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USERS' MANUAL

ELECTRONIC PLUMB LINE

MODEL EPR-01S DIGITAL READOUT UNIT

FOR MODEL EDS-50/EDS-51 NORMAL & INVERTED PLUMBLINE SYSTEM

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1 INTRODUCTION

Plumb line is used in concrete and masonry dams for the measurement and monitoring of relative displace-ment between:

- dam top and the base
- base and the foundation rock

The displacement is measured in the inspection gallery or an adjoining area on an observation table general-ly mounted with two traveling telescopes. This plumb line system is not as simple as an ordinary plumb line used by a construction worker. Great care has to be taken in the mounting of this sophisticated equipment and in its subsequent maintenance and care. The plumb line is a precision instrument.

The plumb line is sometimes also used for monitoring the tilt of high rise buildings and tall structures.

The electronic variant of the plumb line is known as Telecoordinometer or Electronic Plumb Line. The purpose of Telecoordinometer/Electronic plumb line is for measurement and monitoring of relative displacement of the top and the gallery (Normal Plumb line) and from gallery to the foundation (Inverted Plumb line).

NOTE: Personnel involved in installation and monitoring are professionally trained to have:

- A background of good installation and monitoring practices
- Knowledge of the fundamentals of geotechnics
- An understanding of the intricacies involved, which may seem apparently minor but must not be ignored or overlooked, as otherwise the most reliable of instruments and data obtained from them will be rendered useless
- To use their knowledge and common sense to find the solution to a particular problem on site, depending upon field conditions.

2 GENERAL DESCRIPTION

Plumb lines are installed by two different methods, Normal plumb line and Inverted plumb line.

2.1 Normal plumb line

In the normal plumb line assembly the upper end of the plumb line wire is fixed through a collet arrangement centered on a rectangular collet bar, fixed at the top of the dam. A heavy weight of around 10 kg is clamped at the lower end of the wire. To prevent any to and fro oscillatory movement of the plumb due to any vibration or shocks, the weight is damped in a tank filled with oil. A tilt in the dam brings about a shift in the weight, which is measured by the telecoordinometer which has built in proximity sensors.

2.2 Inverted plumb lines

The assembly is used when the displacement between the base of the dam and the rock foundation is to be measured and monitored. A hole of minimum 150 mm or more in diameter is drilled from the gallery to the desired depth upto the foundation rock. Larger diameter hole is required if the depth is greater. One end of the plumb wire is attached to a steel anchor with the help of a collet. The steel anchor is centered and grouted at the bottom of the drilled hole. The upper end of the steel wire is fastened by a collet to a float submerged in a water tank in the observation area. A tension of around 8 kgf is maintained in the plumb wire. The water in the tank acts as a damping medium and prevents any to and fro oscillatory movement of the pendulum due to any vibration or shock. A tilt or displacement in the foundation brings about a shift in the float which is measured by a set of proximity sensors mounted perpendicular to each other in a metal panel called as telecoordinometer.

2.3 Displacement measurement

Measurement of displacement is done by a telecoordinometer which contains a set of four proximity sensors mounted at right angles to each other. Four proximity sensors inside a telecoordinometer measures the x-axis (A) and y axis (B). For taking the zero reading, the plumb wire needs to be adjusted such that its center is adjusted and coincides with the marking on the metal panel. The Electronic system requires four proximity sensors i.e. one pair (mounted opposite) for the X and another pair (mounted opposite) for Y axes. This obviates the necessity of moving and re-aligning the telecoordinometer, plumb line and reference plumb every time a reading has to be taken in the X and Y axes. Advantage of the telecoordinometer is that it records the displacement automatically and eliminate the human error generated in the manual system along with the time consumed. This arrangement also saves a lot of floor space.

2.4 Brackets/Angle frame (Wall Mounting & Groutable)

The pair of brackets/angle frames provided with two holes (center distance 240 mm) for fixing to a wall (or side support) and two holes at the top surface (center distance 240 mm) for fixing telecoordinometer (or side support).

3 TOOLS & ACCESSORIES REQUIRED FOR INSTALLATION

1 Allen Key – 5 mm

2 Screw Driver set

3 Tape measure

4 Spanner – 12/13 & 20/22

5 Power drill

6 Concrete / Masonry drill bit 12 mm

7 Cloth for cleaning

4 OVERVIEW OF THE INSTALLATION OF VERTICAL SHAFTS

4.1 Installation Procedure

4.1.1 Plumb line readout in a Normal Plumb line

This normal plumb line assembly is used when displacement between the top and base of a dam is to be measured and monitored. Figure 1 provides cross sectional layout of the normal plumb line and Figure 2 gives details of fixing brackets and mounting electronic plumb line EPR-01S.

Great care should be exercised during the execution of civil work to prevent any problems during installation.

CAUTION The Encardio-rite model EPR-01S has a dimension of 344 mm x 300 mm with a 242 mm hole through which the plumb line passes. This hole is not in the middle of the observation table. Its center is at 220 mm from the wall edge and 185 mm from the rear edge. Any layout should make sure that this hole should be concentric with the vertical shaft in the dam through which the plumb line passes.

