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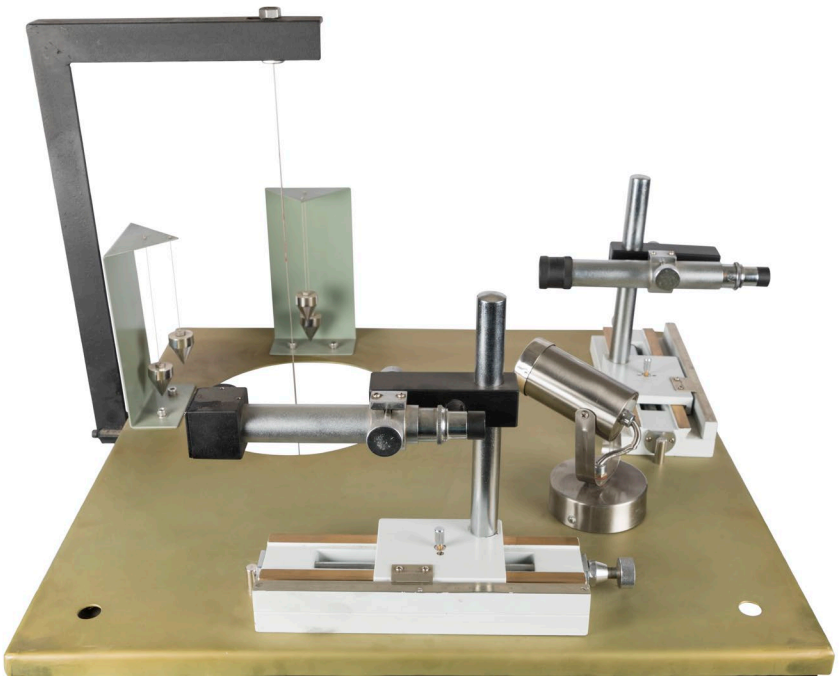
USERS' MANUAL

NORMAL AND INVERTED PLUMB LINE MANUAL READING WITH TELESCOPE

MODEL EDS-50/51



Doc # WI 6002.17 R03

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Contents

1 INTRODUCTION

Plumb line is used in concrete and masonry dams for the measurement and monitoring of relative displacement 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 generally 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.

1.1 Normal plumb line

This assembly is used when displacement between the top and base of a dam is to be measured and monitored. 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 a set of traveling telescopes mounted perpendicular to each other on an observation table. For taking the zero reading of the traveling telescopes, a reference plumb is mounted on the observation table opposite to each of the telescope.

1.2 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 150 mm or more in diameter is drilled from the gallery to the desired depth up to 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 traveling telescopes mounted perpendicular to each other on the observation table. As in the case of the normal plumb line, reference plumbs are provided in this case also.

1.3 Displacement measurement

As already mentioned, measurement of displacement is done by a set of two traveling telescopes mounted at right angles to each other. Even though the readings can be taken with one telescope, the Encardio-rite system requires two traveling telescopes (one each for the X and Y axes) be used. This obviates the necessity of moving and re-aligning the telescope, plumb line and reference plumb every time a reading has to be taken in the X and Y axes. Two traveling telescopes not only cut short the observation time but also minimize any chance of error. To facilitate observation from the same direction, one of the telescopes [(7) in figure 2.1] is provided with a right-angle prism before the objective lens. This helps the observer in taking both the X and the Y readings, sitting in the same position. This arrangement also saves a lot of floor space.

1.4 Specifications

Normal plumb line

Model	EDS - 50
Measurement method	Traveling telescope
Telescope focus range	250 mm to 500 mm
Measuring range	± 75 mm
Resolution	0.01 mm
Accuracy	0.1 mm
Table size	625 mm x 625 mm
Stainless steel wire	1 mm ϕ x 60 m long (other lengths available)
Wire suspension	Collet on a rectangular bar grouted at the top.
Suspension weight	10 kg
Oil tank (PVC)	50-liter capacity
Damping oil	S.A. E 40

Inverted plumb line

Model	EDS - 51
Measurement method	Traveling telescope
Telescope focus range	250 mm to 500 mm
Measuring range	± 50 mm
Resolution	0.01 mm
Accuracy	0.1 mm
Table size	625 mm x 625 mm
Stainless steel wire	1 mm ϕ x 60 m long (other lengths available)
Wire suspension	Collet on hollow float in tank filled with water
Wire tension	8 kgf
Water tank (fiber glass)	800 mm ϕ x 400 mm long
PVC float	800 mm ϕ x 400 mm long

1.5 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

1.6 How to use this manual

This users' manual is intended to provide you with sufficient information for making optimum use of the plumb line in your application.

