NOTES ON THE INSTALLATION, READING AND DATA PROCESSING OF MERCURY MANOMETER TENSIOMETERS, GYPSUM BLOCKS AND THE NEUTRON PROBE SYSTEM

Hillslope Processes Group Working Paper No. 2

M.G. Hodnett[A] and N.J. Schofield[B]

[A] Soil Hydrology Section, Institute of Hydrology, Wallingford, U.K.

[B] Water Resources Branch, Public Works Department of W.A.

(Not to be referenced without permission of the authors)

Report No. W.R.B.

May 1985

CONTENTS

MERCURY MANOMETER TENSIOMETERS

1.1 Tensiometer Installation

Types of installation

Tensiometers may be installed either (a) at the same depth across an area in order to monitor spatial variability of potential or (b) at regular depth intervals to monitor the hydraulic potential gradients in the soil profile at a given location.

In the case of (b) the tensiometers should ideally be located one above the other to minimise the effects of spatial variability when measuring vertical potential gradients.

This may be achieved by:-

i) Using tensiometers where the cups are in the form of annular 'sleeves' fitted on a single 'stem'. These types usually suffer from a small contact area per cup and the risk of leakage down the hole affecting all of the cups. However, only one or two holes are required.

ii) Installing a series of individual tensiometers at an angle (using a jig) so that their cups form a vertical profile (Fig. 1). This can be a fairly complex and difficult procedure.

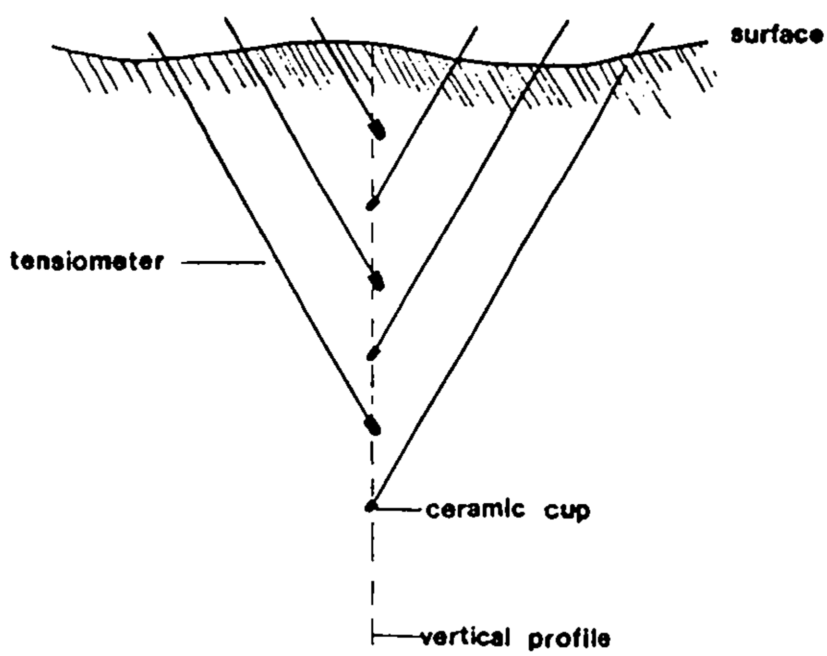


Figure: 1 Inclined installation of tensiometers

A frequently used compromise is to install the tensiometers in tight groups, for example in a 3x4 array with a 0.2 m spacing.

Notes.

1. Depth of placement. For convenience and ease of data handling, the installation depth of tensiometers forming a profile should be measured from a common datum rather than the ground level at their individual location points. This is particularly important when potential gradients are required and when water table depths and high potentials (close to saturation) are to be measured. The datum chosen could, for example, be the ground level at a particular tensiometer, or at the base of the manometer board.

   During installation work, a builder's spirit level can be used to assist in the location of tensiometers at the required depths relative to the datum. If the required depth cannot be reached exactly, the actual depth relative to the datum should be recorded.

   Since tensiometers installed from the surface measure total potential, the matric potential component that can be measured decreases with depth. For example, if full scale is - 800 cm H_2O, a tensiometer at 4.0 m (400 cm) can only measure matric potentials down to -400 cm H_2O.

