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QUESTIONS AND ANSWERS ABOUT TENSIOMETERS

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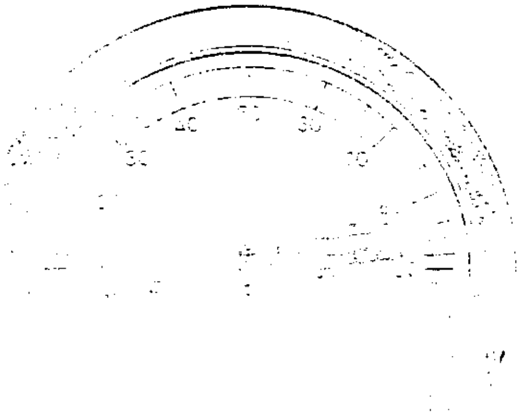

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QUESTIONS and ANSWERS ABOUT TENSIOMETERS and Their Use

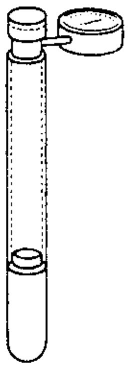
Many California growers are using tensiometers to inform themselves about the soil-water status in the root zones of growing crops and as a guide for regulating irrigation practices. Other growers have questions they would like answered before trying tensiometers. This leaflet presents questions frequently asked and the answers that most often apply.

1. HOW DO TENSIOMETERS WORK?

The tensiometer is a closed tube filled with water. A hollow ceramic tip is sealed to the bottom, and a stopper closes the other end. A gauge or device for measuring vacuum is attached next to the stopper. The tube is installed in soil with the ceramic tip placed where a soil-water measurement is desired. The tube is usually long enough for the stopper and gauge to remain above ground for servicing and reading.

As the soil dries, it sucks water out through the porous wall of the ceramic tip, creating a partial vacuum inside the tensiometer that can be read on the vacuum gauge. This power of the soil (soil suction) to withdraw water from the tensiometer increases as the soil dries and the gauge reading rises.

When the soil is irrigated, soil suction is reduced and water is drawn back into the tensiometer by the vacuum. This reduces the vacuum and the gauge reading is lowered.



A tensiometer.

2. WHAT DO THE READINGS MEAN?

The readings show the relative wetness of the soil. A high reading is caused by a dry soil (having a high suction) and a low reading by a wet soil (having a low suction).

Most tensiometer gauges are calibrated with graduations from 0 to 100 called centibars. One hundred centibars equal one bar—a unit of pressure used by meterologists, that is about equal to a standard atmosphere. A tensiometer can operate within a range of 0 to 80 centibars.

A reading of 0 indicates a saturated soil in which plant roots will suffer for lack of oxygen. From 0 to 5 is too wet for most crops. Readings in the 10 to 25 range represent ideal water and aeration conditions. As readings go higher than 25, water deficiency may occur for sensitive plants or plants having shallow root systems, including potted plants or plants growing in coarse-textured soils. Most field plants having root systems 18 inches deep or more will not suffer for lack of water before readings reach the 40 to 50 range. In medium-textured soils, plants having good root systems 2½ feet deep or more usually will not suffer shortage of water before readings reach 70. In medium to moderately fine-textured soils, plants having well-developed deep root systems may not need irrigating for several days after readings pass 70.

A reading of 80 represents a soil-water condition dry enough to warrant irrigation under most conditions, even though the plants show no symptoms of stress.

These interpretations apply to readings obtained at about the midpoint of the principal root mass.

3. ARE TENSIOMETERS ACCURATE?

Within their working range, tensiometers are more accurate than any other means of evaluating relative wetness of soil (soil-water condition). As with any mechanical device, malfunction can occur.

A malfunctioning instrument does not give accurate readings; but malfunction is usually easy to detect (see question 18), so that you need not be misled. Frequently, a reading remains high after irrigation when the soil should be wet. This sometimes is mistakenly thought to be tensiometer malfunction. Many checks of such situations showed that the irrigation water had not penetrated as deeply as expected, and the instrument was giving an accurate reading of the soil-water condition at its tip.

Some coarse-textured soils create poor conditions for accurate tensiometer response. Root distribution and capillary movement of water in such soils are poor. As a result, the soil immediately surrounding each rootlet may become drier than the soil not touched by rootlets. The tensiometer can indicate only the average moisture condition of all the soil it touches. Growers compensate for this by irrigating coarse soils at lower readings.

4. HOW LONG AFTER INSERTION CAN A READING BE OBTAINED?

Twenty-four hours is usually enough time to obtain a reliable reading after installation. If the soil is dry at installation, an irrigation is necessary before satisfactory readings are obtained. Under favorable soil conditions, a correct reading may be obtained in 15 to 30 minutes with a new tensiometer. Specialty tensiometers having rapid cup reaction will provide a suitable reading in 1 or 2 minutes if the soil is not dry. They are limited to soil depths of about 1 foot.

5. CAN THEY BE MOVED FROM PLACE TO PLACE?

Tensiometers can be moved when they have served their purpose at the original location. For annual crops, they should be removed before harvest. For perennial crops, they are seldom moved, but perhaps should be relocated every 2 or 3 years because the instrument may slightly influence the root pattern or the plant and roots may grow enough that a new location is more representative. With each move, the ceramic tip loses some porosity from crystallization of salts as the surface dries, so a large number of moves is not advisable. The standard tensiometer is not an instrument to be carried from place to place to give readings a minute or two after insertion.

6. HOW MANY TENSIOMETERS DO I NEED?

No definite per-acre figure can be given because conditions vary. There should be at least one, and preferably two, tensiometer locations for each area of the field that differs in soil texture and depth, kind of crop or cover, slope, method of irrigation, time of irrigation (by more than 2 or 3 days), and ease or problems of irrigation.

At each location, tensiometers at different depths may be needed. The number will depend on soil and root depth. Usually, only one depth will be needed for plants rooting less than 15 inches. Two should be used for plants having active roots deeper than 15 inches. For plants rooting deeper than 4 feet, it is desirable to have instruments at three different depths.