NOTE: The installation personnel must have a background of good installation practices and a knowledge of the fundamentals of geotechnics. Novices may find it very difficult to carry on the 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 each and every condition in the field which may affect the performance of the instrument. Also, blindly following the instruction manual will not guarantee success. Sometimes, depending upon field conditions, the installation personnel will have to consciously depart from the written text and use their knowledge and common sense to find the solution to a particular problem.

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 which you may find while going through this manual.

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 types of plumb lines: See § 1 'Introduction'.

For specifications: See § 1.5 'Specifications'.

For installation of normal plumb line: See § 2 'Installation procedure for normal plumb line'.

For installation of inverted plumb line: See § 3 'Installation procedure for inverted plumb line'.

For recording plumb line data: See § 4 'Log book

2 INSTALLATION OF NORMAL PLUMB LINE

2.1 General

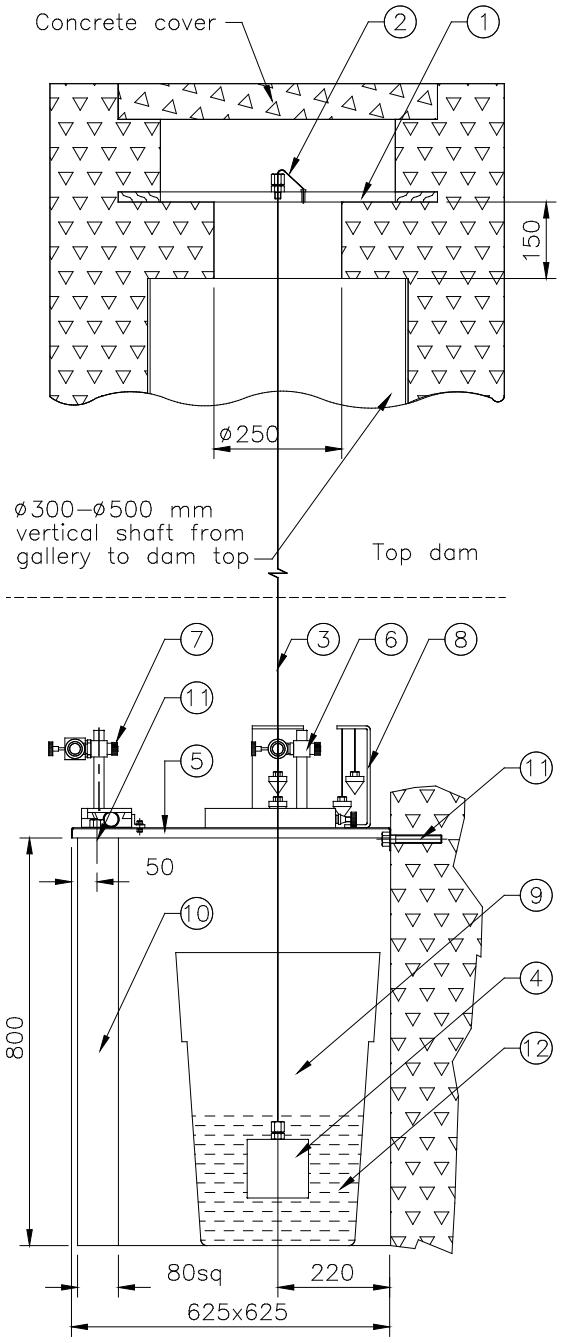
Figure 2-1 provides cross sectional layout of the normal plumb line. Figure 2-2 contains details of fixing observation table and mounting telescopes and reference plumbs.

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

CAUTION: Sufficient space should be available in the observation area for fixing of the observation table and for the technician to sit by the side of the table and take the readings. It is also essential that to and fro movement in the observation gallery does not get restricted. This makes it necessary to widen the observation gallery at the location where the plumb line is located or alternatively use an adjoining area. In a number of installations, the plumb line has been installed in the extra space made available by cutting the corner at the intersection of the longitudinal and cross galleries.

CAUTION The observation table has a dimension of 625 mm x 625 mm with a 220 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.

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



1 Collet bar - 1
2 Collet (SS) - 2
3 Plumb line (SS Wire 1.0 ϕ)
4 Weight (10 kg) - 1
5 Observation table - 1
6 Traveling telescope x-axis - 1
7 Traveling telescope y-axis - 1
8 Reference plumb - 2
9 Oil tank (50 liter capacity) - 2
10 Concrete support - 2 (customers scope)
11 5/8" BSW x 5" expansion fasteners - 4
12 Oil - 40 liter (customers scope)

Figure 2-1

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.

