Moisture•Point™

MP-917 Technical Brief 15

Insertion of Profiling Probes

Ron McFarlane

Overview

To ensure reliable moisture data, it is important to ensure the proper installation of Moisture•Point™ profiling probes. The issues relating to the insertion of these probes are insertion technique, ease of insertion, depth of insertion, soil/probe contact, soil expansion-contraction ratios, alternate insertion methods, and the effects of soil compression due to probe insertion. These issues are discussed in this technical brief.

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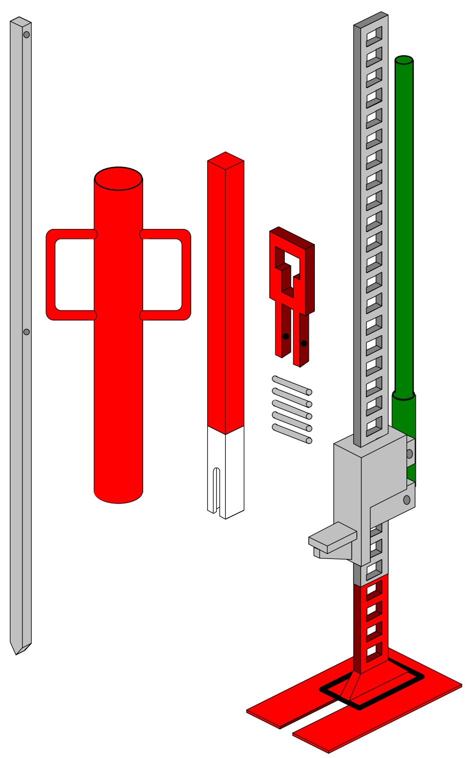
Recommended Insertion Method

Insertion/extraction tools are mandatory in compact soils to ensure no damage occurs to probes in the insertion or extraction process. 500 pounds of lifting force is not uncommon to extract a multiple-segment profiling probe from compacted moist soil. In some cases the extraction force has exceeded 2000 pounds. If the probe is not smoothly inserted into the soil it may be damaged, or create pockets in the soil which may pool water and distort the data.

A TK-917 tool kit, including the storage crate and hearing protection, contains the following specialized components (from left to right):

- pilot rod
- probe driver
- extension shank
- coupling link and pin set
- extraction jack.

These items separately, and in combination, present personnel hazards if used improperly.



Protective Equipment

When in use the probe driver generates harmful levels of acoustic energy. Hearing protection with a Noise Reduction Rating of 20 decibels is provided with the TK-917 and it should always be worn. In addition, the driver user should wear work gloves (user provided), and keep both hands on the driver handles when driving pilot rods or probes.

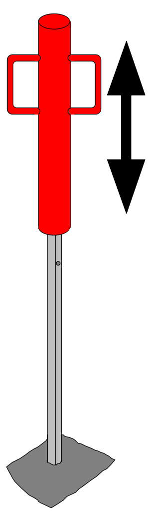
Pilot Rod

The first operation required is preparation of a probe hole using a pilot rod, probe driver, and extension shank. Use of the pilot rod to pre-form probe holes insures that rocks and pebbles do not interfere with probe insertion. A pilot rod must be used to pre-form holes for all probes. It is generally not possible to directly insert a probe into the soil without damaging the probe or deforming the hole. First press the pilot rod into the soil by hand until it can maintain a vertical attitude without assistance. The pilot rod should be as near vertical as possible. This will insure that the rod does not follow subsurface discontinuities in soil layers as it is driven its full length into the soil by the driver.

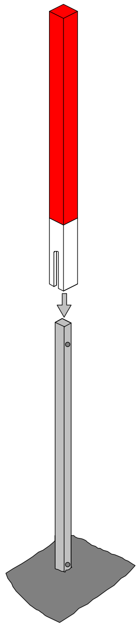
Never use a hammer, or other unapproved driving tool to insert pilot rods or probes. Eye hazards from metal splinters are possible if hammers are used to drive pilot rods. Probes will be permanently damaged if driven with unapproved driving tools.

Probe driver & Extension Shank

To avoid hand injury DO NOT grasp the pilot rod, probe, or extension shank when using the driver. Severe hand injury is possible if these instructions are not followed.

