INSTRUCTION MANUAL

POROUS TUBE TYPE & VIBRATING WIRE TYPE PIEZOMETERS

SENSORS & MEASUREMENTS ENTERPRISES
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Vibrating wire Piezometer

I. Introduction

The pressure experienced by the water contained in the pores of earth materials, concrete structures or rock is generally called pore water pressure. In any instrumentation scheme for geotechnical or geo structural study associated with large civil engineering structures like tall buildings, dams, underground tunnels etc. measurement of pore water pressure (also known as piezometric level) plays an important part.

The study of pore pressure has two main purposes:

- The effect of water in the pores of soil of rock is to reduce the load bearing capacity of the soil or rock. The effect is more pronounced with higher pore water pressure leading eventually in some cases to total failure of load bearing capacity of the soil.
- To determine the flow pattern through earth/rock fill and concrete dams and their foundations.

1. Pore pressure measurement

a) Porous tube piezometer

The porous water measurement was started in 19th century by very simple method using porous material in a pipe and water level was measured directly by using a float and measuring tape. This technique has since been perfected. Porous tube piezometers are widely used, IS:7356(part I) on porous tube piezometer was published in 1974. SME manufactures porous tube piezometer and their accessories as per IS specification.

b) Vibrating wire piezometer

The development of vibrating wire piezometers introduced a reliable and fast method of taking pore pressure readings electrically. The cable is carried from the piezometer tip to the read out unit or data logger and is protected against any possible damage during construction.

2. Applications

SME vibrating wire piezometer is the electrical piezometer of choice as its frequency output is unaffected by external noise, it is able to tolerate wet wiring common in geotechnical applications and it is capable of transmission of signals to long distances. It has applications in the measurement of positive or negative pore pressure in soil, concrete mass or rock including:

- Construction control, stability investigation and monitoring of pore pressure in earth dams, embankments, foundations, shallow underground works and surface excavations.
- Uplift and pore pressure gradients in foundations, embankments and abutments.
- Hydrological investigation, ground water elevation study and water supply operations.
- Monitoring of pore pressure for soil improvement & stability and for slope stability.
- Monitoring & control of de-watering and drainage.

1. Operating principle

The vibrating wire type piezometer basically consists of a magnetic, high tensile strength stretched wire, one end of which is anchored and fixed to a diaphragm that deflects in some proportion to the applied pressure. Any change in pressure, deflects the diaphragm proportionally and this in turn affects the tension in the stretched wire. Thus any change in pore pressure, directly affects the tension in the wire.

The resonant frequency, with which the wire vibrates, induces an alternating current in the

coil magnet. This is read by the readout unit.

Summarizing, any variation in pore pressure cause the diaphragm to deflect. This changes the tension in the wire thus affecting the frequency of vibration. The pore pressure is proportional to the square of the frequency and the read out unit is able to display this directly in engineering units.

2. General description

The piezometer is manufactured in various capacities. Each transducer is individually temperature compensated within specified limits. Together with this, the temperature zero shift in %/°C fs is also specified for each piezometer in the test certificate provided. A thermistor is provided integrally in each piezometer to monitor the temperature and if necessary, to make the temperature correction in the zero reading.

A surge arrestor (optional) provided inside the transducer housing protects the vibrating wire pluck and read coils from electrical surge may be induced by direct or indirect lightning strikes.

a) Stainless steel body

The vibrating wire and coil magnet assembly is enclosed in a stainless steel body which is attached with the diapharagm. The magnet assembly is sealed inside the sensor body resulting the hermatically sealing and unaffected by any ingress of water and other corrosive materials that may be present in the air. As the piezometer is of stainless steel construction, it is not affected by normal chemical corrosion at locations in which it is used.

b) Ceramic filter

A high air entry value ceramic flat filter is provided. It has thickness of 3 mm and a grain size of 40 microns. The water oozing through internal pores or seams in rock formation of dam foundations, mass concrete of structures, foundation soil of structures etc. percolates through the filter to actuate the diaphragm. A locking nut holds the filter in position. For filling up the cavity behind the filter with De-aired water before installation and for saturating the filter with water.. Depending upon the application filters with different porosity and air entry values are available.

c) Cable connection

The leads from the coil magnet are terminated on a glass to metal seal which is integrally electron beam welded to the stainless steel body of the piezometer. The two pins marked red & black are connected to the coil magnet. The other two pins are connected to the thermistor. A cable joint housing and cable gland is provided for the cable connection.
Normally the piezometer is supplied without any cable attached to it. The cable jointing with the appropriate cable can be very easily done at site. However, if specifically requested, the piezometers are supplied with the requisite length of cable attached.