NOTE: Packed weight of plumb line (Sl. no. 1-11) is around 42 kg.

2.2 Installation procedure

Complete the civil work as per figure 2-1 and 2-2. Proceed with installation of the plumb line as follows (for numbers in parenthesis, refer to figure 2-1)

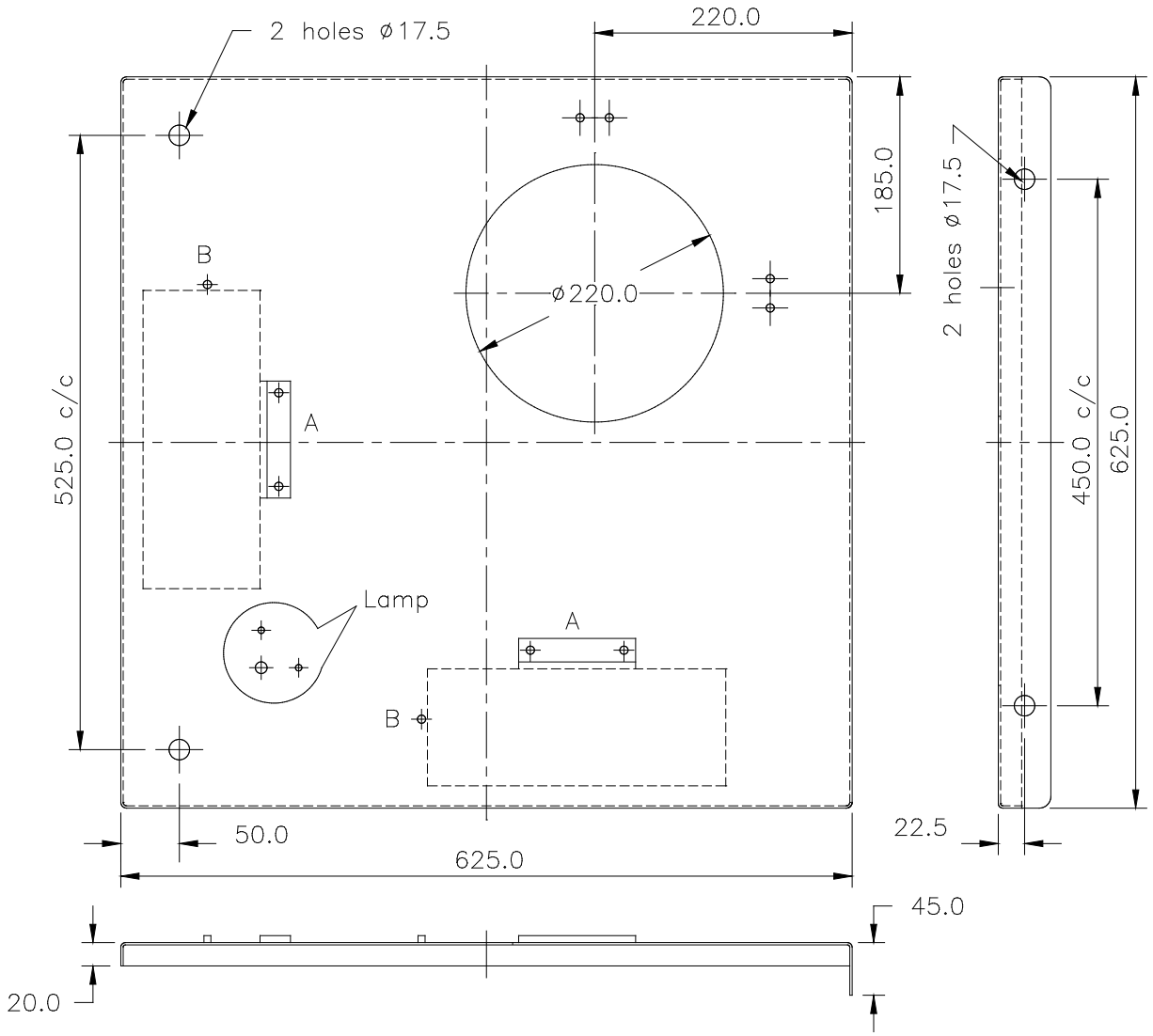


Figure 2-2

2.2.1 Positioning of observation table

The observation table is provided with two side holes (center distance 450 mm) for fixing to a wall (or side support) and two holes at the top surface (center distance 525 mm) for fixing to the two 80 mm square concrete columns. Position the mild steel observation table (5) on the two 0.8 m high concrete columns and prop it against the wall such that the 220 mm ϕ hole in the observation table is approximately below the vertical shaft. Place the oil tank (9) below the 220 mm ϕ opening.