   This limitation can be avoided by installing the tensiometers at an angle from the walls of a pit and having the manometers in the pit. Data can be corrected to a datum at the surface.

2. The depth of placement should be measured from a consistent position on the cup. This is usually the centre of the cup or the tip. The depth of the installation hole should be adjusted accordingly.

3. The tensiometer cups should be wetted before placement. This can be achieved by standing them in a bucket of water so that the water soaks through the cup in one direction only.

4. During installation and when making observations or maintaining the tensiometers, the ground surface at the site should be protected from disturbance. Any disturbance to vegetation should also be minimised. On rehabilitation sites, it is advisable to install equipment before planting.

5. The porous cups should be kept clean and handled as little as possible to avoid clogging the pores and reducing the cup conductivity and effective surface area.

Installation method

A diagram of a tensiometer installation is shown in Fig. 2.

For installation at depths of less than about 1 metre (in amenable soils) tensiometers can be installed directly in holes of the cup diameter, augered from the surface.

In general however, installation is easier if a larger diameter hole (e.g. 45 or 50 mm diameter) is drilled to 20-25 cm above the required location of the tensiometer cup. The technique used to install neutron probe access tubes is generally used. The hole is then 'cased' with a length of tubing (of diameter the same as that of the hole - to avoid preferred paths down the outside) which should be pushed firmly into position to leave about 50 mm above the ground surface.

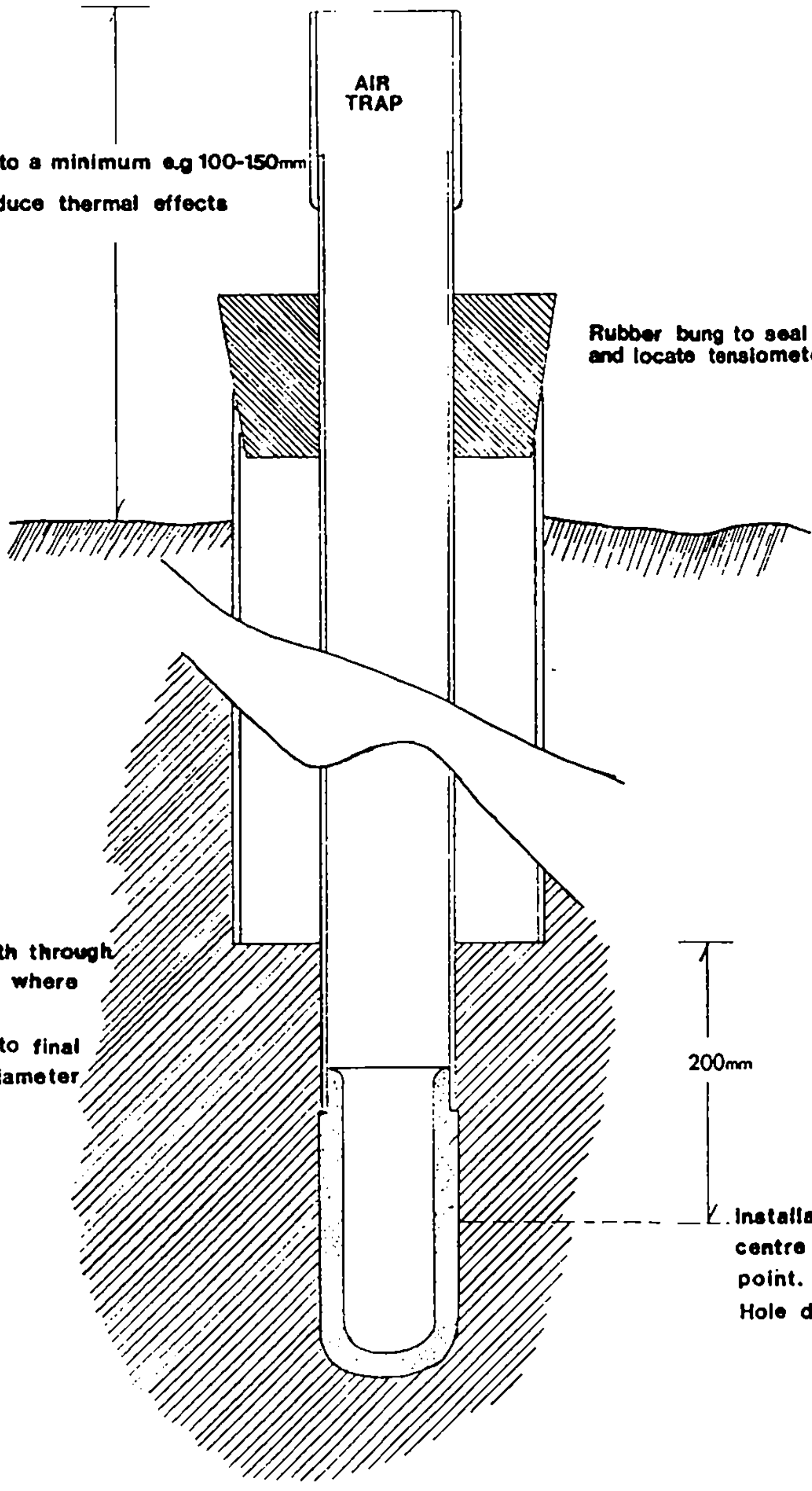
A hole of the tensiometer cup diameter is then augered (or cored or punched with a rod) to the final depth. It is advisable to make the hole 10-20 mm deeper than the final depth to allow room for debris pushed in front of the cup when it is fitted into place.