3. Taking readings with model 2460-P vibrating wire indicator

The model 2460-P vibrating wire Indicator is a microprocessor based read out unit for use with SME range of vibrating wire transducers. It can display the measured frequency in terms of time period, frequency, frequency squared or the value of the measured parameter directly in proper engineering units
The SME- 2490-P indicator can store calibration constant up to 100 vibrating wire transducers so that the value of the measured parameter from these transducers can be shown directly in proper engineering units.
The indicator has an internal non-volatile memory with sufficient capacity to store about 720 readings from any of the 100 programmed transducers in any combination. You can store either 720 readings from any one transducer or 7 sets of readings from all 100 transducers. Each reading is stamped with the date and time the measurement was taken.

The calibration coefficients are given in the individual TEST CERTIFICATE provided with each transducer. Refer to the model 2460-P instruction manual for entering the transducer calibration coefficients. The gage factor and the factory zero reading (frequency) can directly be taken from the test certificate for setting up transducer coefficients in the read out unit.

The stored readings can either be uploaded to a host computer using the serial interface or can be printed out of any text printer equipped with a RS-232C serial communications interface.

An interval 8 rechargeable battery cell is provided to operate the indicator. A fully charged new cells provides nearly 20 hours of operation on a single charge. A separate battery charger is provided with the 2460-P indicator to charge the internal battery from 230 VAC mains. The 2460-P indicator is housed in a light weight Aluminum enclosure and carrying case is provided for easy transportation.

4. Installation procedure

I. Preparation of the sensor before installation

a. Remove the cable jointing housing from the cable end of the sensor.

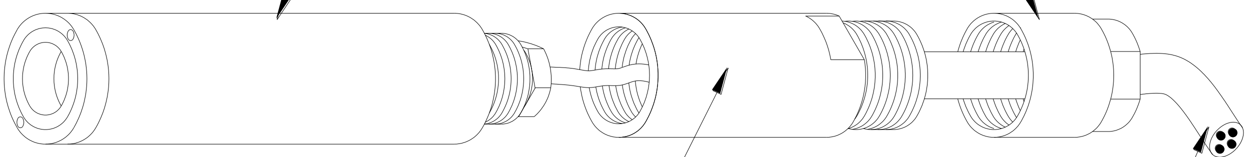
b. Check the working of the sensor as follows:

The coil resistance measured by a digital Multi meter between the red and black wire should lie between 120-140 Ohm. Determine resistance at the room temperature from thermistor temperature resistance. This resistance should be equal to that between the wire green and white. For example, in case the room temperature is 25°C, this resistance would be 3,000 Ohm.

c. Connect the sensor to the SME model 2460-P portable readout unit and switch it on.

d. Connect the required length of cable to the sensor as suggested in the operating manual on cable jointing.

e. Check the working of the sensor again following the procedure described above.



NOTE: Remember to add the cable resistance when checking the resistance between the wires after the cable jointing.

f. Boil the filter in water for about 15 minutes such that it saturates with water.