NOTE: Depending on the site, some modifications may have to be made from the installation procedure described here. For example, the horizontal distance of the sidewall from the vertical shaft may not be 220 mm and appropriate corrective action will have to be taken.

2.2.2 Fixing collet bar to top of vertical shaft

Grout the rectangular collet bar (1) at the top of the vertical shaft as illustrated in figure 2.1. Ensure that its top surface is level. Complete the civil work according to the drawing and allow the concrete to set firmly. Ensure that the collet lies in the center of the vertical shaft

2.2.3 Lowering of weight

Determine the approximate length of the stainless-steel wire from the top of the collet bar to the bottom of the oil tank (9) in the observation area. Make an extra allowance to about 2 m and cut the wire. Thread one end of the wire through the collet (2) from the collet side. After the wire emerges from the lower surface, thread the weight (4) by pushing the wire into the collet arrangement provided on the weight. The wire emerges through its lower end. Secure the end of the wire firmly to the anchor screw provided on the weight. Exert a tension on the wire by lifting the weight and tighten the collet provided on the weight by a set of spanners. Two people may be required to do this job.

WARNING! Be careful that the weight does not drop down through the vertical shaft. It could injure or even kill a person passing through the gallery below.

Pass around a meter of the wire through the collet on the collet bar and tighten the collet to clamp the wire securely. Loosen the collet (2) and gradually lower the weight into the vertical shaft, past the opening in the observation table to the a depth of around 100 mm above the bottom of the oil tank in the observation gallery. Tighten the collet on the collet bar with a set of spanners. Use of two spanners during the tightening of the collet is recommended to avoid any jerks or undue force which may bend the collet bar. Tension the wire and secure it firmly around the anchor screw provided on the collet bar.

2.2.4 Fixing the observation table

Shift the observation table to center the plumb line inside the 220 mm hole on the observation table. Align the edges of the table such that they are parallel to the two perpendicular directions in which the tilt of the dam is to be measured. This will ascertain that the vernier scales on the traveling telescopes will be aligned with the longitudinal and transverse axes and will correctly measure the deflection of the dam in the two perpendicular directions. The observation table should now be firmly grouted in place by using the 5/8" BSW x 5" expansion fasteners provided along with the equipment. Take the center markings on the wall and the 80 mm square concrete columns. Use a 16 mm carbide tipped drill bit to drill four 12 cm deep holes at the location of the mounting holes on the observation table. Two of the mounting holes are on the top of the observation table and two on the 40 mm wide side. Place the 5/8" BSW expansion fasteners (thread side outside) in the holes, one at a time and tighten them with a spanner to expand them and be firmly seated in the drilled holes. The threaded portion of the expansion fasteners should be around 20 mm outside the observation table. Firmly secure the observation table in position by using the supplied nuts and washers. Take any other necessary precautions to ensure that the observation table is firmly grouted.

2.2.5 Filling of Oil Tank

Obtain requisite quantity of Indian Oil Servo Pride oil (SAE 40 Mobil) and fill up the oil tank such that the level of oil is approximately 5-6 cm above the surface of the hanging weight. The capacity of the oil tank is around 50 liter.

2.3 Positioning, operation and care of the traveling telescope

The traveling telescopes are packed in a specially designed case. Position the two telescopes on the observation table such that the front edge butts with the telescope reference plate (A) and the left edge touches the reference pin (B). Refer to figure 2-2.

The traveling telescope consists of a heavy aluminum base which is provided with a sliding mechanism which permits the vertical pillar to be moved across the base along the horizontal vernier scale. To slide the pillar, the knurled set screw provided on its base is loosened so as to disengage it. This arrangement provides for any coarse setting which is required to be made. For finer adjustment of the telescope barrel in the horizontal axis, the knurled knob referred to above, is to be tightened fully and the movement accomplished by rotating a large knurled knob provided on the right-hand side on the telescope. The barrel of the telescope can also be moved up and down in the vertical plane by loosening an Allen head screw provided on the bracket on the vertical pillar. A focusing knob is provided on the right-hand side of the telescope barrel.

A cross can be seen through the eye piece. Provision for rotating the cross and aligning it vertically with the plumb line is available in the eye piece. For ease in alignment, the objective lens can be rotated to slightly shift the vertical axis. The travelling telescope can focus between 250 mm and 500 mm from the end of the objective lens

Due care of telescopes should be taken. They should be kept covered with a plastic dust cover. Lenses should be cleaned periodically with a camel hair brush and lens cleaner available from any good photographic dealer. Telescopes require gentle handling and should be given the care and protection generally given to quality optical equipment.