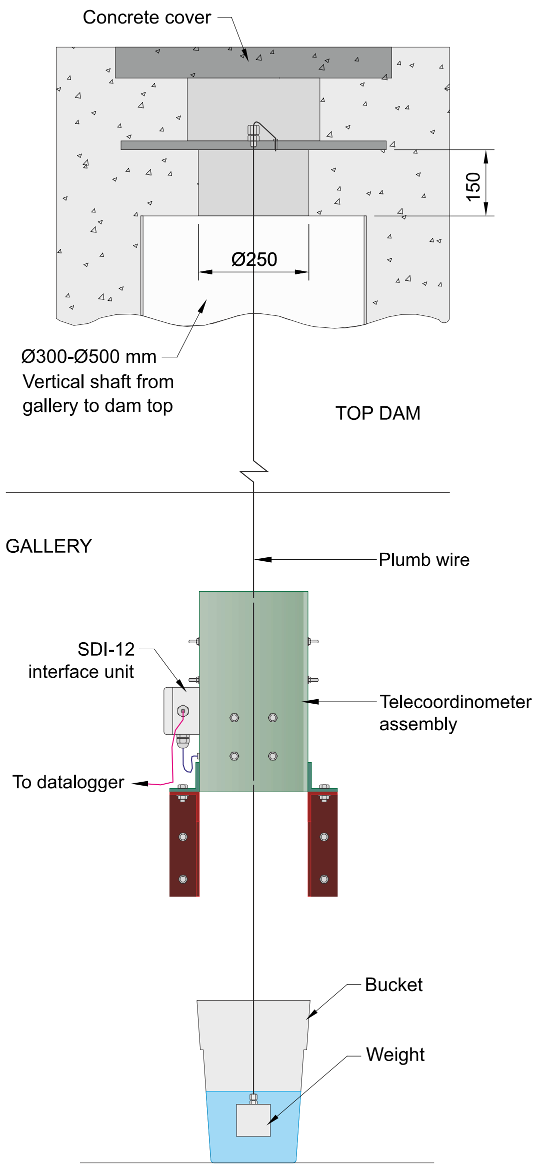
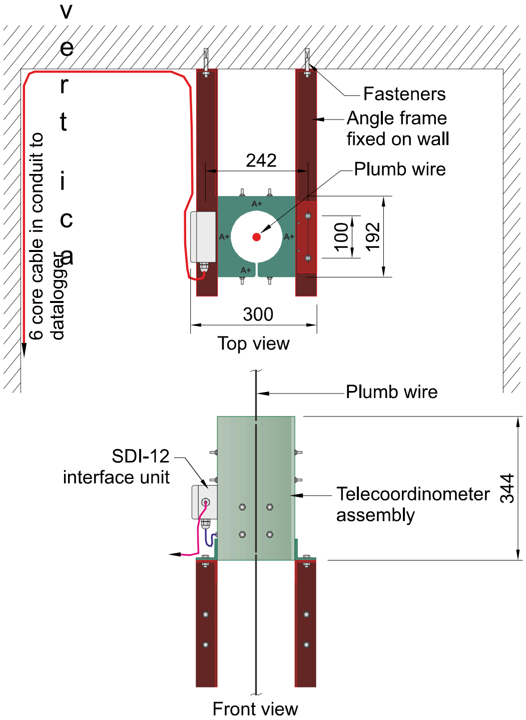


Figure 1 – Cross sectional view of the Normal Plumb Line

CAUTION In case of the normal plumb line, during the construction of the dam, a vertical cement pipe is cast in position from the gallery to the top of the dam for the plumb line to pass through. Depending upon the height of the dam, the internal diameter of this vertical shaft should be anything between 300-500 mm. This vertical shaft which interconnects the top of the dam to the base gallery should be plumb within close limits such that the plumb line in its two extreme positions does not foul with the sides.



4.1.2 *Plumb line readout in an Inverted Plumb line*

The assembly is used when the displacement between the base of the dam and the rock foundation is to be measured and monitored. A hole of minimum 150 mm or more in diameter is drilled from the gallery to the desired depth upto the foundation rock. Larger diameter hole is required if the depth is greater. One end of the plumb wire is attached to a steel anchor with the help of a collet. The steel anchor is centered and grouted at the bottom of the drilled hole. The upper end of the steel wire is fastened by a collet to a float submerged in a water tank in the observation area. A tension of around 8 kgf is maintained in the plumb wire. The water in the tank acts as a damping medium and prevents any to and fro oscillatory movement of the pendulum due to any vibration or shock. A tilt or displacement in the foundation brings about a shift in the float which is measured by a set of proximity sensors in the telecoordinometer mounted perpendicular to each other.