In a large uniform field irrigated as a unit, or in several sets over 1 to 3 days, one location per 10 acres may be sufficient. In a 10-acre orchard on rolling ground irrigated by different sprinkler lines, one grower used six tensiometer locations with two instruments at each location. The average is somewhere between these two examples.

It's a good idea to start with a few. Install them at two or more locations per area, but limit the number of areas until you gain some experience. Ask for technical assistance, if needed. After a trial period, it is easier to determine total number needed.

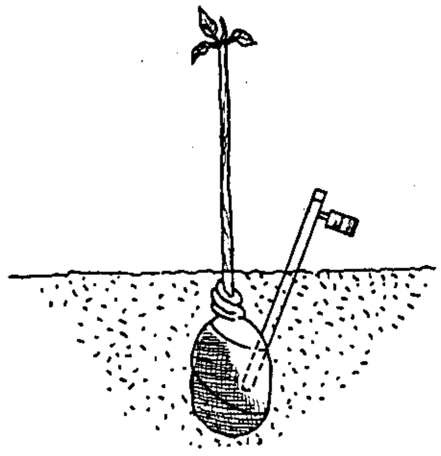
7. HOW MUCH WILL THEY COST?

At present, several makes of tensiometers are available. The range in price has a ratio of about 2:1. Assuming you need an average of one tensiometer for each 2½ acres, the cost will be $1.25 to $2 per acre per year, for the expected life of the instrument, depending on number purchased at one time. It is common for growers using tensiometers to save one or more irrigations per year. While irrigation costs vary widely, you can compute the savings this might mean for you. Further gains that may be balanced against the cost are improved health and vigor of plants, as well as quantity and quality of production. Some growers claim production gains at $50 to $500 per acre.

8. WHERE SHOULD THEY BE PLACED?

Install a tensiometer so that the tip is in the active root zone, in good contact with soil, and in a position where irrigation water is sure to wet the soil. Observe the active-root-zone concentration and depth by digging near an adjacent plant, but not right where the tensiometer is to be installed.

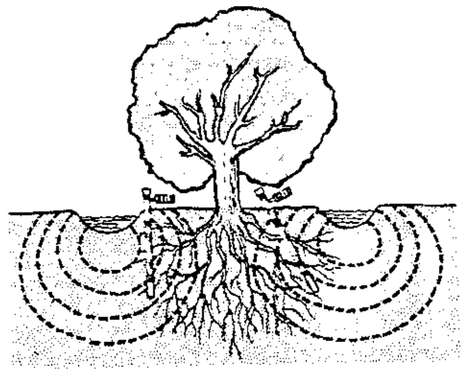
In new orchards, place the tip in the root ball since soil texture in the ball may differ from that in the field, and water transfer could be impeded. After several weeks the tensiometer can be reinstalled near the drip line of the growing tree. Subsequent moves may occur annually during the rapid growth period, less frequently thereafter.



In new orchards, place tip in root ball.

With furrow irrigation, place the instruments near enough to the furrow so that water will be certain to reach them. With most row crops, they are placed in the plant row. With sprinkler irrigation, place tensiometers where they can "see" the sprinkler; that is, where water from the sprinkler is not blocked by a post, tree trunk, branch, leaves, vines, etc. With drip irrigation, place them 12 to 18 inches from an emitter.

For some crops, you may place the instruments in critical or problem locations where you especially want knowledge of the soil water. These locations may be difficult to wet, may dry out quickly, or remain excessively wet. Tensiometers are very useful for identifying and helping to solve irrigation or soil-water problems.

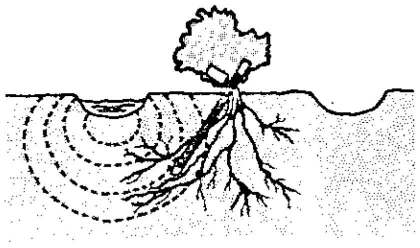


With furrow irrigation, the tip should be in the wetted zone. With non-tillage, the vertical position is best; but with tillage, the slanted position interferes less. (Dotted lines show the spread of water at successive times during an irrigation.)

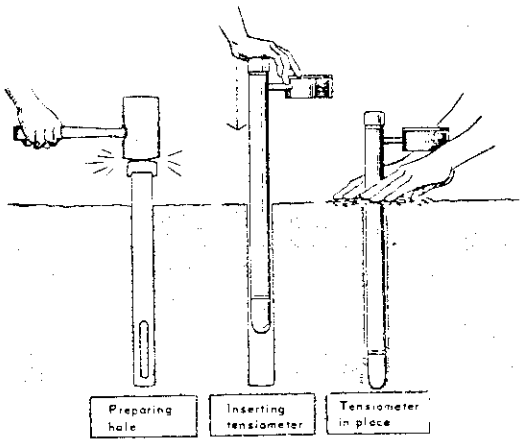
9. HOW SHOULD THEY BE INSTALLED?

For a good installation, insert the ceramic tip into a prepared hole with a glove-tight fit so that the walls of the tip are in close contact with undisturbed soil and roots. For depths to 4 feet, prepare the hole by driving a solid rod having a tapered driving point, or a hollow tube with a sharp cutting edge, to the depth desired. Carefully remove the rod or tube so that the hole remains round and uniform. Use a rod or tube having the same diameter as the tensiometer. Various makes of tensiometers differ slightly in diameter. Push the tensiometer to the bottom of the hole, being careful not to push on the gauge. Press the soil around the tensiometer at the surface, and pile it slightly so water will not collect and seep down along the tube of the tensiometer.

Installations deeper than 4 feet are not frequent, but are sometimes necessary. They require special installing tools and techniques, and probably the assistance of a qualified person like your farm advisor or Soil Conservation Service technician.



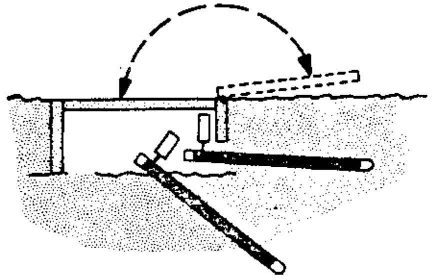
For better protection, install in the row. If the bed wets completely and easily with each irrigation, a vertical position is good. If water does not always wet across the bed, the slanted position shown here is useful.