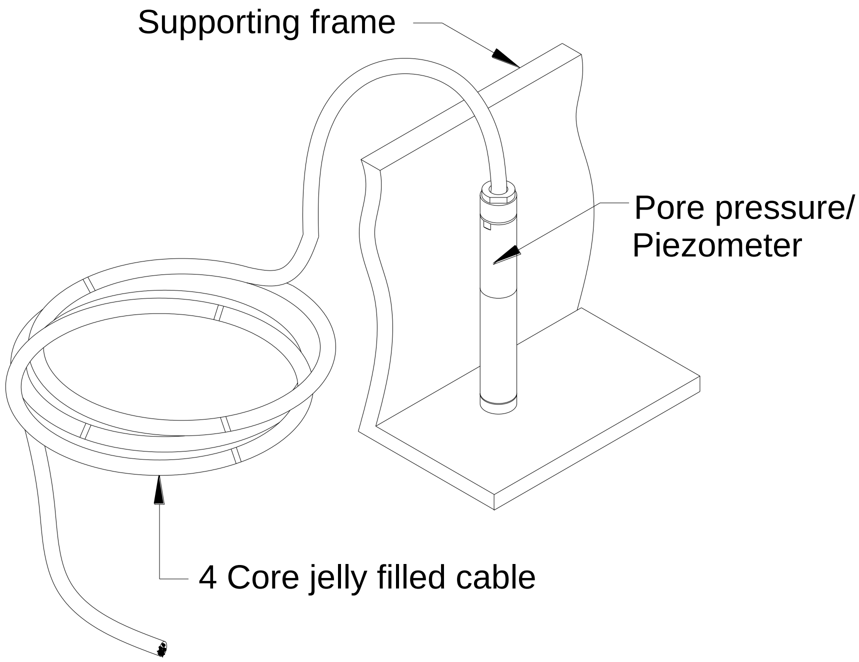
g. once saturated, attach the filter to the piezometer under de-aired water. Cooled down boiled water can be used as de-aired water.

h. Place the ‘O’ ring and filter in position in that order over the diaphragm and tighten the locking nut by the locking nut spanner. It should be made sure that the water does not leak out of the sensor when it is tilted or turned around.

CAUTION: Make sure that the de-aired water does not leak out of the piezometer. If this happens, an air lock will develop behind the filter resulting in erroneous reading of the pore pressure. In case water leaks out repeat process making sure that ‘O’ ring provided sits properly in its position and locking nut is properly tightened. In the unlikely event of not being successful and getting stuck, mount the sensor vertically with the filter at the top.

NOTE: The assembled piezometer should be bagged in de-aired water to maintain saturation until installation.

i. Cable should be marked very carefully by providing steel tags.



CABLE JOINTING FIGURE

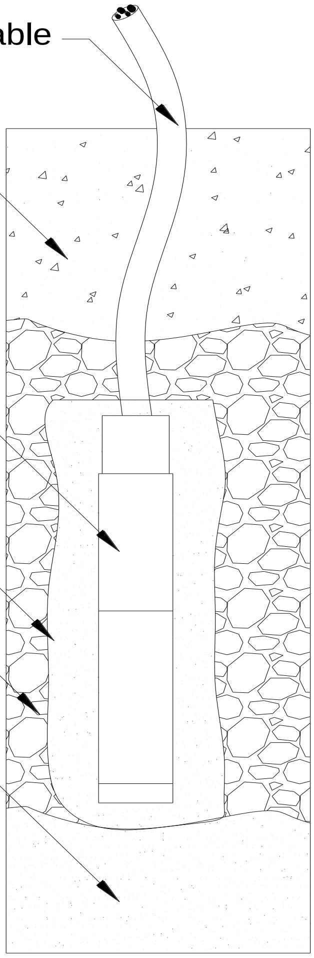
2. Installing the piezometer in the foundation

- **a.** Bore a 100mm Φ hole in the foundation rock/soil to a depth of around 50cm below the point where the piezometer is to be installed.
- **b.** In case of cased holes in soil, after the depth has been reached, the hole must be cleaned with water until the water in the hole becomes clear. This can be done by pumping the dirty water out of the hole or pouring in fresh clear water, as required at the installation. Most of the casing should be removed as installation progresses. In case this is not possible, There should be no casing in at least one meter of the depth from the bottom. In case the side walls of the hole have a tendency to cave in, the casing should be withdrawn in steps of 15 cm or less after lifts of stand are placed to support the hole.
- **c.** Fill in clean saturated sand (2-4 mm) to a height of 300 mm from the bottom of the borehole.
- **d.** Fill the cloth bag with saturated sand(2-4 mm) and insert the piezometer in it. Tie the bag at the top by pulling the string. Enclose the bag in the brass wire mesh screen and tie with the tie wire to make the assembly into a cylinder of around 75 mm Φ.
- **e.** Before lowering the sensor into the hole, saturate the sand by dipping the assembly in water.
- **f.** Lower the sensor into borehole to depth at which it is to be installed and note this depth.
- **g.** Place enough sand/gravel (2-5 mm) to cover the sensor all around and up to a height of 300 mm above the cable joint housing. Pour water into the hole to cover the sand gravel mixture with water. The purpose is to keep the surrounding material around the piezometer always saturated with water, during installation.
- **h.** Back fill the hole with cement sand grout with one part of sand and four parts of sand.