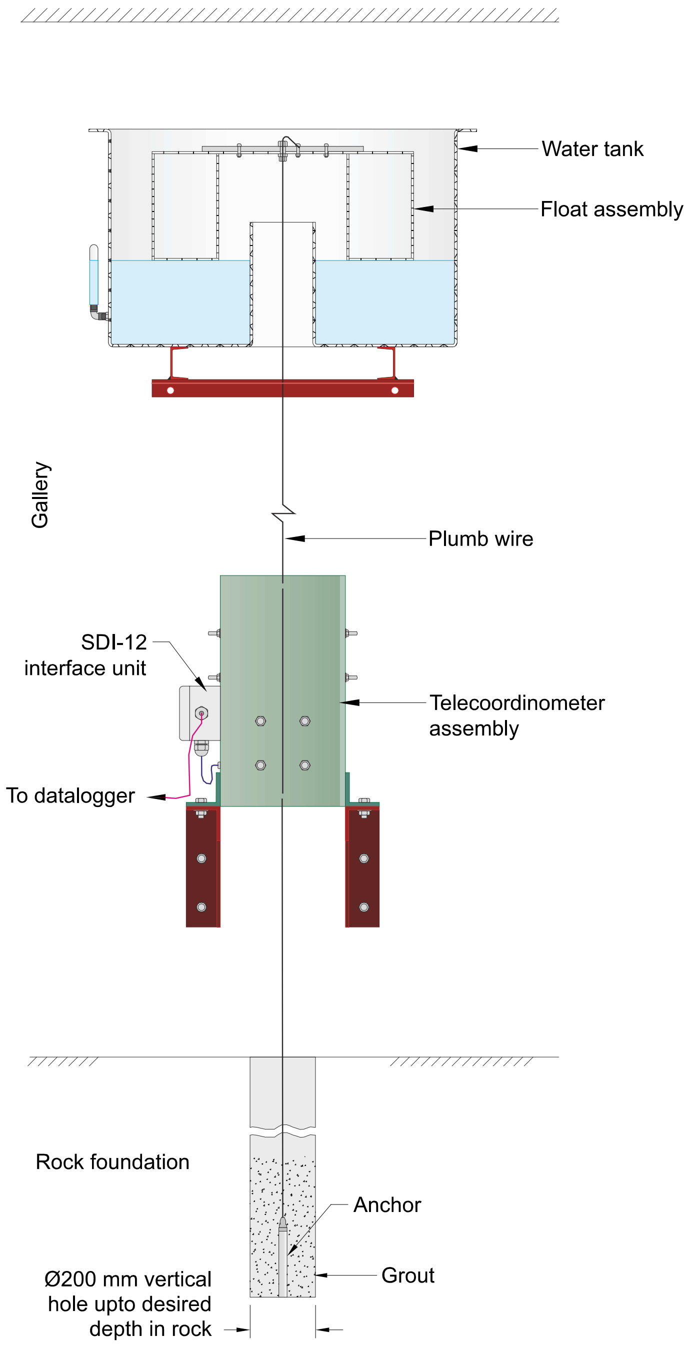


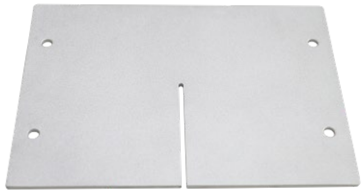
Figure 2 – Cross sectional view of the Inverted Plumb Line

5 INSTALLATION OF ELECTRONIC PLUMB LINE READOUT UNIT (EPR-01S)

5.1 Pre-installation checks

- Verify the installations as per its orientation and as per the location.
- Check the slots in the brackets for any physical damage.
- Check the telecoordinometer and the proximity sensors are physically ok.
- Check the orientation of plumb wire.

Picture 3 – Hilti Anchor



Picture 4 – Plate template

5.2 Pre- assembly

- H10 Hilti anchors – four no. (Picture 3) is used to fix the brackets on the wall.
- Plate template (Picture 4) is being used to mount the brackets on the wall.
- The string of hex bolts, hex nuts, special washers, washers are strongly recommended for fixing the EPR-01S on the bracket.
- Picture 5 shows the correct position of each component of the kit while mounting the EPR-01S bracket.

Picture 5 – M8 Hex bolt assembly

- Reflector plate assembly – two sets of reflector plate assembly placed 90° apart is installed around the plumb wire and in between the inbuilt four proximity sensors. These are part of the whole assembly of electronic plumb line readout and the displacement of the plumb wire are used to convert the magnetic field into an electric current which generates an SDI output.
- Plumb wire clamps – One of the two plumb wire clamp is used at the top of the reflector plate assembly

Picture 6 – Reflector Plates (2 sets at 90°)

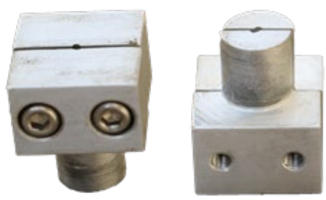
5.2.1 Installation procedure

Complete the civil work for the installation of plumb wire, water tank, float assembly for normal and inverted plumb line as per figure 1 and 2.

Proceed with installation of the Plumb line readout (EPR-01) as follows:

5.2.1.1 <u>Fixing of Brackets/fixed frames</u>

- Position the mild steel brackets and prop it against the wall such that the 240 mm gap is maintained around the plumb wire and approximately below the vertical shaft.