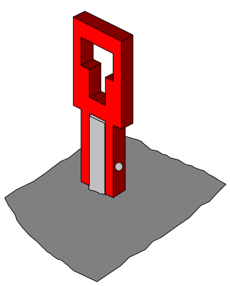


Slip the probe driver over the pilot rod until contact is made with the inside top surface. Keep hands and feet clear of the pilot rod during the driving operation. Keep both hands on the driver handles. Raise and drive downward with force in a smooth linear motion. Continue driving in the pilot rod until the bottom of the probe driver makes contact with the soil at the extreme end of the downward stroke.



Then remove the driver and place the extension shank over the end of the pilot rod. ***It is important to insure that the pilot rod is fully seated in the extension shank cavity.*** Slip the probe driver over the extension shank and continue driving in the pilot rod until the bottom of the extension shank is just making contact with the soil (Be sure to minimize the side to side wobbling of the pilot rod/extension shank while driving. This will prevent the pilot hole from being enlarged at the surface of the soil and creating an air gap between the probe and the soil). Driving the pilot rod to this depth ensures a hole of sufficient depth so that all segments of a probe will be in the soil. Remove the driver and extension shank from the pilot rod and tamp the soil around the rod so that it is roughly leveled for the extraction jack base plate.

Coupling Link & Steel Dowel Pin Set



Attach the coupling link to the pilot rod using the hardened steel dowel pin provided. Insure that only the correct hardened steel dowel pins are used with the coupling link. Undersized dowel pins may eventually enlarge the holes in the pilot rod and probes, and underrated dowel pins may break under load. ***DO NOT use shear pins.*** Replacement pins are available from ESI.

Extraction Jack

The jack assembly can present a foot or hand crush hazard if improperly used. Failure to heed the following cautions may result in probe damage, damage to the jack, or personal injury.

Before extracting a rod or probe make sure the jack is in a stable vertical position and the lift point is directly centered over the pilot rod or probe. When extracting a rod or probe, keep hands away from the moving parts in the jack's lifting mechanism. Always keep a firm grip on the steel handle of the jack, using both hands, when raising or lowering a loaded jack head.

DO NOT grasp or stand on those parts of the jack painted RED when changing the position of the jack reversing latch

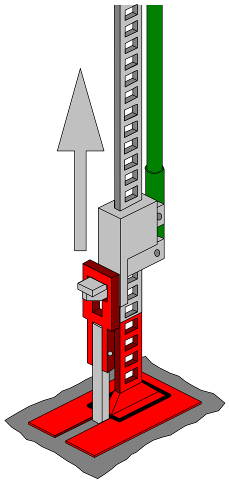
To prevent injury to hands and feet when lowering the jack head the jack user should proceed as follows:

- Lower the jack handle until it is perpendicular to the jack standard (upright post).
- Insure that hands and feet are clear of the jack areas painted **red**.
- Move the reversing latch to its lower position.

The jack must be loaded (45 kg. or more) to lower the jack head step-by-step. If the jack is upright and not loaded when the reversing latch is moved, the jack head will instantly return to its lowest point. This can result in personal injury if hands or feet are in contact with the red areas of the jack base plate.

Position the jack for use by placing the base plate such that the pilot rod is both fully inserted in the base plate slot and vertically parallel to the jack standard (vertical post). Make certain that the base plate is on firm level soil and the jack standard is vertical.

If the jack is not at its lowest position, lower the jack reversing latch. Once the jack is at its lowest position place the reversing latch in the up position until it locks.



With the coupling link attached to the pilot rod, slip the large opening over the jack head lifting nose and insure that the center of lift will be vertical and parallel to the jack standard.

Manually raise the jack head by grasping the lifting nose, pulling it up as far as possible. Then grasp the steel jack handle firmly and pump it up and down in a smooth motion. The pilot rod will be easily extracted. Depending on the holding strength and stability of the soil it may be necessary to relocate the coupling link in the middle of the pilot rod during extraction. A hole at the midpoint of the pilot rod has been provided for that purpose. The mid-length hole may be difficult to locate if it has become packed with soil. It may also be necessary to use the mid-length hole if the jack becomes unstable due to loose soil. It is important to extract the pilot rod in a smooth vertical motion to insure a well formed hole.