2.4 Reference plumb setting

The reference plumb provides a permanent reference point for the transverse and longitudinal measurement of displacement of the structure. The deflection of the plumb line is measured with respect to these permanent reference plumbs.

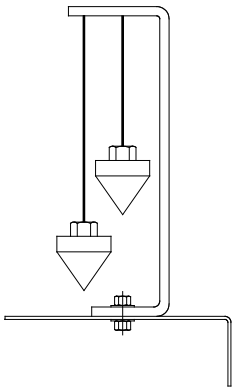


Figure 2-3

Each reference plumb is provided with two plumb line bobs hanging from strings. Mount the reference plumbs with the plumb line bobs facing the traveling telescope in the holes provided on the observation table. Apply a coat of two component water proof epoxy between the observation table and the base of the reference plumbs. Adjust one of the reference plumbs by moving it sideways and rotating it so as to align the threads of the two plumb line bobs in a straight line with the vertical line of the cross, of the telescope. Tighten the reference plumb into position. Let the epoxy set such that the reference plumb becomes an integral part of the observation table. This setting should never be disturbed.

NOTE: The reference plumb provides a permanent reference point for all future measurements. The reference plumb is fixed once and for all and is not to be moved, removed or dismantled under any circumstances at any later stage.

2.5 Taking initial reading in transverse direction

Loosen the horizontal movement coarse adjustment knob on the telescope base. Slide the telescope vertical pillar side ways so as to coarse align the vertical cross wire within the telescope barrel with the two threads of the reference plumb. Lock the coarse adjustment knob. Fine align the vertical cross wire with the reference plumbs using the right-hand side fine adjustment knob. Note the vernier reading on the horizontal scale and enter it into the log book. Next, focus the telescope to the dam plumb line and align the vertical cross wire to it. Take the new vernier reading and enter it in the log book. The

difference between the two readings represents the initial position of the plumb line with respect to the performent reference plumb.

The readings should be entered in the format given on page 4.1 of this manual under the heading "Log Book - Observation Table".

For convenience the telescope used for the transverse reading and the reference plumb opposite it, should be marked with the letter `TU'. `U' stands for upright or normal.

2.6 Taking initial reading in longitudinal direction

Repeat the procedure outlined above using the longitudinal traveling telescope and likewise enter the observations in the log book. For convenience, the telescope used for the longitudinal reading and the reference plumb opposite it, should be marked with the letter `LU'.

2.7 Dam axis shift

In the event of dam axis shift, the deflection of the plumb line can be accurately measured in both the transverse and the longitudinal directions by aligning the vertical cross wire with the reference plumb and then with the dam plumb line and noting the new vernier reading in the observation table given on page 4-1. Column D and column H will respectively give the transverse and longitudinal deflections.

2.8 Vertical Deflection

Any vertical movements in the dam structure can also be monitored by the plumb line if a suitable mark is made on the plumb line wire and appropriate readings taken.

3 INSTALLATION OF INVERTED PLUMB LINE

3.1 General

Figure 3.1 provides the general cross-sectional layout of the inverted plumb line. Figure 2.2 contains the details for fixing the observation table and mounting the telescopes and reference plumbs.

Great care should be exercised during the execution of the civil work such that after its completion no problems are encountered in the installation.