If the material is not amenable to augering or coring at about 22 mm diameter for the cup, the hole can be drilled to the final placement depth at the larger diameter. It is then backfilled 25-30 cm and the casing is installed to bed in on the backfill. The backfill material may be the ground and sieved material extracted from the hole, or a material whose pore size distribution is close to, or finer than, that of the surrounding material. If the material is dry, it may be damped to increase cohesion and allow a hole of the cup diameter to be made (as above) to the final depth.

Before the tensiometer is pushed into place, a large rubber bung (to fit the casing tube) with a central hole of diameter about 1 mm less than that of the tensiometer stem is pushed over the cup and slid up the stem (see Fig. 2). The installation depth should be marked on the stem to allow fairly precise positioning. The tensiometer is then pushed to the correct depth. If some difficulty is encountered, it may be withdrawn and the hole reamed carefully, before trying again. The large bung is then slipped down the tensiometer stem and pushed firmly into the casing tube. If such bungs are not available, a rubber disc can be used instead. This should be a tight fit on the tensiometer stem and make contact with the casing tube walls. This is pushed about 20 mm below the casing top and the space above it is filled with silicone rubber (e.g. silastic).

Manometer board

The manometer board should be mounted vertically and rigidly on a suitable stake so that the reservoir is 350-450 mm above the ground surface. This makes the scales easier to read when



gure: 2
t to scale

Vertical Tensiometer Installation

readings are low and reduces the likelihood of soil debris being splashed into the reservoir. Spacers are provided to keep the board away from the stake and allow room for the manometer tubes. The board should be set up so that it never receives direct sunlight on the face. Alternatively a tall box with a door can be fitted over the manometer board to protect it from the sun. (See thermal/solar protection, below).

Connecting the manometers

Cut the nylon manometer tubing to the required length. (Enough to reach from below the reservoir to the top of the board, down the board to the ground, along the ground and up to the tensiometer, allowing for about 150 mm inside the tensiometer body).

Push one end through the small hole in the No. 23 bung (from the top) so that the end extends 100 mm below the bung. Slip the required length of opaque tubing (see thermal protection) over the nylon tube which will be exposed to the sun.

If the nylon tubes are to run across the ground, they can be threaded through a length of rigid tubing (25 mm electrical conduit is suitable) to protect them from the sun (and boots and rodents). A similar tube can be used to guide the tubes up the back of the manometer board.

Feed the nylon tube over the top of the board from the back and then down the face of the board under each of the tube clamps. These should be fixed loosely at this stage. The tubes should not be put into the reservoir yet.