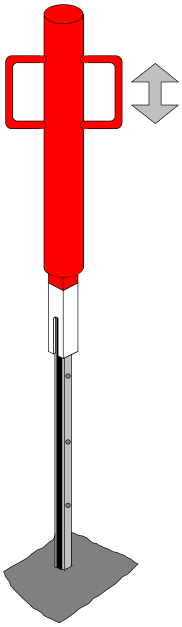
Short Cut

If the soil is loose enough the pilot rod or probe may be extracted by hand. Following the driving operation, attach the coupling link. Grasp the coupling link through the large hole and take a squatting position over the pilot rod/probe. Pull upward smoothly and in one motion using the muscles of the legs and not the back. If any back strain is felt, discontinue manual pulling and use the Extraction jack.

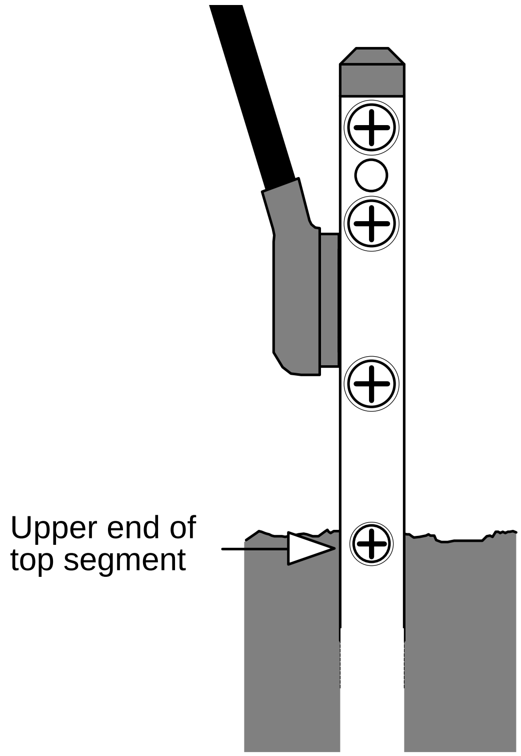
If the jack is overloaded and the safety shear pin breaks it can be temporarily replaced with a 5/16" SAE grade 2 bolt. Never, under any circumstances use a bolt of higher strength as a temporary safety shear pin. The temporary shear pin should be replaced as soon as possible with the manufacturers safety shear pin (Mfr. P/N SP-13). Once the pilot rod can be removed by hand pull it from the hole.

Probe Insertion

Remove the jack and insert the probe as soon as possible. Any delay in inserting the probe into the pre-formed hole may allow moisture to swell the hole sides, or fill the hole with water.



Carefully insert the probe into the pre-formed hole, pressing it in by hand as far as possible before using any driving tools. If probe driving is necessary, always use the extension shank between the probe and the probe driver. **Never use the probe driver directly on the head of a probe.** Use short strokes of the probe driver to tap the probe into the soil until it is fully inserted. When driving probes with the probe driver the driving stroke must be limited to no more than 3-6 inches. Probes will be permanently damaged by excessive pounding. Insert the probe far enough into the soil so that the soil/air boundary passes through the screw marking the top of the uppermost segment (see diagram below). This ensures that the top segment is completely buried in the soil but not over buried. You can partially insert probes, however, since the moisture content for a segment is an average across the entire length of the segment, only segments completely within the soil will produce meaningful moisture readings.



The probe extraction method is identical to that used to extract the pilot rod.

Problems Affecting Soil/Probe Contact

When a Moisture•Point™ profiling probe is interrogated by an MP-917 an electromagnetic field propagates out from the probe and into the soil. The effect the soil has on this field is the basis of operation of the Moisture•Point™ system. The electromagnetic field strength diminishes with the distance away from the probe in an exponential fashion. The net result of this changing field strength is that the soil right next to the probe has a much greater influence on the moisture reading than the soil further away from the probe. In practical terms, the volume of soil that affects 99% of the moisture reading is within approximately 1 cm of the side of the probe. The fact that most of the moisture reading is based on measurements taken from soil that is close to the probe requires that the contact between the soil and the probe be very good. This in turn, has a bearing on how, and into what type of soil, the probe is inserted.