Figure 3.1 Inverted plumb line

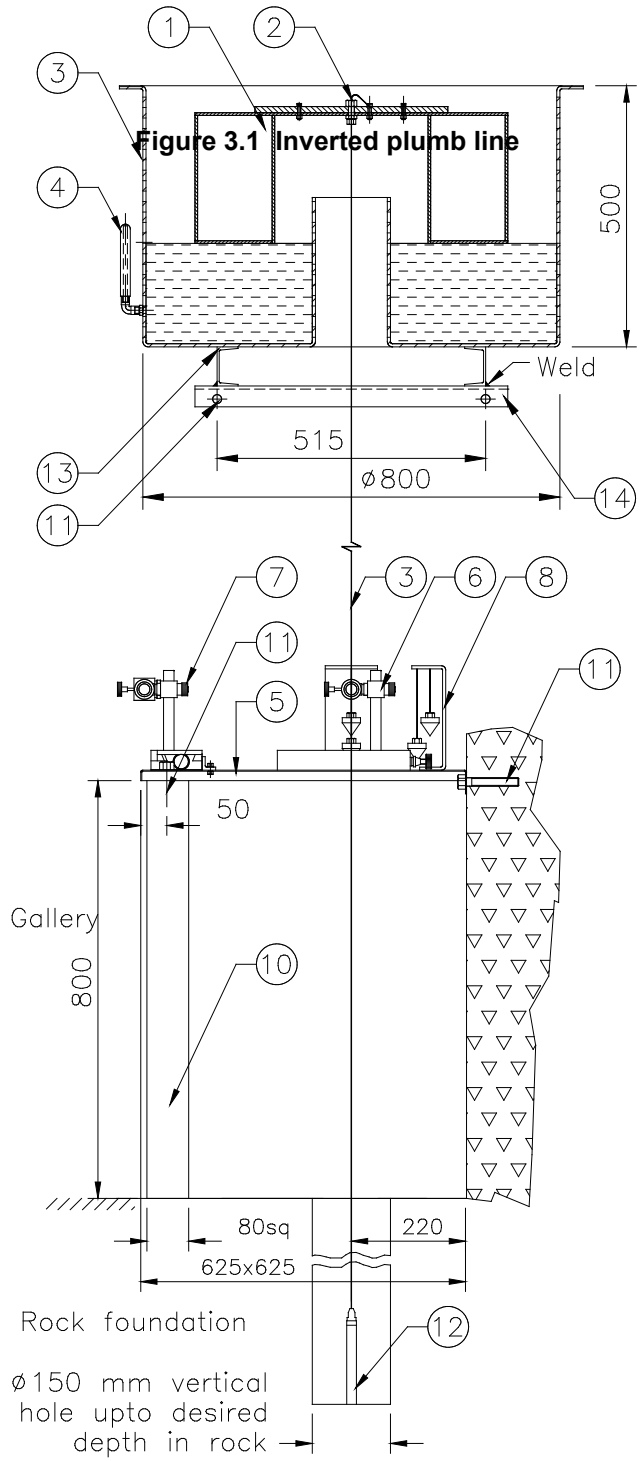


Figure 3-1

1 Float (PVC) -1
2 Collet (SS) - 2
3 Water tanks (Glass fiber reinforced)- 1
4 Water level indicator - 1
5 Observation table -1
6 Traveling telescope x-axis - 1
7 Traveling telescope y-axis - 1
8 Reference plumb - 2
9 Plumb line (SS Wire 1.0 mm ϕ)
10 Concrete support - 2 (Customer's scope)
11 5/8" BSW x 5" expansion fasteners - 8
12 Anchor (steel) - 1
13 MS angle 40 x 40 x 600 - 2
14 MS channel 75 x 40 x L - 2 (Customer's scope. Length 'L' depends upon width of observation area)

NOTE: The packed weight of the inverted plumb line (Sl. No. 1-9 & 11-13) is around 45 kg.

The concrete supports (Sl. No. 10) have to be constructed at the site. Sl. No. 14 is in customer's scope of supply as its length varies from site to site and it cannot be supplied by Encardio-rite as a standardized item.

CAUTION: Sufficient space should be available in the observation area for fixing of the water float system, observation table and for the technician to sit by the sides of the table and take the readings. It is essential that to and fro movement in the observation gallery does not get restricted. This makes it necessary to widen the observation gallery at the location where the plumb line is located. In a number of installations, the plumb line has been installed in the extra space made available by cutting the corner at the intersection of the longitudinal and cross galleries.

CAUTION: The observation table has a dimension of 625 mm x 625 mm with a 220 mm ϕ 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. Please also note that the water drum is 800 mm in diameter and in any layout the center of the water drum should be concentric with the 220 mm ϕ hole in the observation table and also the vertical hole in the dam foundation through which the plumb line passes.

CAUTION Depending upon the depth to the foundation rock from the observation gallery, a vertical hole of minimum 150 mm ϕ should be drilled into the rock foundation. Larger the depth, larger should be the hole diameter. This vertical hole which interconnects the base gallery to the foundation rock should be plumb within close limits such that the inverted plumb line in its two extreme positions does not foul with the sides of the hole. Many a hole have to be re-drilled at a close-by location or their diameters increased because the plumb line fouls with the sides during the installation itself. Even in case the plumb line does not foul with the sides of the bored hole during installation, it should have sufficient provision to take care of the deflection with time.

3.2 Installation Procedure

Complete the civil work as per figures 3-1 and 2-2. Proceed with installation of the plumb line as follows (for numbers in parenthesis, refer to figure 3-1):

3.2.1 Positioning of observation table

The observation table is provided with two side holes (center distance 450 mm) for fixing to a wall and two holes at the top surface (center distance 525 mm) for fixing to the two 80 mm square concrete columns. Position the mild steel observation table (5) on the two 0.8 m high concrete columns and prop it against the wall such that the 220 mm ϕ hole in the observation table is approximately above the vertical hole in the foundation

NOTE: Depending on the site, some modifications may have to be made from the specified installation procedure. For example, the horizontal distance of the side wall from the vertical shaft may not be 220 mm and a separate block may have to be built to firmly fix the side of the observation table.