Installation of tensiometer.

10. WILL THEY BE IN THE WAY?

You can usually choose a location where the tensiometers will not be in the way of the normal field operations. Sometimes you may have to place them where they are partly in the way of certain operations. If properly protected and marked, they can be avoided with only minor inconvenience. Or they may be installed with the tip placed where needed and the top emerging from the ground at a more protected position (see diagrams). When installed in a submerged box with a hinged lid (see diagram), tensiometers are out of the way and protected from all but plowing and disking operations. This method is particularly useful in sprinkler irrigated turf, hay, and forage.



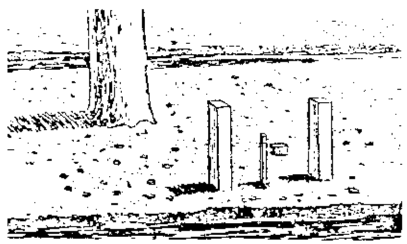
Optional positions for buried installation. The box is placed in position after tensiometers are installed.

11. ARE THEY SUBJECT TO DAMAGE?

Yes. Tensiometers can be broken if struck a hard blow, and the gauge can be ruined if exposed to freezing temperatures.

Tensiometers must be protected from damage. To protect against accidental striking by tools, machinery, or feet, bracket the instruments with bright-colored stout stakes (plain stake carrying a colored flag will do); cover them with a box, tile, steel pipe, or similar protective device; or bury them in a box.

To protect against freezing, cover the instruments during the frost season. Burlap sacks, blankets, a mound of soil, or a box full of sawdust gives protection for short-time temperatures as low as 20 degrees. Where lower temperatures are likely, protection by covering is uncertain, and the tensiometers should be removed from the ground, emptied, cleaned, and stored in a warm place. Water is difficult to remove from inside the gauge; it can still freeze even when the body of the tensiometer has been emptied.



A tensiometer protected by bright colored stakes.

A tensiometer protected by box and insulated with burlap.

12. WHEN AND HOW OFTEN SHOULD INSTRUMENTS BE READ?

For most purposes, an early-morning reading is desirable. Water movement in plants and soil at that time has almost stopped—a condition near equilibrium exists. It is a good practice always to read at about the same time of day.

Frequency of reading depends on the rate of water used in relation to the supplying capacity of the root-zone soil. A minimum of three readings should be made between irrigations. Take readings frequently enough so that the change from one reading to the next is not greater than 10 to 15 centibars. Many users take readings three times a week. If irrigation is oftener than once a week, take daily readings. If irrigation is monthly, twice a week is adequate. During winter, weekly readings suffice.

13. AT WHAT READINGS SHOULD I IRRIGATE?

This depends on crop, soil, climate and irrigation method. It is best determined by each user to fit his conditions—a not too difficult task. Experience and research have provided some useful general guides to start a program.

With full-coverage irrigation, do not irrigate when readings are in the 0 to 10 range. The soil is already too wet and plant roots may suffer a lack of oxygen. In most field conditions, irrigation is not needed in the 10 to 25 range. With few exceptions, do not delay irrigations much after readings reach 75 to 80. The soil has become quite dry, and its ability to supply water rapidly to plants during periods of rapid use is poor.

Here are suggestions for irrigation readings that can be used as a guide for some crops irrigated by full-coverage methods. They can be adjusted to fit individual needs:

Deciduous fruit trees	70 – 80
Citrus	50 – 70
Avocados	40 – 50
Grapes	40 – 60
Tomatoes	60 – 70
Lettuce	40 – 50
Strawberries	25 – 35
Celery	20 – 30
Melons, carrots	50 – 60
Turf (except putting greens)	20 – 30

With frequent part-coverage irrigation such as drip or trickle, the aim is to maintain readings within the 10 to 25 range by controlling the amount of water applied.

14. DO I NEED TO RECORD READINGS?

Full benefit from use of tensiometers is obtained by recording readings and, preferably, by plotting them on a chart. The chart lines show what has happened in the past; by extending them ahead you have advance indication of what you can expect in a few days. This information helps you plan and prepare for the next irrigation, to see if a previous irrigation failed to penetrate adequately, and to learn why the soil became dry sooner than expected.

USEFULNESS OF PLOTTED READINGS

A. Shortly after a good irrigation.

B. From this point it is possible, by extending line AB, to predict when an irrigation will be needed.

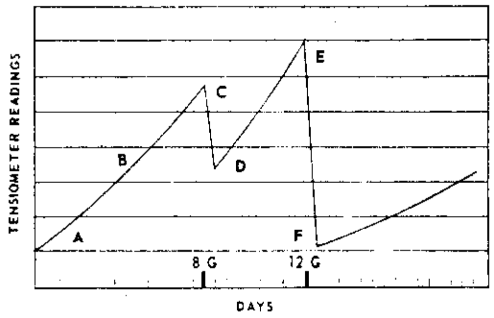
C. Just before irrigation.

D. After an irrigation which did not penetrate adequately.

E. Soil dried sooner because of inadequate irrigation.

F. Reflects an adequate irrigation following E.

G. It is helpful to show date and hours of irrigation.



15. DO TENSIOMETERS NEED ATTENTION OTHER THAN READINGS?

Occasionally, tensiometers need to be refilled with water. At each reading, check the water level. If it falls more than 1 or 2 inches below the stopper, add water. All tensiometers should be tested three or four times a year with a test pump.

16. WHY DO THEY NEED WATER ADDITIONS?

When soil suction remains low, very little water is lost from a tensiometer. When soil becomes dry, its suction draws water out of the instrument, creating a high vacuum against which it is difficult to prevent minor air leakage. At high suctions, the pores of the tip allow some air to pass into the instrument. When the soil is irrigated, water is drawn back inside the tensiometer, but not enough to fill it if air has entered. The best time to add water is after an irrigation when the natural refill has done part of the job, the vacuum is low, and the stopper can be removed easily. If considerable water is added, use a vacuum pump to withdraw air bubbles.