3.Installing the piezometer in the embankment

Installing of the piezometer in the embankment of earth/rock fill dams and concrete dams is a fairly simple operation. It is described in greater detail.

- **a.** The positions where the piezometer is to be mounted is carefully marked.
- **b.** Place some sand/gravel to form a plain surface in the earth/rock fill or concrete dam.
- **c.** Fill the cloth bag with saturated sand(2-4 mm) and insert the piezometer in it. Tie the bag at the top by pulling the string. Enclose the bag in the brass wire mesh screen and tie with the tie wire to make the assembly into a cylinder of around 75 mm Φ.
- **d.** Place enough sand/gravel to cover the sensor and the adjoining cable all around. Cover the sensor with enough back fill material in the case of an earth/rock fill dam. In case of a concrete dam pour concrete by a hand shovel to embed the sensor to a depth of around 0.5 m before commencing normal operation.



4. Embedment of sensor and cable laying

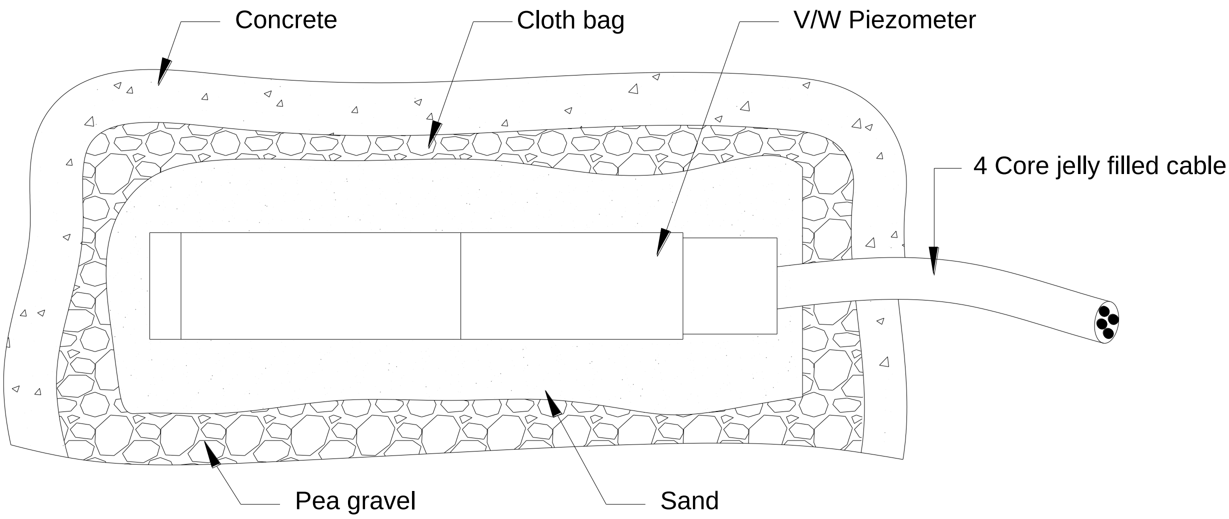
a. General precautions in the mounting of the cable

Very careful and skilled cabling is required in installation of piezometr as the sensor/cable joint and a large part of the cable is permanently embedded and no future access is available for any maintenance and corrective action.