LABEL EACH NYLON TUBE with the tensiometer number just above the no. 23 bung. The tensiometers should also be clearly numbered. This is to eliminate the possibility of accidentally swapping the manometers between tensiometers, for example during purging, when replacing tubes or when repairing damage. Manometer swaps such as this are a headache to track down and correct in the data.

Once all of the tubes have been threaded, carefully pull them taut (from the bottom) and tighten the tube clamps. This can be done in stages, from the top down and from left to right.

Adjust the reservoir to approximately the correct zero position (Fig. 3). This can be found from:-

$$L \sim h/12.5 + 10 \qquad (1)$$

where h is height of scale zero above the chosen datum in mm

L is the distance (mm) from the reservoir base (above the holes) to zero on the scale on the board

10 mm is the approximate depth of mercury above the holes.

Cut the tubes (at an angle) to the length required to extend about half way into the holes in the reservoir base. Put the tubes into the holes, one per hole.

Setting up the mercury reservoir and scale zero

Fill the reservoir with mercury to about 10-12 mm above the manometer tube holes in the bottom. Remove the bung from the top of a tensiometer and fill the manometer tube with water, using a syringe, until water appears on top of the mercury.

Fill a beaker with water and place it so that the water surface is at the chosen datum level.

Place the full manometer tube in the water (make sure there are no bubbles in the line).

The mercury reading on the manometer board should be at scale zero. If it is not, loosen the reservoir screws, which fit through slotted holes in the reservoir back, and adjust the reservoir so that the mercury level in the manometer is at zero on the marked scale. If there is not enough adjustment, mercury can be added to, or removed from the reservoir to bring the manometer reading to zero.

If a zero setting cannot be attained, the distance from the mercury level in the manometer to the scale zero should be measured. This distance is the 'zero set' correction and is used to correct the mercury readings before they are converted to potentials. (See notes on data processing). The correction is +ve if the mercury level is below the scale zero and -ve if above.

Thermal/solar protection

The nylon tubing gradually becomes embrittled by UV in sunlight and it is advisable to sheath it by passing it through an opaque flexible tube of slightly larger diameter. The manometer board should ideally face North to avoid direct sunlight on the face.

Sudden heating of the water in the tensiometer body can cause short term changes in the manometer readings due to expansion. The length of tensiometer extending above the ground should be as short as practicable (e.g. 100-150 mm) to reduce the volume of water affected. The body of the tensiometer can be insulated using a sleeve of white PVC tubing (~50 mm OD) lined with insulating material and slit up the side to allow the manometer tube to pass through. A cap is fitted over the top.

Mercury traps

A trap can be fitted on the end of the nylon manometer tube where it hangs down inside the tensiometer body. The trap prevents any mercury which finds its way to the top of the manometer from filling the porous cup of the tensiometer.

The trap consists of a glass or plastic sample vial about 12 mm external diameter and 40 mm in length with a snap-in or screw-on cap. Two holes are made in the cap. The nylon manometer tube passes through one and it must be a tight fit. The other is left open as a vent. A short section of neoprene tubing can be slipped over the nylon tube on the inside of the cap to prevent the tube pulling out. In use the trap is checked when the tensiometer is purged and any mercury present is removed. When the trap is replaced in the tensiometer, care must be taken to ensure that there is no air trapped in it.

1.2 Purging

Purging method

Purging, or removing air bubbles from the air trap and manometer tube, should be done if there are more than a few tiny (e.g. 2 mm diameter) bubbles in the system. Air in the system slows the response time. When readings are low, up to about 250 mm Hg, purging is not required very often (once a fortnight may be sufficient), but when readings are higher, more frequent purging is necessary. However, very frequent purging may disturb the soil system so it should be limited to about twice a week.

To purge:-

1. Remove No. 9 bung from purging hole in No. 23 bung in the top of the tensiometer;

2. Remove No. 23 bung;) This procedure helps to eliminate all bubbles from the air trap.

3. Fill tensiometer brim full;)

4. Carefully replace No. 23 bung.)

5. Insert full syringe (with adaptor No. 9 bung) in purging hole and gently force water into the tensiometer. 15-20 ml should be sufficient to clear the manometer. Check to see if it is free of bubbles.

   N.B. Pour de-aired water carefully to minimise re-aeration. Ensure that there are no bubbles in the syringe.