17. DO TENSIOMETERS FAIL IN USE?

Sometimes, though not often. If one has been damaged, it will not perform. A gauge may rust and stick if water gets under the glass, or it may be frozen and fail. A leak in the stopper, body connections, or gauge may admit air. A stopper may crack from the action of sunlight or air pollution. If the stopper is released suddenly when the reading is high, the gauge hand may strike the zero pin with enough force to slip the friction mounting of the hand so that an incorrect reading will be obtained. In rare cases, a crystalline deposit occurs in the neck of the gauge, blocking its action. Remove the deposit by poking with a short piece of wire.

The pores of the ceramic tip are filled gradually as dissolved materials from the soil solution crystallize. This slows the water transfer through the tip and increases the time required for the tensiometer to respond to changing soil-water conditions. Some slowing does no harm, but if the response time becomes too slow for satisfactory use, a new tip should be installed. The response rate can be partly recovered by sanding the tip exterior with sandpaper.

The length of time taken to reach this condition depends on the soil and manner of use. If tensiometers are left in the ground, the tip porosity remains satisfactory for several years in most soils.

Each time the instrument is removed from the soil, its tip life is reduced, especially if the soil is calcareous and saline. In extreme cases, where tensiometers are installed and removed several times, the tip porosity may become unsatisfactory in 1 year. To minimize damage the tip of a tensiometer that has just been removed from the soil should be protected from dry air until the instrument has been emptied, cleaned, and dried.

18. HOW DO I KNOW WHEN A TENSIOMETER IS NOT WORKING?

An instrument out of water, or leaking, will remain at zero. Two or more successive zero readings on the same tensiometer are a sign of malfunction and should not be accepted as true readings. In most cases, the trouble is easily corrected (see question 19). If the gauge has rusted or has a crystalline deposit in its neck, it will stick at one reading even when the stopper is removed. A frozen gauge may or may not respond as the soil dries, but even if it responds, it will be incorrect. If you suspect a reading is incorrect, check the gauge with a test pump. Readings higher than expected, especially after an irrigation, are generally not tensiometer failure but failure of the irrigation water to penetrate to the depth of the tensiometer tip.

19. WHAT CAN BE DONE TO CORRECT A FAILURE?

If the gauge remains at zero refill with water and use a test pump. The instrument may have been empty because of dry soil. With test pump at a high reading, watch for bubbles. If the tip was dry, fine bubbles will rise rapidly for several minutes but eventually cease. If larger bubbles rise and continue, a leak is indicated. Determine the source. If the bubbles rise from the bottom, remove the tensiometer and send it in for repair—possibly a new tip. If bubbles rise from the gauge, the gauge may leak or the threaded connection may need resealing. If no large bubbles arise, it may be that the stopper is cracked or was not sealed properly.

If the gauge sticks and appears rusted, remove, disassemble, and dry it out if it is still wet. Apply rust-removing oil to all moving parts and surfaces.

A day or two after oiling, wipe carefully to remove rust, and flex the movement carefully by hand. Apply a thin coating of very light oil and reassemble. Check with a test pump for operation and accuracy.

If readings considerably different from the test pump show that the gauge has been frozen, then remove it and replace with a new gauge. Some frozen gauges can be restored to accuracy, but the job is tedious and the chances for success are limited.

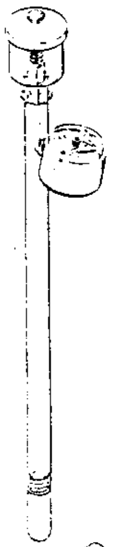
20. CAN TENSIOMETERS HELP AUTOMATE IRRIGATION?

Tensiometers are available with electric contact points that can be set at any soil suction reading desired. When the soil dries to the selected suction, an electric circuit is closed in the tensiometer gauge. The circuit generally includes an irrigation programmer connected to remote control valves. The remote control valves are in a water supply line and can start or stop irrigation as signalled.

A variety of arrangements are possible permitting the tensiometer signal to initiate and stop irrigations directly or to be stored in the programmer until a preselected time has been reached. The programmer avoids irrigations at undesirable times even when the tensiometer has signalled for it. Likewise, the programmer cannot initiate irrigation until a signal has been received from the tensiometer. The result is the most complete irrigation automation possible.

Soilmoisture Equipment Corp.

About Our Tensiometers



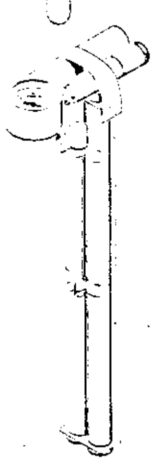
Tensiometers are the only accurate, inexpensive instruments capable of continuously monitoring soil moisture for irrigation control purposes. We provide the greatest variety and the most advanced tensiometers available.

Enclosed is our sales literature on our tensiometers, together with additional background articles and instructions, which we feel will give you full information on the features of our instruments, together with details of installation and operation.

Our Model 2725 Jet Fill Tensiometer, pictured and described on the small pocket-size brochure, is the most advanced tensiometer on the market today for fixed installation for irrigation control purposes. The unique Jet Fill feature and the high flow ceramic tip assure accuracy of reading and minimum of maintenance in all types of soils.

The brochure on our Model 2710 Soilmoisture Tensiometer carries on the reverse side placement information for fixed tensiometers as they are conventionally used for irrigation control purposes.

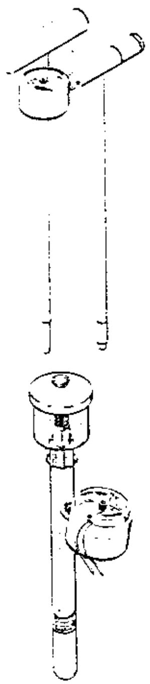
Our Model 2900 "Quick Draw" Soilmoisture Probe is a portable tensiometer that is available in 12" and 18" sizes. The same type of instrument, our Model 2950 Soilmoisture Turf-Probe, is also available for use at shallow depths in turf. These are the only portable tensiometers on the market today, and they are pictured on one of the enclosed brochures. Incidentally, these instruments are now supplied with a 2" diameter dial gauge for improved readability. In contrast to electrical probes on the market which do not give correct, meaningful measurements of soil moisture, our Soilmoisture Probes read out accurately in centibars of soil suction, and can be continuously maintained for indefinite length of service.