The procedure for laying of cables differs with individual installations. In general, however all installations have the following common requirement:

- The cable must be protected from damage by angular and sharp particles of the material in which the cable is embedded.
- Cables may be spliced without affecting the sensor reading; nevertheless splicing should be avoided wherever possible. If necessary use special cable jointing kits available from the factory.
- In earth and rock embankment and backfill, the cable must be protected from stretching as a result of differential compaction of the embankment. The cable must also be protected from damage by compaction equipment.

Precaution must be taken that the tables are properly tagged, onward from the point from which they come out of the dam with the best possible precautions, mistakes may still occur. Tags may get lost due to the cable getting accidentally cut. SME uses the convention that looking from the end of the trench towards the sensors, the cable from the most distant sensor is always at the left hand side and the offset trenches are to the right of the cable trench. In that order, the cable from the closest sensor is at the extreme right.

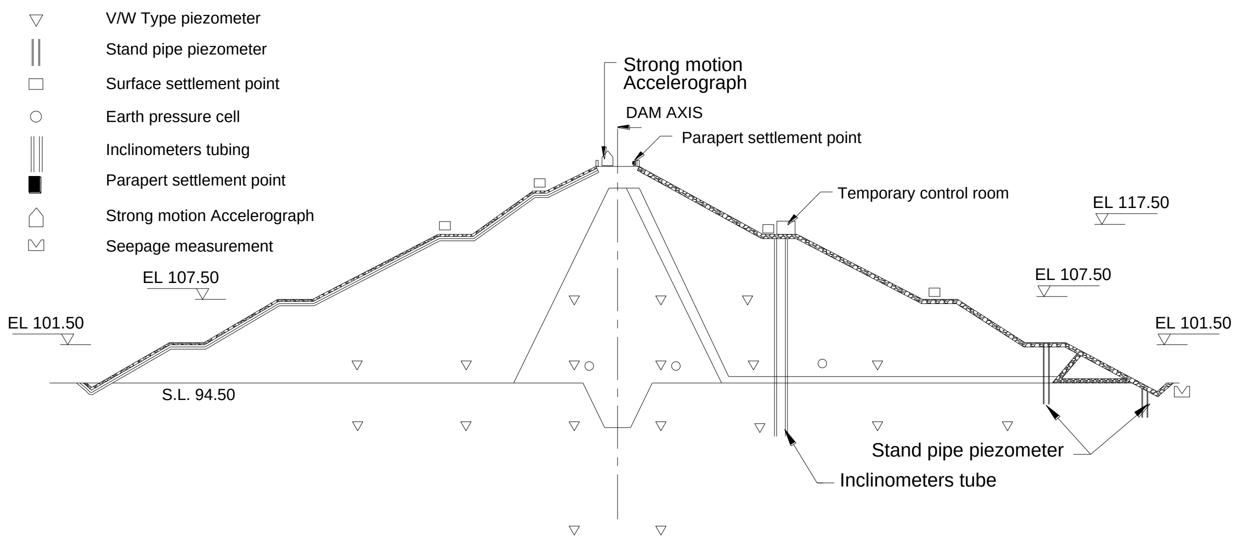


NOTE: A simple code for remembering this is “LL-SR”. Longer (cable) left, shorter (cable) right when viewing the sensors from the observation room.

CAUTION: All cables should be properly identified by tagging them every 5 m, onwards from the point from which they come out of the dam body. The tags should be of a non- corrosive material like stainless steel or plastics.