CAUTION: The over head tank and the float are to be mounted above the observation table. They require a minimum space of 600 mm in height. It is desirable to have a space of 1-1.5m in height above the channels on which the water tank is placed.

3.2.2 Fixing of tank support channels

Hang an ordinary plumb from the ceiling of the observation area such that its center aligns with the center of the drilled hole at the bottom of the observation area. Grout two base frames consisting of 40 x 40 mm angles, 600 mm long at the requisite height on the two sides of the observation area of the inverted plumb as shown in figure 3.2 on the next page. Use a 16 mm carbide tipped drill bit to drill four 12 cm deep holes at a distance of 515 mm from each other and mount the 40 x 40 mm x 600 mm long angles with the 4 no. of 5/8" BSW x 5" expansion fasteners provided for this purpose. Position the two 75 x 40 mm MS channels across the width of the observation area on the pre-grouted base frames parallel to each other as shown in figure 3.1. The length 'L' of the channels is determined by the width of the observation area. The channels may have to be cut to size at the location. Fix the channels to the base frames by welding.

3.2.3 Positioning of water tank & float on the MS channels

Position the water tank on the fixed channels such that its center hole is approximately concentric with the 220 mm hole in the observation table below. Fill water in the tank up to a level of around 200 mm. Place the float in the water tank.

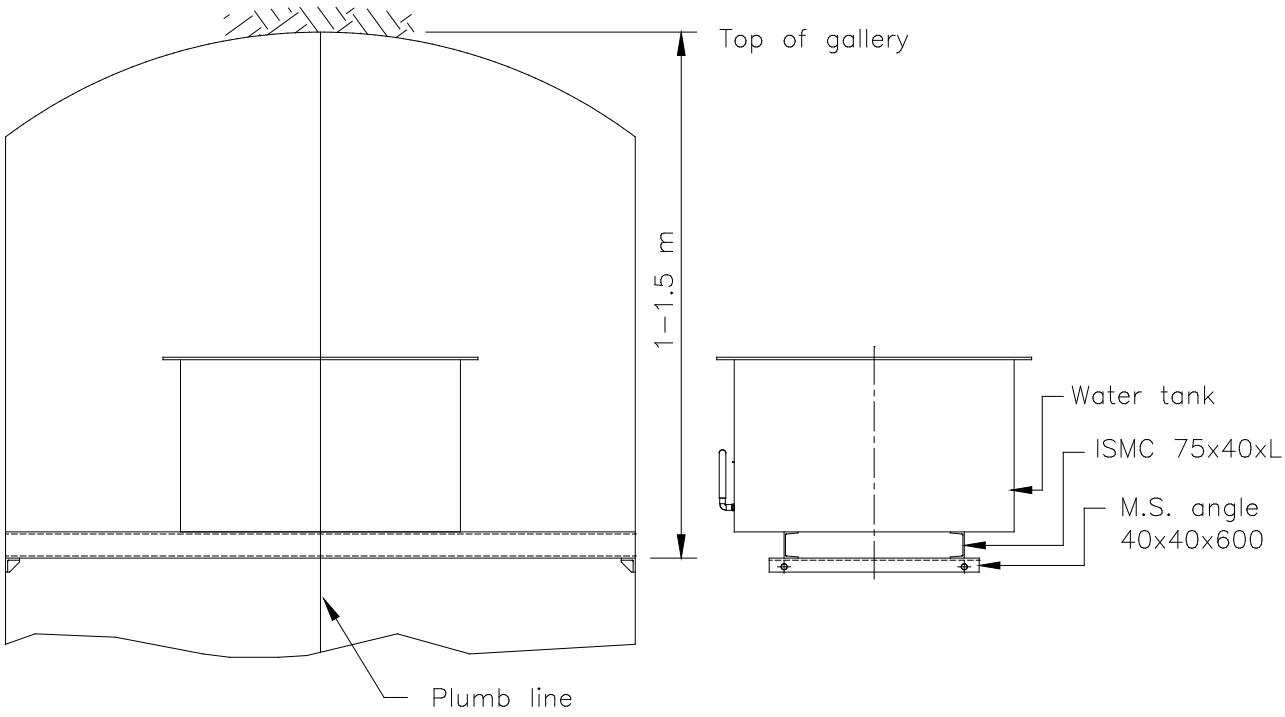


Figure 3-2

3.2.4 Lowering of anchor & fixing it in position

Determine the approximate length of the stainless-steel wire from the top of the collet (2) in the float (1) to the bottom of the drilled hole. Make an extra allowance to about 2 m and cut the wire. Thread one end of the wire through the anchor collet (12) from the collet side and secure the end of the wire firmly to the anchor screw provided on the anchor. Cut a mild steel disc of diameter around 5 mm less than the drilled hole. Fix it concentric with the anchor to its bottom by epoxy or by welding. Gradually lower the anchor with its attached disc into the vertical hole to its bottom. The disc helps in centering the plumb line in the drilled hole. Lower a PVC pipe into the drilled hole and pump in the requisite amount of mortar to set the anchor in position.