Picture 7 – A set of plumb wire clamps

- Mark the locations to fix the brackets by placing the plate template (picture 8) on the top of bracket.
- Slide the plate template carefully to match with the slots on the angle of the bracket (picture 8)

CAUTION: Make sure the groove in between the template does not come in contact with the existing plumb wire.

- Drill a 10 mm Φ x 50 mm deep hole for Hilti anchor HSA M10 x 50 or equivalent on the wall where the plumb wire is installed.
- Insert anchors in the drilled four holes.
- Level the brackets with the help of spirit level.
- Mount the brackets on the anchor and tighten it slightly.

5.2.1.2 <u>Fixing of EPR-01S on the brackets</u>

- Fix the hex bolt in the slots provided on the brackets/angle frame (refer picture 9)
- Now place the angles of EPR-01S on top of the hex bolts
- Adjust the EPR-01S during fixing such that the suspended plumb wire passes through the center of the EPR-01S.
- Tighten the angles with the hex bolt kit in sequence on the given slot of the bracket/fixed frame as shown in picture 9.
- Fasten the EPR-01S angle brackets to the hex bolt kit (refer picture 9). Check the relative position of the nuts, washers and angle brackets from the picture 5.

Picture 8 – Brackets / fixed frame

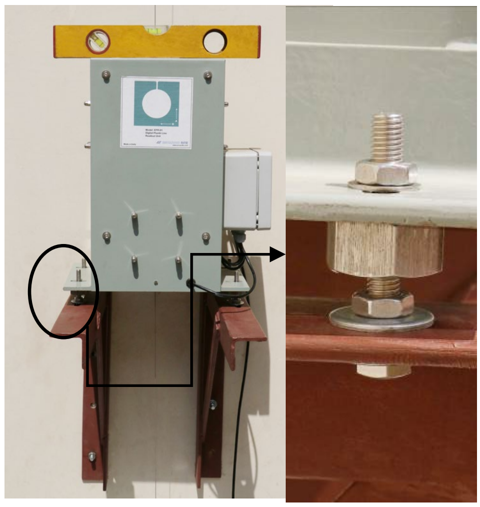
5.2.1.3 <u>Fixing of the Reflector plate assembly</u>

- Fix one of the given two wire clamps, one around the suspended plumb wire, at the top of the reflector assembly plates.
- Tighten the allen grub screws with 5 mm allen key around the plumb wire (refer Picture 11).

CAUTION: Do not tighten it beyond a certain limit else the plumb wire may get damaged.

- Open the screws of one plate of the reflector assembly.
- Hold the assembly and place the slot over the plumb wire such that the plates are positioned exactly opposite of the proximity sensors (refer Picture 12).

Picture 9 – Brackets



Picture 10 – Hex bolt kit to fix the angle of EPR-01S

- Place the opened plate back to its position and tighten the screws to fix (refer Picture 14).
- Now fix the second wire clamp at the bottom of the reflector assembly plates and tighten the allen grub screws with 5 mm allen key around the plumb wire (refer Picture 15).

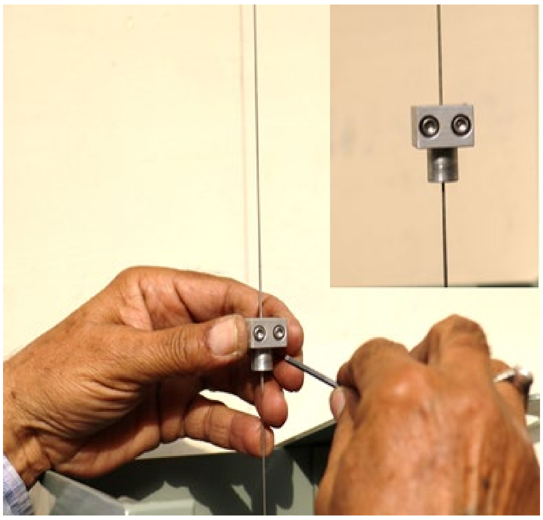
NOTE: Make sure the placement of reflector plates are aligned exactly opposite of all the four proximity sensors.

- Place the front panel of the electronic plumb line readout and tighten the screws to complete the installation.

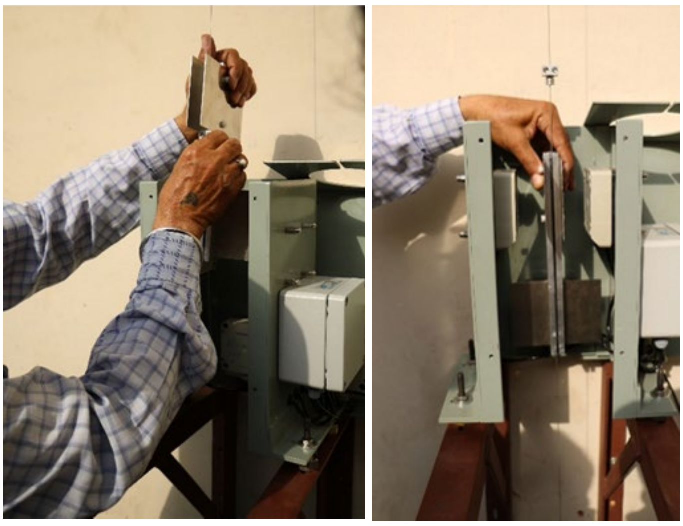
5.2.2 Positioning of the Electronic Plumb line readout in an existing dam