b. Earth and rock fill dams

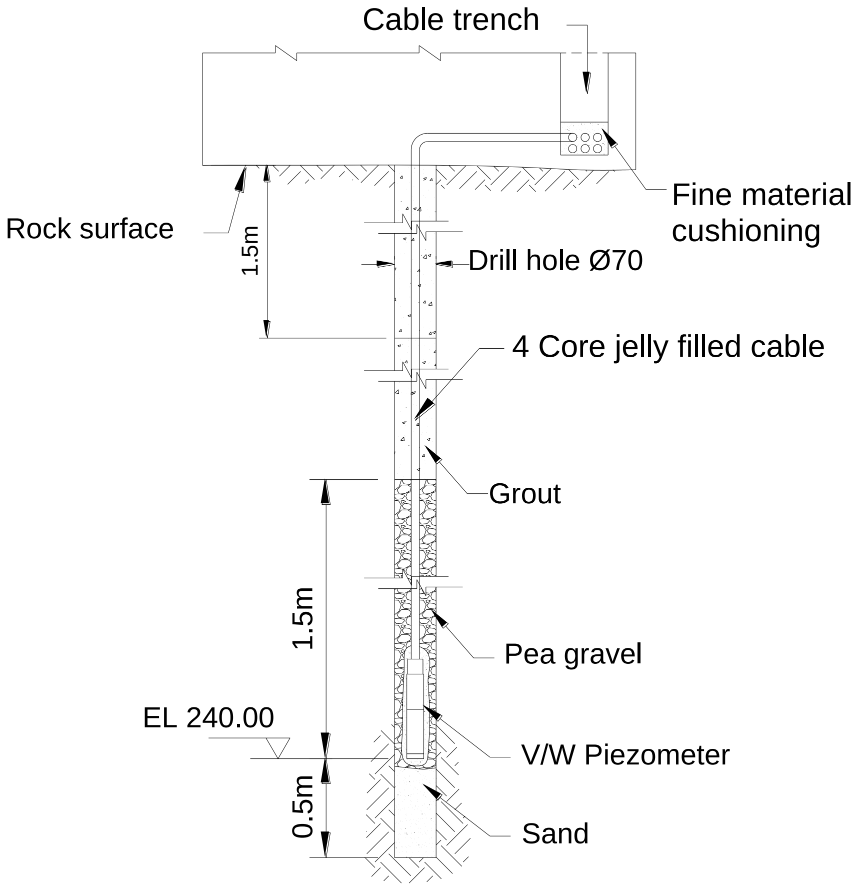
In this, a number of piezometer and may be other sensor are installed at selected elevations at different cross sections. Monitoring of readings from group of piezometers installed at different elevations help in determining the phreatic line and give and indications on how it advances with time till steady state conditions are reached.



EARTHEN DAM INSTRUMENTATION

At any cross section the filling of the dam is allowed to continue to and elevation of around 0.5 to 1m higher than where the piezometer are to be mounted .the position where the piezometers (whether foundation or embankment) are to be mounted, are carefully marked. Offset trenches (around 1mX 1m) to reach the correct required elevation are dug at these positions.

The material around the sensor should be placed by hand shovel and compacted with a light duty pneumatic or petrol backfill tamper. The first layer of material over the sensor should be 250 mm high and compacted properly. Similar layers of material should be put over this and compacted properly until at least 500 mm of material has been placed. Rubber tired equipment can now cross this location, but no vibratory rollers should be permitted over the sensor until a compacted thickness of at least 1 m is laid.



FOUNDATION TYPE

In case foundation piezometers are to be installed at any of these locations, the necessary boring is done to the required depth.

A cable trench around 400-800 mm wide and upto 500 mm is dug along the offset trenches. The depth and width depends upon the no. of cables the trench has to carry. Based upon the cable layout designed, the trench runs into the abutment and then along the abutment to the downstream side or directly to the downstream side towards the observation room. These cable trenches carry the individual cables from the piezometers to the observation room.

Before laying the cables, the trench should be properly cleaned and leveled with 30 mm of fine sand at the bottom of the trench along the path. Any sharp rocks should be removed to prevent the cable from accidentally getting damaged. The center distance between successive cables should be kept at a distance of 25 mm with the help of the wooden cable spacer provided. A distance of 100 mm must be left free from the sides of the trench. To take care of any increase in length due to settlements, the cable should be zig zagged by providing a uniformly distributed slack of around 0.5 m in a 15 m length of each cable.

In embankments, the sensor and cables may be embedded in a protective covering Of sand or selected fine embankment materials. A typical installation might, for Example comprise the positioning of a series of sensors and cables on a prepared Layer consisting of not less than 100 mm of compacted selected fine material. In

order to establish an acceptable grade without undue interference with construction operations the prepared layer may be located either in a trench or an exposed ramp.