Our Models 2711 and 2726 Switching Tensiometers, described on Product Bulletin -A19, are used for automatically turning on and off the irrigation system in order to maintain pre-set soil moisture values.

One of the fliers enclosed gives a rather detailed explanation of how tensiometers work and the meaning of "soil suction". If you are seriously interested in the correct measurement of soil moisture, you should read this explanation carefully, so as to best understand the moisture measuring problems in soils.

We have also enclosed copies of several articles pertaining to the use of tensiometers which will give you additional information on their application, and which you may find interesting to read through. One chart gives typical plant feeder root depths for various crops which can be used as a guide for the placement of tensiometers. It is



customary to place one tensiometer so that the sensing tip is one-quarter of the way down into the active root zone, and another adjacent tensiometer so that the sensing tip is three-quarters of the way down into the active root zone. This procedure gives a good reading of moisture conditions throughout the whole active root zone. It is difficult to make completely firm recommendations about placement of tensiometers in the root zone, since rooting depths vary considerably, depending upon the soil profile, the soil type, and the irrigation practice.

The soil moisture gauge readings at which irrigation should be started are referred to in some of the enclosed articles. However, it has been determined in recent years that it is better to keep soils somewhat more moist than was originally practiced in order to get the best water penetration when irrigating and also to provide the healthiest environment for optimum crop production. The best thinking in this regard at the present time is to keep soil suction values at a maximum of 40 to 50 centibars and to arrange irrigation so that you do not create a saturated condition (0 to 10 centibars of soil suction) for any length of time in the feeder root zone. Where you are working with sandy soils which have extremely limited water storage capacity, irrigation is started at lower soil suction values, frequently in the range of 20 to 30 centibars. Where you are working with drip irrigation systems and the tensiometer is installed approximately 12" to 18" away from the emitter, tensiometer readings are also maintained at a relatively low value (usually in the range from 10 to 25 centibars, depending upon soil type).

The enclosed instruction information will also give you further details on the installation and use of our tensiometers.

Soilmoisture Equipment Corp. P.O. Box 30025, Santa Barbara, Calif. 93105 U.S.A.

SUPPLIED FOR YOUR INFORMATION BY *Soilmoisture Equipment Corp.*

PRINCIPLES INVOLVED IN THE OPERATION OF A TENSIOMETER TYPE MEASURING INSTRUMENT

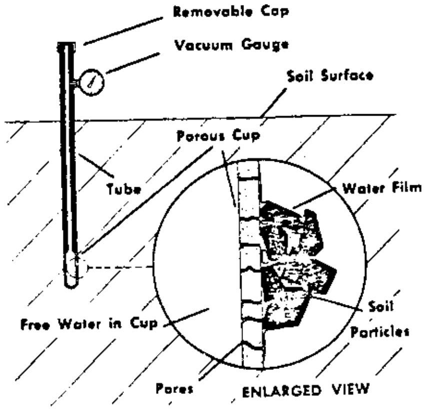


FIG. 1

Fig. 1 shows a section view of a tensiometer in place in the soil. A tensiometer consists essentially of a tube, sealed at one end by a porous ceramic cup which is in contact with the soil. The other end of the tube is above ground and is connected to a vacuum gauge. This end of the tube is sealed with a removable cap after the tube has been filled completely with water.

The insert in Fig. 1 shows a magnified view of the porous cup in contact with the soil particles. The special thing about the porous ceramic is the size of the pores. The pores are reasonably uniform and of controlled maximum size. When the porous ceramic is wetted and the pores filled with water, the surface tension of the water at the air-water interface, at each of the pores, seals the pores. Water can flow through the pores but the water film at each pore acts like a thin rubber diaphragm and will not let free air pass, throughout the working range of the tensiometer.

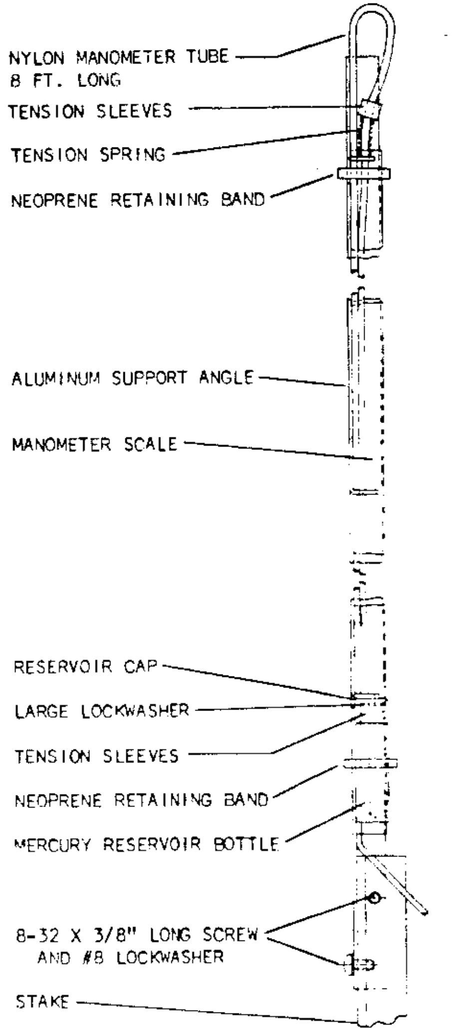
The insert in Fig. 1 also shows the water film which surrounds each soil particle. These films of water are bound to each of the soil particles by strong molecular forces. As soil dries out, these water films become thinner and more tightly bound. The "tension" thus produced within these water films causes water to be sucked from the tensiometer through the pores in the ceramic cup. These same strong molecular forces make it increasingly difficult for plants to suck moisture from the soil as the soil dries out.