1. While placing the EPR-01S, note down the water level in the dam reservoir during the time of installation.

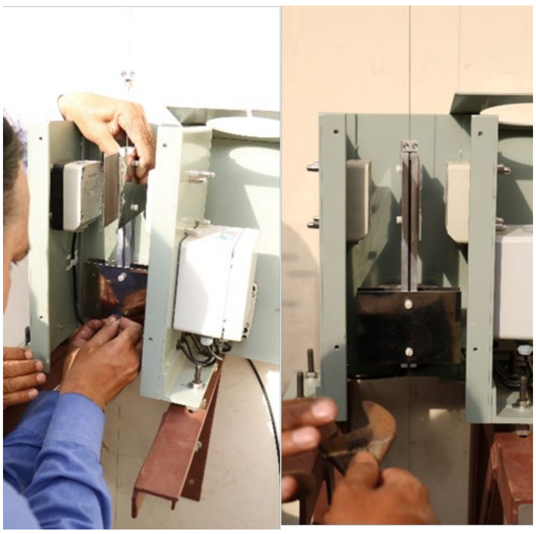
- If the reservoir level is about to be filled, then we need to adjust the EPR-01S system with reference to 50 mm scale (A-axis) to be at the minimum level - 10 mm approx. (Refer Picture 16).
- If the reservoir is completely filled then we need to adjust the EPR-01S system with reference to 50 mm scale (A-axis) to be at the maximum level – 40 mm approx. (Refer Picture 16).



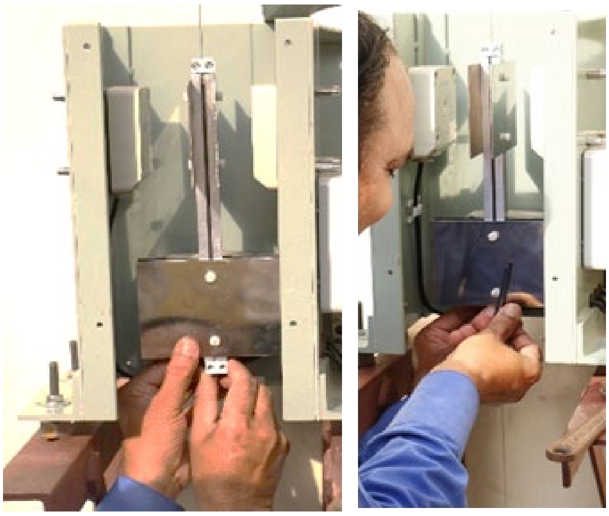
Picture 11 – fixing of top wire clamp



Picture 12 – fixing of reflector plates



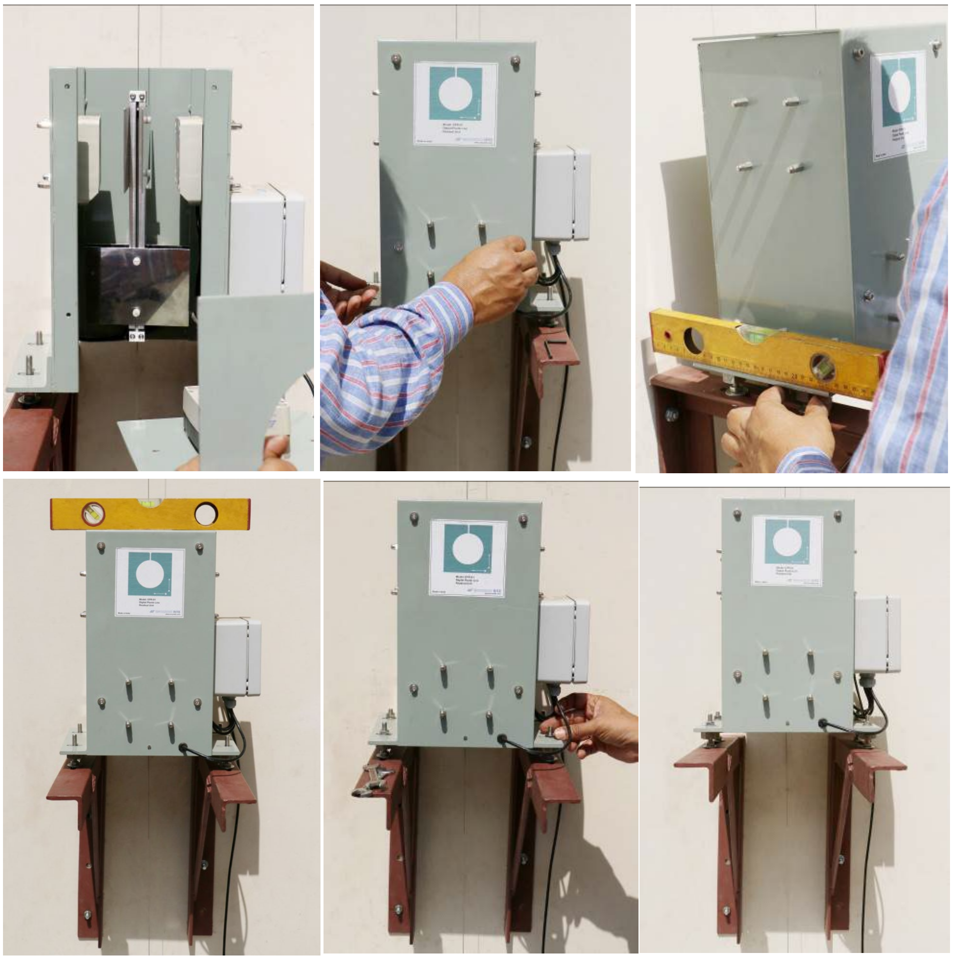
Picture 13 – fixing of placing one plate and tightening