In rock fill dams with earth fill cores, for example, it is frequently convenient to install the sensors and the cables in trenches in the core and fine filter zones and in ramps in the coarse filter and compacted rock fill shell zones. In an earth embankment it is convenient to install in a trench. By doing so, adequate degrees of compaction of the backfill can be more easily obtained without damage to the sensor or the cable trench. As the sensors and cables are being covered and compacted repeated readings should be taken to ensure that they are continuing to function properly.

NOTE: In case of an earth dam before packing the trench with backfill, a plug approximately 100 mm thick, made of a mixture of 5% detonate (by volume) exhibiting a free swell factor of approximately 600%, and 95% sand should be placed in the trench at intervals of approximately 10 m.

C. Concrete Dams

As access galleries are available in concrete dams, the cable from the sensors is first routed to the gallery. These cables may be terminated in junction boxes inside the gallery. The data from the various sensors can be taken or logged from the junction boxes with the help of a readout unit or data logger. Alternatively, if required, the signals from the junction boxes may be carried through multi core cables to any observation room outside the dam structure.

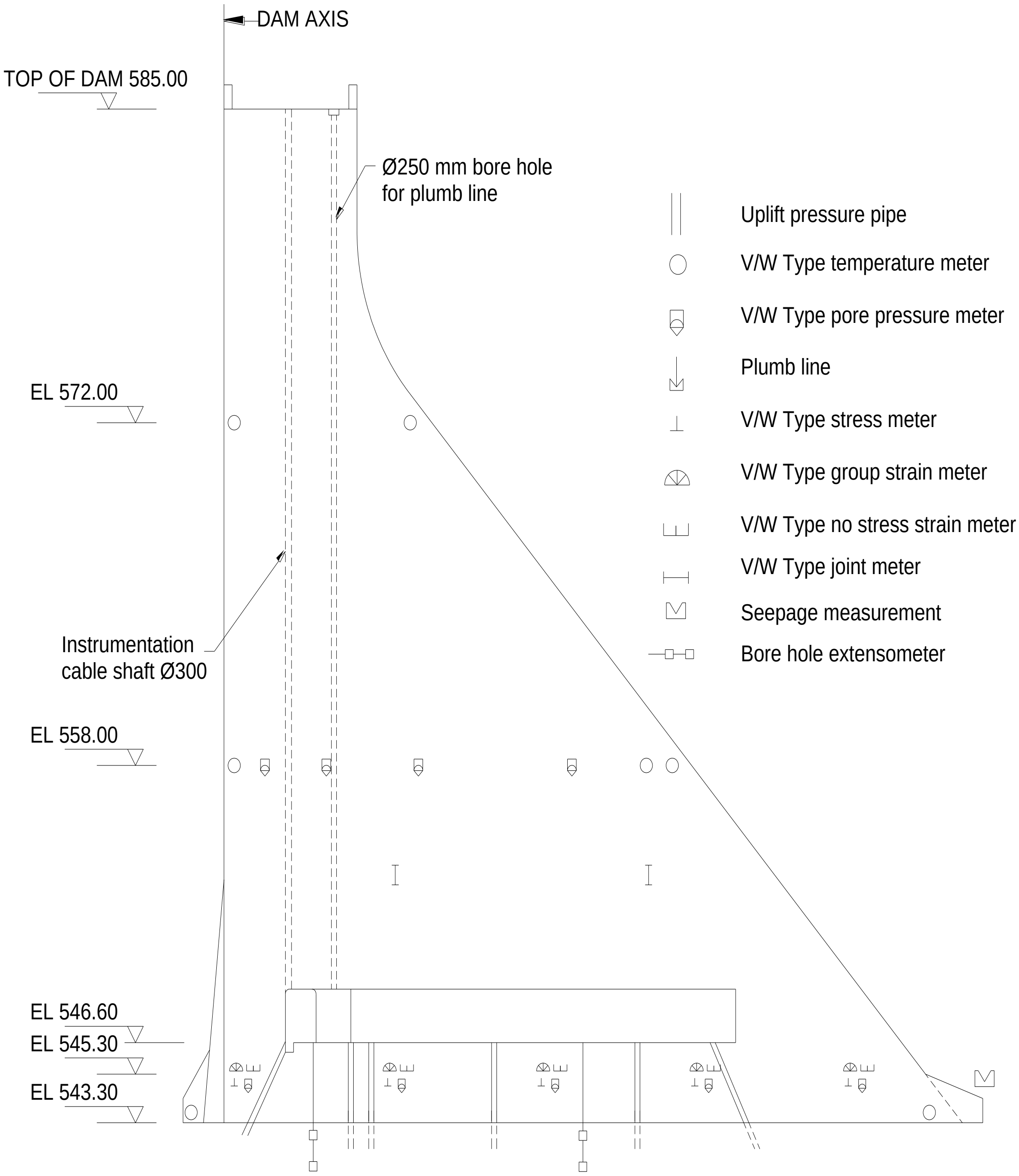
In a concrete dam, a number of piezometers along other sensors are installed at selected elevations at different cross sections. For example, three piezometers, five strain rosettes, five no stress strain containers, five stress meters and two temperature meters are installed at elevation 132 m. cables from these sensors have to be taken to junction boxes to be mounted inside one of the cross galleries. the gallery may be above or below the elevation at which the sensors are to be installed. As a general practice, all the cables from sensors at any particular elevation are routed to a vertical shaft on the upstream side of the dam. The cables are then lowered or lifted through the vertical shaft to the gallery.