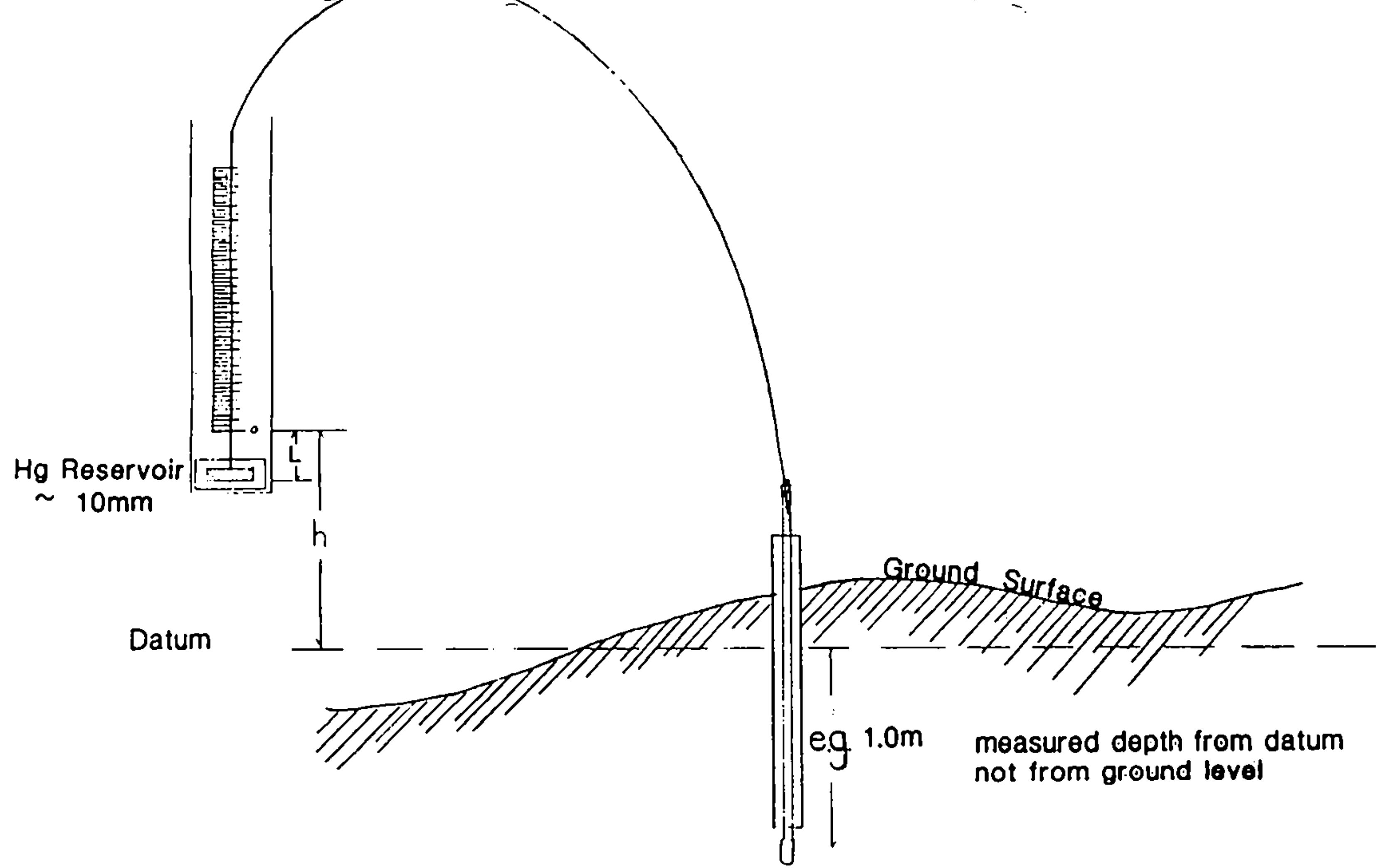


Figure 3: Setting Up Mercury Reservoir And Scale Zero

6. Remove syringe, top up the No. 9 hole full and insert the No. 9 bung making sure that there are no air bubbles trapped.