As water is sucked from the tensiometer by the soil, a partial vacuum is created in the tensiometer since the unit is completely sealed except for the porous cup. As more water is removed, the vacuum inside the unit becomes higher. The amount of the vacuum is registered on the vacuum dial gauge. Water is sucked from the tensiometer by the soil until such time as the vacuum created inside the tensiometer is just sufficient to overcome the suction of the soil. At this point an equilibrium is reached and water ceases to flow from the cup. The tensiometer then reads directly the amount of "soil suction". As the soil moisture is further depleted through evaporation, drainage or the action of plant roots, the soil suction increases. More water is then sucked from the tensiometer until the vacuum in the unit is increased and a new equilibrium point reached.

When water is added to the soil from rainfall or irrigation, the soil suction is reduced. Then the high vacuum in the tensiometer causes soil moisture to be drawn from the soil through the walls of the porous cup into the unit. This flow of water back into the tensiometer reduces the vacuum. The flow continues until the vacuum in the tensiometer drops to the value where it is just balanced by the soil suction. If water is added to the soil until the soil is completely saturated, then the vacuum dial gauge on the tensiometer will drop until it reads zero.

As outlined above, a tensiometer always is maintaining a balance with the soil suction and the vacuum gauge on the unit indicates the value of the soil suction at the porous cup.

● SINGLE MANOMETER KIT MODEL 2300

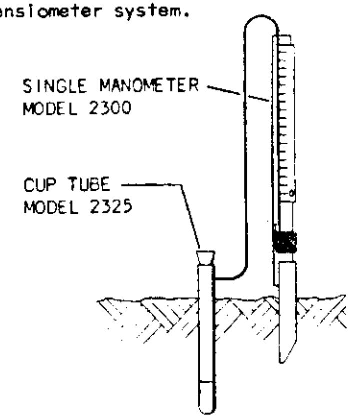


30 Grams or .07 lbs. of mercury required per unit.

The Model 2300 Single Manometer Kit provides a simplified manometer assembly for use in a tensiometer measuring system, particularly in conjunction with the Model 2325 Cup Tubes. It includes parts as indicated in the assembly drawing, and makes use of a single, transparent, plastic tube that serves both as the manometer measuring tube as well as the connecting link between the manometer assembly and the tensiometer Cup Tube. The unit is supplied with a steel stake for mounting in the ground. It may also be mounted on other apparatus for use in laboratory experiments. The manometer scale is graduated in millibars of soil suction, which is the standard of measurement accepted throughout the world. All of the parts required for the complete assembly are supplied in the kit. The only tools required are a sharp knife and a screwdriver.

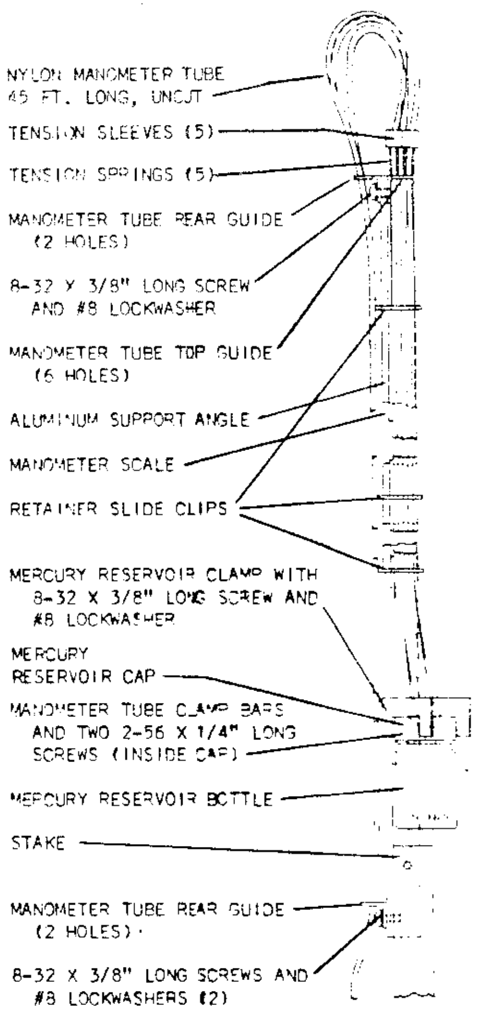
NOTE:

The Cup Tube Kit, Model 2325, is necessary to make a complete mercury manometer tensiometer system.



Typical assembly of the Model 2300 Single Manometer and the Model 2325 Cup Tube to make a tensiometer measuring system.

MULTIPLE MANOMETER KIT MODEL 2310



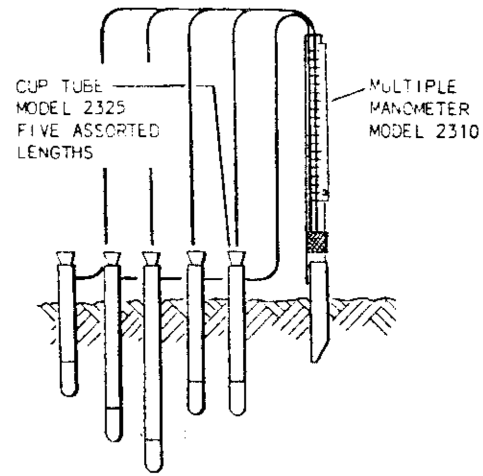
150 Grams or .33 lbs. of mercury required per unit.

The Model 2310 Multiple Manometer Kit provides a simple manometer assembly for simultaneous use with as many as five Model 2325 Cup Tubes for use as a Multiple tensiometer measuring system. Since each of the five manometer tubes are measured with the same manometer scale, it provides direct comparison of the soil suction values in each of the Cup Tubes.

The Model 2310 Multiple Manometer Kit includes parts, as indicated in the Assembly Drawing, and makes use of transparent plastic tubing that serves both as the manometer measuring tube, as well as the connecting link between the manometer assembly and the tensiometer Cup Tubes. The kit is supplied with 45 ft. of the nylon manometer tubing for connection to the Model 2325 Cup Tubes. Additional tubing should be ordered in the event the Cup Tubes are to be placed at a substantial distance from the manometer assembly. A steel stake is provided as part of the Multiple Manometer Kit for mounting in the ground. The manometer may also be mounted on other apparatus for use in other laboratory experiments. The manometer scale is graduated in millibars of soil suction, which is the standard of measurement accepted throughout the world. All of the parts required for the complete assembly are supplied in the kit. The only tools required for assembling are a sharp knife and a screwdriver.