At any cross section, the filling of the dam is allowed to continue to an elevation of around 25 cm higher than where the sensors are to be mounted, leaving 0.5 m X0.5mX 25 cm deep trenches at the positions where the sensors are to be placed. Larger trench may be left in case the piezometer is to be installed along with other sensors, specially the strain rosette and the no stress strain meter that the require more space. In case the latter are to be mounted along with the piezometer, The cable from the sensors should be routed through a carefully marked channel trench ending into the vertical shaft and running parallel to the line of the sensors. The depth and width of the channel trench depends upon the number of cables the trench has to carry. In case all the cables an elevation fit in one row, the depth of the channel can be around 10 cm. If more than one row is required to lay all the cables, the depth should be increased by 10 cm per row before laying the cables, the channel trench should be properly cleaned and leveled. Any sharp rocks or objects should be removed to prevent the cable from accidently getting damaged. The center distance between successive cables should be kept at a distance of 25 mm with the help of the wooden cable spacer and cable rake provided. To take care of settlement effects and temperature effects during concrete setting, the cable should be zig zagged by providing a uniformly distributed slack of around 0.5 m in a 15 m length of each cable. After laying the cable in any row, it should be covered with concrete by a hand shvel to a depth of around 10 cm and allowed to set. This is necessary to prevent any accidental damage to the cables.

To make doubly sure that some of the precautions in the laying of the cable are definitely followed, they are being repeated in the following few paragraphs.

Precaution must be taken that the cables are properly tagged, onward from the point from which they come out of the dam into the vertical shaft. With the best possible precautions, mistakes may still occur. Tags may get lost due to the cable getting accidentally cut. SME uses the convention that looking from the vertical shaft end towards the sensor, the cable from the most distant sensor is always at the left hand side and the offset trenches are to the right of the channel trench. In that order, the cable from the closest sensor is at the extreme right.

CAUTION: All cables should be properly identified by tagging them every 5 m or closer, onwards from the point from which they come out of the dam body into the vertical shaft. The tags should be of a non-corrossive material like stainless steel or plastics.



CONCRETE DAM INSTRUMENTATION

6. Observation Sheet

Model SME 2460-P Readout Unit

Sl. #	Date	Sensor no. Location E.L.	Sensor no. Location E.L.	Sensor no. Location E.L.	Sensor no. Location E.L.
		Stress in kg/cm2	Stress in kg/cm2	Stress in kg/cm2	Stress in kg/cm2
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					
11.					
12.					
13.					
14.					
15.					
16.					
17.					
18.					

6.1. Frequency of observation

There is no fixed rule on frequency of taking readings. Pore pressure readings will be taken after completion of Dam work or other work. The frequency of taking readings will be increased during the full water level in the dam or other location.