**

7.1.1 Sensor Configuration with ESDL-30

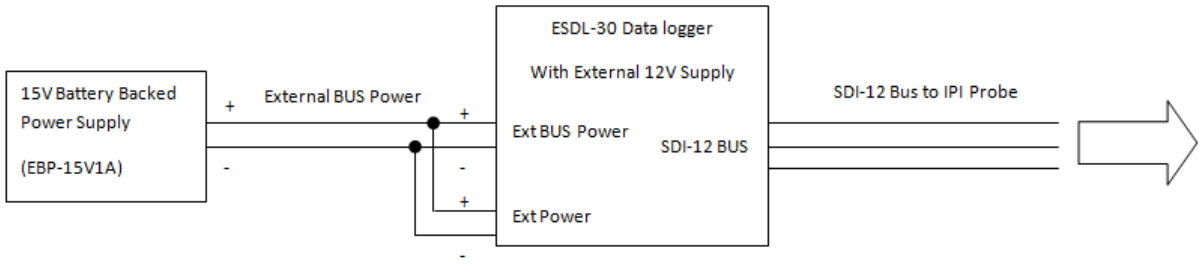
For sensor configuration with ESDL-30 refer to manual "ESDL-30UNI-Configuration-Manager-for-Windows – Doc. # 6002.110".

7.1.2 SDI-12 Bus Power

The IPI Probe is designed to work on standard SDI-12 Bus protocol. Probe operating voltage range is 12V – 16V. Probes are connected in a daisy chain on SDI-12 Bus. Cable length between bottom most probe and the datalogger will cause significant amount of voltage drop due to its higher cable resistance. Since probe cannot work properly below 12 V at its terminal, it is recommended to use 15V Battery backed power supply to power SDI-12 Bus for its smooth operation. The battery pack is an integral part of dispatch of the complete assembly kit.

7.1.3 15V Battery Backed Supply Wiring with ESDL-30

Refer the following wiring diagram to connect 15 V Battery backed power supply to ESDL-30 Datalogger



8 SAMPLE TEST CERTIFICATES