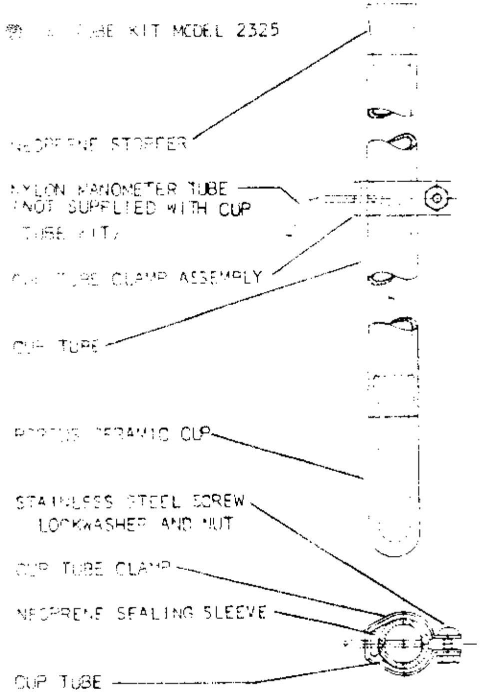
NOTE:

The Cup Tube Kit, Model 2325, is necessary to make a complete mercury manometer tensiometer system.



The Multiple Manometer Tensiometer lends itself to measuring the soil suction values at a given depth in five separate locations, or it can be used to measure soil suction values at five separate depths in essentially the same location for studies involving the measurement of hydraulic gradient in soils.

CUP TUBE KIT MODEL 2325



CROSS-SECTION VIEW OF CUP TUBE CLAMP ASSEMBLY

Cup Tube Kits are used in conjunction with the Model 2300 Single Manometer Kit or the Model 2310 Multiple Manometer Kit to make up inexpensive, versatile tensiometer systems for the measurement of soil suction. They are suitable for field installation as well as setups within the laboratory, or for demonstration purposes in the classroom.

The Model 2325 Cup Tube Kit includes the various parts, as indicated in the assembly drawing. The assembly process is simple and requires only the use of a screwdriver.

The Cup Tube is available in 6", 12", 24", 36", 48", and 60" lengths.

A hole is cored in the soil to accept the Cup Tube. Our Model 241 Insertion Tool is designed to core a hole for a precise fit to the Model 2325 Cup Tubes. For proper operation, it is essential that the porous cup be in tight contact with the surrounding soil. After coring a hole, the Cup Tube is pushed down to the required depth and the top 2" or 3" of soil are packed tightly around the Cup Tube to prevent irrigation water from moving directly to the cup.

MODEL	DESCRIPTION
2300	Single Manometer Kit
2310	Multiple Manometer Kit
2325L6	Cup Tube Kit 6" Size
2325L12	Cup Tube Kit 12" Size
2325L24	Cup Tube Kit 24" Size
2325L36	Cup Tube Kit 36" Size
2325L48	Cup Tube Kit 48" Size
2325L60	Cup Tube Kit 60" Size
241L30	3/4" Insertion Tool, 30" Size
241L54	3/4" Insertion Tool, 54" Size
241L78	3/4" Insertion Tool, 78" Size
2326	Cup Tube Clamp Assembly
2091	Manometer Scale, Fiberglass 0-850 Millibars
	Nylon Manometer Tubing 3/32" O.D. X 1/64" Wall
	Mercury Required: 30 Grams or .07 lbs for Model 2300
	150 Grams or .33 lbs for Model 2310

SEE SEPARATE PRICE LIST FOR CURRENT PRICES.

SOILMOISTURE equipment corp.

1 BAR POROUS CERAMIC CUPS

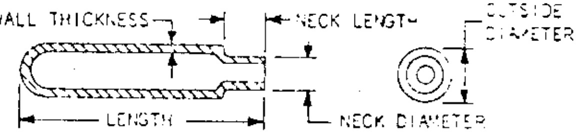
A variety of standard size cups, listed below, suitable for many soil moisture measuring and control uses are available for shipment from stock. These cups are fabricated from 1 bar porous ceramic material. The bubbling pressure or air entry value for this material, when it has been completely wetted with water, is greater than 1 bar (15 psi). When cast it the form of cups this value is usually about 2 bars (30 psi). Transmission rate of water through a 1/16" wall is usually greater than 10 ml/cm^2/hr/bar of pressure difference across the cup wall.

Cups as listed, are "as cast". We can cut these cups to make shorter cups or the closed ends can be cut off to make cylinders. Diameters can be machined to provide shoulders or special dimensions. We can also make up at modest cost, with our normal manufacture, special cups to meet your specific requirements. Special porous cups fabricated from 3 bar or 15 bar porous ceramic can also be provided. For special cups write for further information giving complete dimensional requirements and quantities desired.

STRAIGHT WALL POROUS CUP

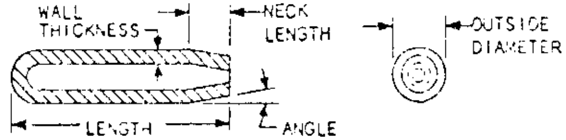
CAT. NO.	LENGTH	OUTSIDE DIAMETER	WALL THICKNESS	TYPE OF BOTTOM		PRICE
2133	6.5 CM	6 mm	1 mm	ROUND		[redacted]
2133-1	8.0 CM	6 mm	1 mm	ROUND		[redacted]
2105-1	1/4 IN.	1-1/8 IN.	1/16 IN.	ROUND		[redacted]
2550-1	1-1/8 IN.	3/8 IN.	1/16 IN.	ROUND		[redacted]
2134	10 CM	1 CM	2 mm	ROUND		[redacted]
2135	12 IN.	1/2 IN.	1/16 IN.	FLAT		[redacted]
2605-1	2-3/8 IN.	7/8 IN.	3/32 IN.	ROUND		[redacted]

NECK TOP POROUS CUP



CAT. NO.	LENGTH	OUTSIDE DIAMETER	WALL THICKNESS	TYPE OF BOTTOM	NECK DIAMETER	NECK LENGTH	PRICE
2131	2-3/4 IN.	7/8 IN.	3/32 IN.	ROUND	9/16 IN.	1/2 IN.	[redacted]
2191	2-7/8 IN.	1-7/8 IN.	1/8 IN.	ROUND	1-3/4 IN.	7/16 IN.	[redacted]

TAPERED TOP POROUS CUP



CAT. NO.	LENGTH	OUTSIDE DIAMETER	WALL THICKNESS	TYPE OF BOTTOM	ANGLE	NECK LENGTH	PRICE
2132	2-3/4 IN.	3/4 IN.	3/32 IN.	ROUND	10°	7/8 IN.	[redacted]

All prices are in U.S. Dollars, F.O.B. Santa Barbara, and subject to change without notice.