Picture 14 – fixing the plumb wire clamp at the bottom of reflector assembly

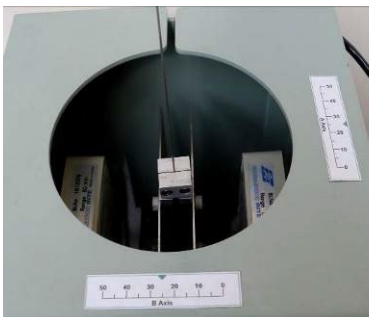
2. Sign Convention

   For convenience the orientation notification is present on the EPR-01S body with A-axis and B-axis (Refer Picture 17). Carefully orient the assembly during installation. Make a note of the orientation. Adjust the reflective plates and make sure they should be perpendicular to each other.

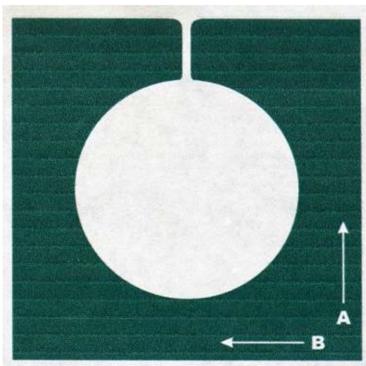


Picture 15 – Fixing of the front panel of EPR-01S

Either of the axis will be perpendicular to the dam axis.



Picture 16 – Positioning scale for A and B axis



Picture 17 – A and B axis

6 TAKING READINGS

6.1 Wiring

Colour coding of the cable coming out from the proximity sensors is given below:

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

The four proximity sensors altogether connected to a 4:1 SDI junction box.

Individual SDI-12 connecting cable will be connected to an Encardio-rite model datalogger ESDL-30.

Picture 18 - SDI-12 Junction Box

6.2 Positioning of the existing thirteen nos of electronic plumb line

The detailed drawing for positioning the Electronic Plumb Line on all the thirteen locations of the existing plumb lines installed in the gallery and outside area are shown in Annexure 1.

6.3 Connecting sensor to Data acquisition system

6.3.1 With EDAS-10 Data acquisition system

Model EPR-01S (telecoordinometer) sensors having SDI-12 interface require a power source of 12V DC which is provided by the EDAS-10 data acquisition system through Encardio-rite power supply model EBP-127AH. Since the output is SDI-12 network, only a three core cable is routed to the data acquisition system. Depending upon the application, the data acquisition system can be based on Campbell measurement and control modules CR1000, CR800 or CR200.

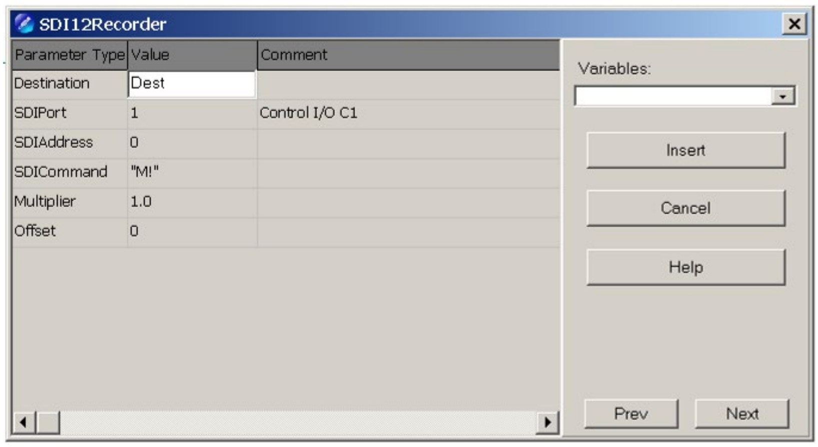
NOTE: For detailed instructions on configuration of Encardio-rite model EDAS-10 data acquisition systems based on measurement and control modules CR 1000/CR 800, refer to Campbell Scientific's relevant Users' Manal.