7. Repeat for all tensiometers in the set.

8. When finished, note the time on the field sheet and/or in a field diary. If the entire set has not been purged, note which ones were done.

Making readings after purging

The tensiometer response time is the time taken to attain an equilibrium reading after a given change in potential. The time taken to attain equilibrium after purging (the recovery time) may be very long - up to 24 hours or more.

The response time depends on:-

1. The sensitivity of the pressure sensor. In the case of the manometer, it is the volume/unit length of the tubing used. (In this case, about 2.6 ml/m).

. The properties of the cup:
   a) Wall thickness
   b) Conductivity of the ceramic
   c) Surface area

3. Contact area with the soil. Good contact is essential to minimise response time.

4. The conductivity (K) of the soil surrounding the cup. K is a sensitive function of θ, the moisture content and ψ_m, the matric potential. Over the full scale of a tensiometer (0-850 cm H_2O) the conductivity of most soils falls by up to 3 orders of magnitude.

1 and 2 are fixed by the tensiometer/manometer design. 3 must be dealt with at the time of installation.

4 must be taken into account by allowing the maximum possible time for recovery. As a rough guide, when readings are below ~250 mm Hg, recovery in most soils will occur in 2-3 hours, but when readings are 400-500 mm Hg, it is advisable to leave at least 24 hours recovery time before reading. Ideally, leave them as long as is practicable. When potentials in the soil are very low, the tensiometer readings will increase gradually to a maximum over several days and then fall, as air comes out of solution. The mercury columns may also break up and are then difficult to read. Readings taken a week or more after purging may not therefore be reliable. If the mercury columns break, some mercury may be drawn through the nylon tube into

the tensiometer, in which the case mercury traps would be required to prevent mercury filling the porous cup.

In practice, it is advisable to read and then purge the tensiometers immediately after arriving at the site, make all the other readings, chart changes, checks etc. and then, just before leaving the site, read the tensiometers again. An alternative method is to purge the tensiometers on one day and read them the next. If the tensiometers are obviously 'off-scale' and no significant rainfall is expected, they can be emptied with a syringe and length of flexible tubing. The tensiometers can then be refilled when the soil has rewetted or is about to rewet.

The time of purging should always be recorded on the field sheet and it is valuable to use an 'error code' e.g. 0, 1, 2, 3 to describe the state of the tensiometer at the time of reading. This is a very useful aid to subsequent data analysis and checking. (0 = no air, 1 = a little air in lines and trap, 2 = air trap half empty and Hg column broken, 3 = not working).

1.3 Time of observations

Ideally, this should be done at the same time each day. This is because there is often a diurnal fluctuation in the readings. These fluctuations may reflect real potential changes arising as a result of moisture abstraction by roots, or they may be caused by thermal effects perturbing the readings.

In heavy soils, or those with impeding layers, the readings of tensiometers below these layers may show the effects of changes in atmospheric pressure. In highly permeable soils, the air pressure in the soil equilibrates very quickly with atmospheric pressure changes and readings are not affected.

1.4 Data processing

The tensiometer depths should ideally be measured from a datum at the ground surface close to the set of tensiometers. The data (mm Hg) are then converted to total potential (ψ_T) expressed in units of centimetres of water relative to that datum.

$$\psi_T = - 1.256\ (h+c) \qquad (2)$$

where h is the reading in mm Hg and c is the 'zero set correction'. When the tensiometers are set up in the manner described above, c should be zero.

The matric potential is calculated from:-

$$\psi_m = \psi_T - z \qquad \ldots (3)$$

where z is the depth (-ve) of the tensiometer cup below the datum.

The tensiometer data may be presented in the form of a table:-

Date: 080884 Time: 1230 Obs: MGH Purged 070884/1600

No.	Depth (m)	Reading (mm Hg)	Total potential (cm H_2O)	Matric potential (cm H_2O)	Potential gradient (cm H_2O/cm depth)	at Depth (m)
1	0.2 0	120	-150.7	-130.7	1.26	0.3
2	0.4 0	140	-175.8	-135.8	1.46	0.5
3	0.6 1	163	-204.7	-144.7		