Address all orders and correspondence to: Soilmoisture Equipment Corp.
P. O. Box 30025
Santa Barbara, Calif. 93105

February 1982
[illegible] No. 2
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NOTE

A NEW SOLID-STATE DEVICE FOR READING TENSIOMETERS[1]

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ABSTRACT

A solid-state device that has recently become available provides a means for easily and very accurately measuring the vacuum created in soil tensiometers, making gauges and mercury manometers obsolete. It is a backward-gauge-type transducer that is compatible with water, screws directly into the tensiometer, has internal voltage regulation, temperature compensation, and signal conditioning, and is suitable for field use.

Ceramic porous cup tensiometers, as developed by Richards and his associates (1936, 1937, 1942), have been the most widely used method for determining soil water potential. Tensiometers cover the range of soil water potential between 0 and 0.85 bar. This range includes nearly 90% of the available water in sandy soils (Haise 1955) common to the southeastern United States.

F[illegible]d tensiometers are normally read manual[illegible] [illegible] vacuum gauges (Perrier and Evans 196[illegible] [illegible] with attached mercury manometers. Man[illegible] [illegible]s these readings are not as accurate as des[illegible] for field research. Also, such manual reading[illegible] are awkward and time-consuming. When [illegible]ny tensiometers are installed in field experim[illegible]nts, the time required for reading discourage[illegible] reading more than once per day. Such infreque[illegible] readings preclude any detailed study of water movement in the field. Pressure transducers have also been used to read tensiometers, but these too have been cumbersome, because they were usually not directly attachable to the tensiometers (Rice 1969; Long and Huck 1980).

A pressure transducer recently developed is ideal for measuring the vacuum created in soil tensiometers (Fig. 1). The transducer is a #LX1804GB, made by National Semiconductor Corporation,[2] and has a range of −15 to +15 psig. This transducer has ¼-in. male pipe threads that, together with a ¼- to ⅛-in. reducing bushing, can be screwed directly into the commercially available tensiometers. It is housed in either zinc metal or nylon. It is a backward-gauge type transducer, meaning that the pressure or vacuum is applied to the back side of the sensor, allowing compatibility with water. The low internal volume of the transducer and the angle at which the transducer screws into the tensiometer prevent trapped air from accumulating in the transducer.

Each device has voltage regulation, temperature compensation, and full signal conditioning by an operational amplifier. Typical excitation voltage is 15 V DC, with a 10-V DC output over the range of the transducer (−15 to +15 psig). The relationship of output voltage to vacuum is linear within the general working range of tensiometers, i.e., 0 to 0.85 bar, or 0 to 867 cm water. In this range, the output voltage change is 4.89 mV per cm water. The equation for calculating the water potential is

$$\text{cm water} = 1553.539 - 204.662 \text{ (volts)}$$

A high-quality millivolt meter can easily read to the nearest millivolt, or, in this case, the equivalent of 0.2 cm water. This is much more precise than can be read visually with a mercury manometer and more than adequate for most field research needs.

[1]Contribution from Science and Education Administration, U.S. Department of Agriculture, and Department of Agronomy and Soils, Auburn University (Alabama) Agricultural Experiment Station, Alabama 36849.

[2] Mention of a trademark or a proprietary product does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture and does not imply approval of the product to the exclusion of other products that may also be suitable.

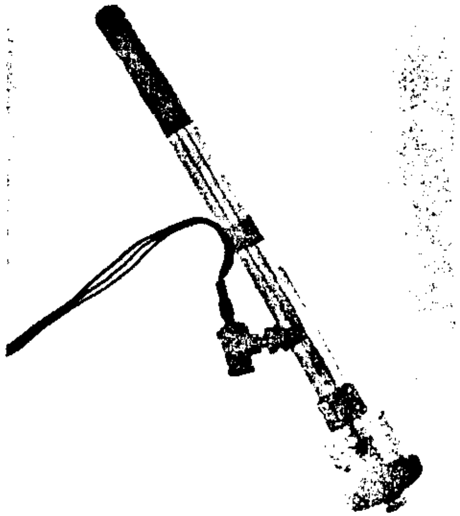

FIG. 1. Transducer attached to tensiometer.

The transducer has automatic internal temperature compensation. Because the water in the tensiometer is in direct contact with the transducer, the two are essentially at the same temperature. There are only three electrical connections to the transducer; input, output, and a common ground. A receptacle built into the transducer accepts a standard Waldom/Molex[2] plug. A tensiometer reading is obtained by simply applying the excitation voltage, reading the output with a millivolt meter, and calculating the potential using the equation. Where several tensiometers are installed in close proximity, a rotary switch arrangement can be used for making the readings more rapidly.

Using this transducer, one can assemble a fully automated field system that will automatically turn on the excitation voltage, scan all the tensiometers at preselected intervals, record the readings and time on some nonvolatile medium, such as a cassette tape, and turn itself off. The cassette tape would be picked up every few days and, through a suitable interface, the data would be put on computer tape for further processing. The cost of the transducer is approximately $70. Considering that almost continuous water potential measurements can be obtained, however, the cost of one transducer is less than the labor cost for one day of manual reading to get the same amount of information.

The measuring device is a great improvement over the mercury manometers and vacuum gauges normally used and should be of benefit to those interested in measurements of soil water potential in their field soils research.

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