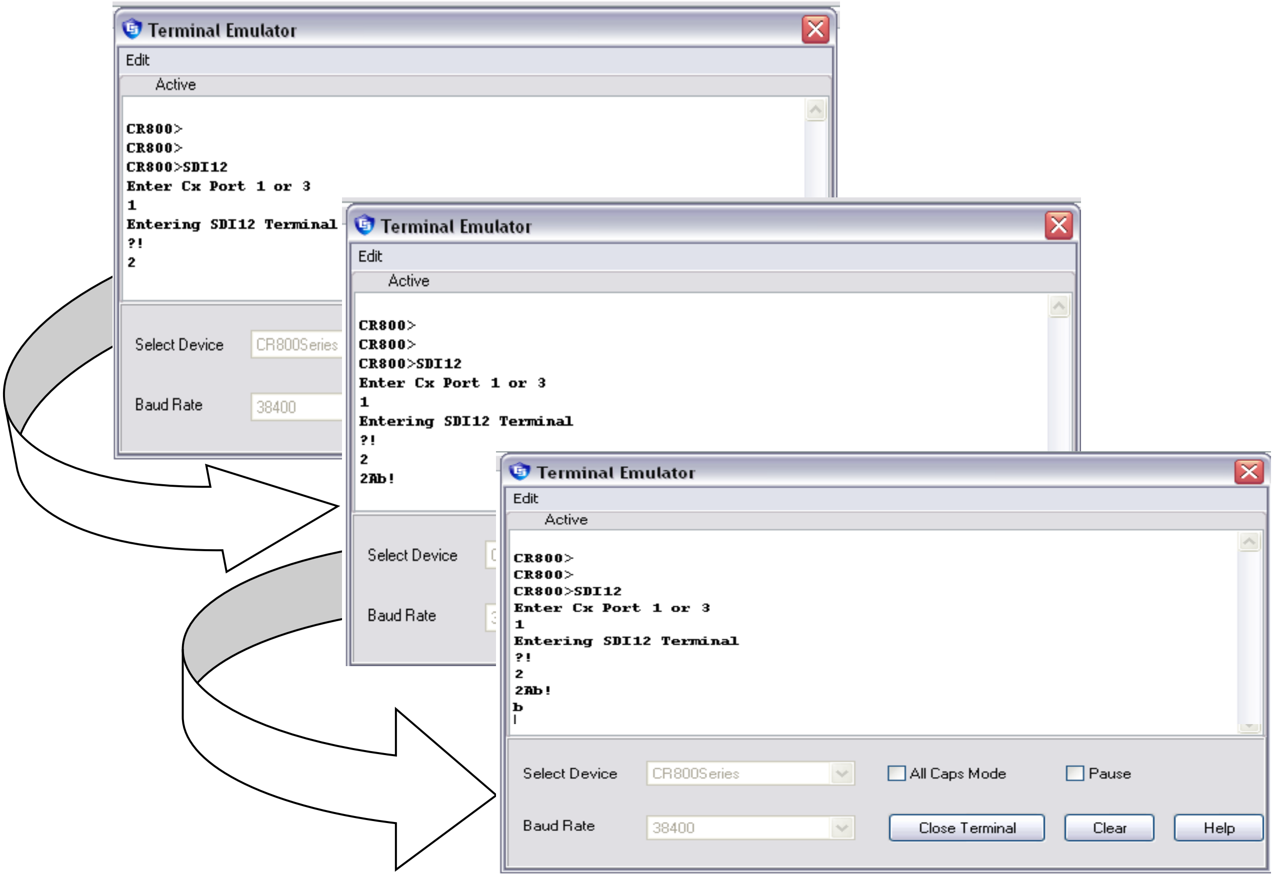
Typical wiring/connection of in-place inclinometer system to CR1000 or CR800 based data acquisition systems are shown in the figures on the next page. In case data is to be transmitted via GSM/GPRS or RF modem only the CR 1000 or CR 800 based data acquisition system can be used.

6.3.1.1 <u>Program for SDI-12 sensor</u>

Encardio-rite can supply a program for monitoring electronic plumb line based on information provided by customer. For details, contact Encardio-rite's head office in India.

SDI12 Recorder- The SDI12 Recorder instruction is used to retrieve the results from an SDI-12 sensor.





Syntax- SDI12 Recorder (Dest, SDIPORT, SDI Address, SDI Command, Multiplier, Offset)

Where Destination is the defined address for storage, SDIPORT is the control port connected to sensor, SDI Address is the defined address of the connected sensor, SDI Command is taken as "M!" The Multiplier and Offset have purpose as per the name suggested.

The SDI-12 Command basically has three components i.e. ***aM1!***. An active sensor responds to each command.

Sensor address (a) – a single character, and is the first character of the command.

Command body (e.g., M1) – an upper case letter (the "command") followed by alphanumeric qualifiers.

Command termination (!) – Command terminates with an exclamation mark.

SDI12 Sensor address change:

To change a sensor's address we need to send a command as given below. Command: **0A2!**

(Previous_AddressNew_Address!) Note: Here "2=Previous_Address" and "b= New_Address"

6.3.1.2 Typical programming for reading one SDI-12 sensor using CRBasic

The telecoordinometer sensor response can be checked before installation at site with the help of simple program module as shown in picture 20.