In case there is seepage of water from the drilled hole, the mortar may not set and flow out of the bore hole. In such a case use quick setting cement to fix the anchor.

CAUTION: To prevent the anchor from slipping over the plumb wire and getting lost into the bored hole, secure the end of the wire firmly to the anchor screw provided on the anchor.

3.2.5 Fixing of water tank

Pass the other end of wire through the 220 mm hole in the observation table and through the collet on the float. Tighten the collet, maintaining a tension on the plumb wire such that the float is submerged in water upto the marked level. This will result in a tension of about 8 kgf on the plumb wire. During tightening of the collet on the float use a set of spanners. Use of two spanners during the tightening of the collet is recommended to avoid any jerks or undue force which may damage the float. Tension the wire and secure it firmly around the anchor screw provided on the float. Check the concentricity of the float with the walls of the water tank. The float has an outside diameter of 600 mm and an inside

diameter of 300 mm. Make minor adjustments by shifting the water tank on the fixed channels. Permanently fix the water tank on the channels, after the float becomes concentric with the water tank.

3.2.6 Fixing of observation table

Shift the observation table to center the plumb line inside the 220 mm hole on the observation table. Align the edges of the table such that they are parallel to the two perpendicular directions in which the tilt of the dam gallery is to be measured in respect to the foundation. This will ascertain that the vernier scales on the traveling telescopes will be aligned with the longitudinal and transverse axes and will correctly measure the deflection of in the two perpendicular directions. The observation table should now be firmly grouted in place by using the 5/8" BSW x 5" expansion fasteners provided along with the equipment. Take the center markings on the wall and the 80 mm square concrete columns. Use a 16 mm carbide tipped drill bit to drill four 12 cm deep holes at the location of the mounting holes on the observation table. Two of the mounting holes are on the top of the observation table and two on the 40 mm wide side. Place the 5/8" BSW expansion fasteners (thread side outside) in the holes, one at a time and tighten them with a spanner to expand them and be firmly seated in the drilled holes. The threaded portion of the expansion fasteners should be around 20 mm outside the observation table. Firmly secure the observation table in position by using the supplied nuts and washers. Take any other necessary precautions to ensure that the observation table is firmly grouted.

3.3 Positioning, operation and care of the traveling telescopes

Refer to § 2.3

3.4 Reference Plumb Setting

Refer to § 2.4

NOTE: The reference plumb provides a permanent reference point for all future measurements. The reference plumb is fixed once and for all and is not to be moved, removed or dismantled under any circumstances at any later stage.

3.5 Taking Initial Reading in transverse direction

Refer to § 2.5

3.6 Taking Initial Reading in longitudinal direction

Refer to § 2.6

3.7 Shift in respect to Foundation Rock

Refer to § 2.7

3.8 Vertical Deflection

Refer to § 2.8

4 LOG BOOK

Observation table

Date	Sl. #	X-axis reading				Y-axis reading			
		Ref. Plumb	Plumb line	XB-XA	XC-1C	Ref. Plumb	Plumb line	XF-XE	XG-1E
	X	A	B	C	D	E	F	G	H
	1				0.00				0.00
	2								
	3								
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5 MAINTENANCE

5.1 Normal Plumb line (NPL)

- Cleaning of Telescopes must be ensured on regular basis.
- Oiling of Vernier of Telescopes must be ensured on regular basis using Machine oil.
- Screw on movable part of the telescope must be tightened before taking the readings.
- If the readings of NPL are not changing for a long time, then check Plumb wire might be touching to the walls of Vent Hole.
- Plumb bob should be fully submerged in damping oil (SAE40 grade).
- In case of seepage/ rain water, table should be protected from water.

5.2 Inverted Plumb line (IPL)

- Cleaning of Telescopes must be ensured on regular basis.
- Oiling of Vernier of Telescopes must be ensured on regular basis using Machine oil.
- Screw on movable part of the telescope must be tightened before taking the readings.
- In case of seepage/ rain water, table should be protected from water.
- Check the level of floating tank on regular basis. Level must be always kept up to the indication mark that is fabricated on gage out outside the Tank.