" SDI-12 Sensor measurements with CR1000 Series Datalogger
'Declare Public Variables
Public batt_volt
Public PTemp
Public Results(6)
Public Sensor_ID(2)
Public watchdog

```
'Declare Other Variables --Sensor name can be changed as required
Alias Results(1)=Sensor_1
Alias Results(4)=sensor_2

'Define Data Tables
DataTable (SDI_DATA,True,-1)
                    DataInterval (0,5,min,0)
                    Sample (1,batt_volt,FP2)
                    Sample (1,PTemp,FP2)
                    Sample (1,Sensor_1,IEEE4)
                    Sample (1,Sensor_2, IEEE4)
                    Sample (1,watchdog,FP2)
EndTable

'Main Program
BeginProg
          watchdog=0
                    Scan (10,sec,1,0) ' Scanning Interval Can be changed
                    PanelTemp (PTemp,250)
                    Battery (batt_volt)
                    'Sensor_ID()=value
                    Sensor_ID(1)=0     'for connected sensor
                    Sensor_ID(2)=1
'SW12(1)
Delay(0,3,sec)

' SDI-12 Sensor measurements
SDI12Recorder (Results(1),3,Sensor_ID(1),"M!",1.0,0)
SDI12Recorder (Results(4),3,Sensor_ID(2),"M!",1.0,0)
Delay(0,5,sec)
If watchdog = 0 Then
          watchdog = 10
          EndIf
                    CallTable(SDI_Data)
          NextScan
EndProg
```

6.3.1.3 Typical programming for reading one SDI-12 sensor using Terminal Emulator

Terminal Emulator emulates a terminal connected to a datalogger or communications device. On selecting a device and baud rate and clicking Open Terminal causes PC400 to attempt to connect with that device. If the device is a datalogger, PC400 will call the datalogger over whatever communications link has been established and will attempt to get a prompt from that datalogger. The data response through emulator is as per figure 21.

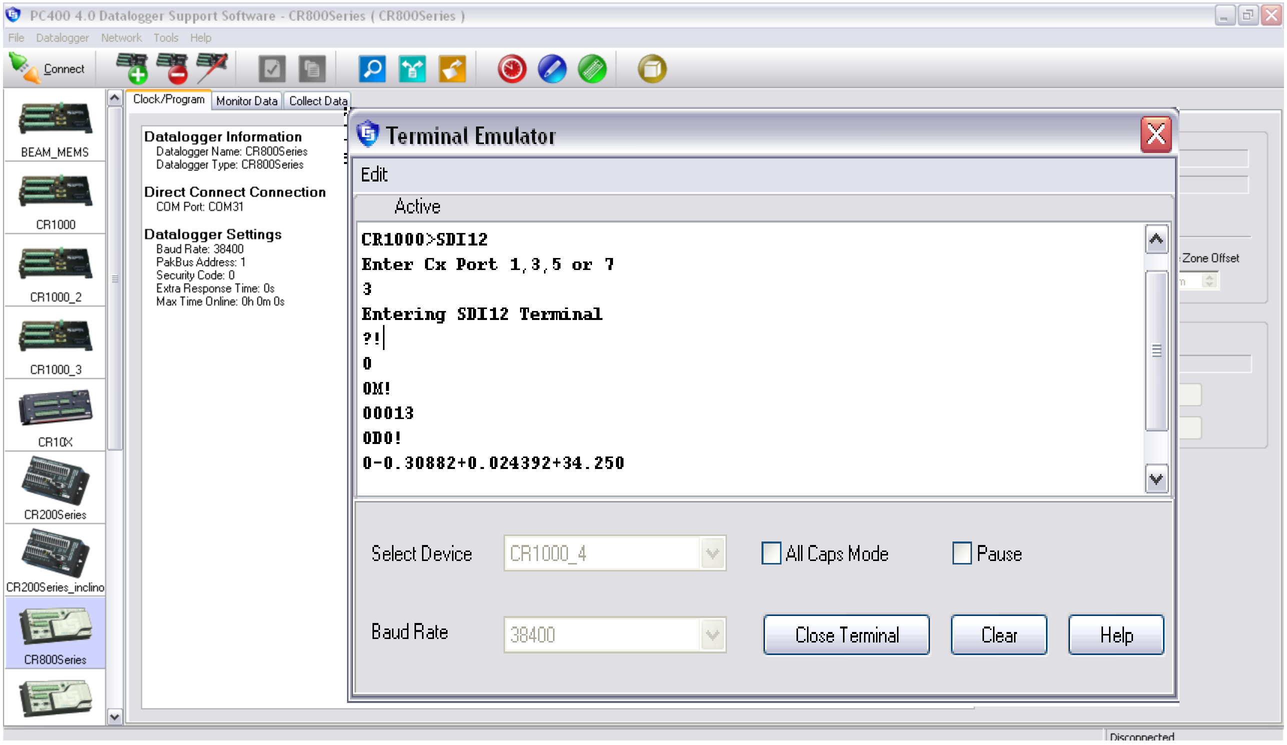


Figure 21: Terminal Emulator

6.3.2 With ESDL-30 Data acquisition system

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.

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.