The goal of the insertion process is to place the probe into the soil and have no air gaps between the probe and the soil. Air gaps can be caused by a number of processes. A cavity can be created near the probe when the pilot rod pushes rocks out of the way and soil doesn't completely fill the space previously occupied by the rock. While being tapped into the soil the pilot rod or probe can wobble back and forth, enlarging the pilot hole at the surface and for 15 to 20 cm below the surface. If inserted at an angle relative to the vertical, the pilot rod or probe will sag under the weight of the extension shank, enlarging one side of the hole at the surface and for several centimeters below the surface. Field experience has shown that air gap problems are avoided by following the recommended insertion method.

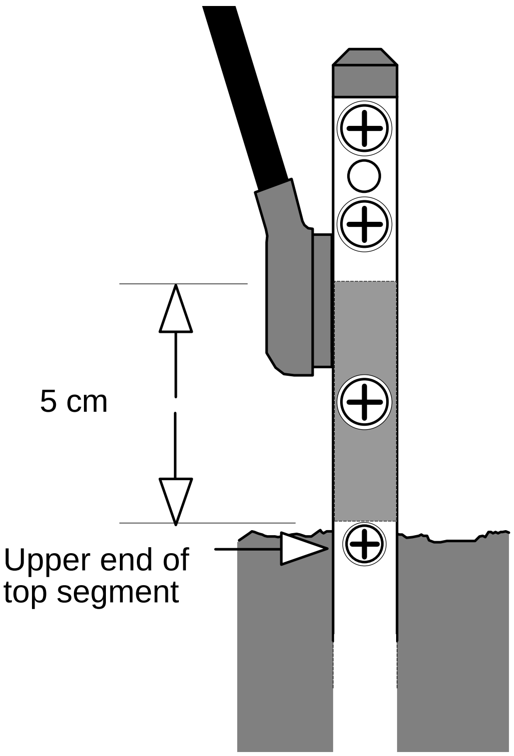
Even if the insertion process initially results in an installation with no air gaps it is still possible for air gaps to form. Certain types of clay soils will expand as they get moist and contract as they dry out (only some clay solid expand and contract; it depends on the type of clay). If the probe were inserted into this type of soil when it was moist and the then the soil subsequently dried out, air gaps will form as the soil shrinks away from the probe. Even inserting the probe into this type of soil when it is dry is no guarantee of good soil/probe contact. The expansion/contraction characteristics of the soil can exhibit significant hysteresis. After a few wetting/drying cycles the soil will not fit snugly around the probe giving rise to air gaps. This type of soil is often characterized by the appearance of moderate to severe surface cracks when the soil dries out.

Air gaps caused by enlargement of the pilot hole can be minimized by preventing the pilot rod/extension shank or probe/extension shank from wobbling back and forth during the insertion process. This caution is mentioned in the recommended insertion method documented above.

Air gaps caused by the motion of rocks during the formation of the pilot hole as required for the recommended insertion method may be unavoidable. If the soil contains a significant amount of rock, an alternative insertion method may be required to obtain reliable soil/probe contact. See below for a description of alternate insertion methods.

Air gaps caused by the soil expanding and contracting are more difficult to overcome. In an agricultural setting it may be possible to limit the variation of moisture content of the soil by periodic irrigation. Limiting the variation in moisture will limit the amount of expansion and contraction and thus reduce the chances that an air gap will form between the probe and the soil. If it is not possible to limit the variation in moisture level of the soil then a technique of filling the gaps may work. If, after a probe has been inserted into the soil for some time, the soil pulls away from the side of the probe, a slurry can be poured down the resulting crack to fill it. The slurry is made by mixing some of the soil from the immediate vicinity of the probe with water. The amount of water should be enough to make the slurry quite liquid. Some time after the slurry is poured down the crack it will dry out and shrink. This process will need to be repeated a number of times before the crack remains filled.

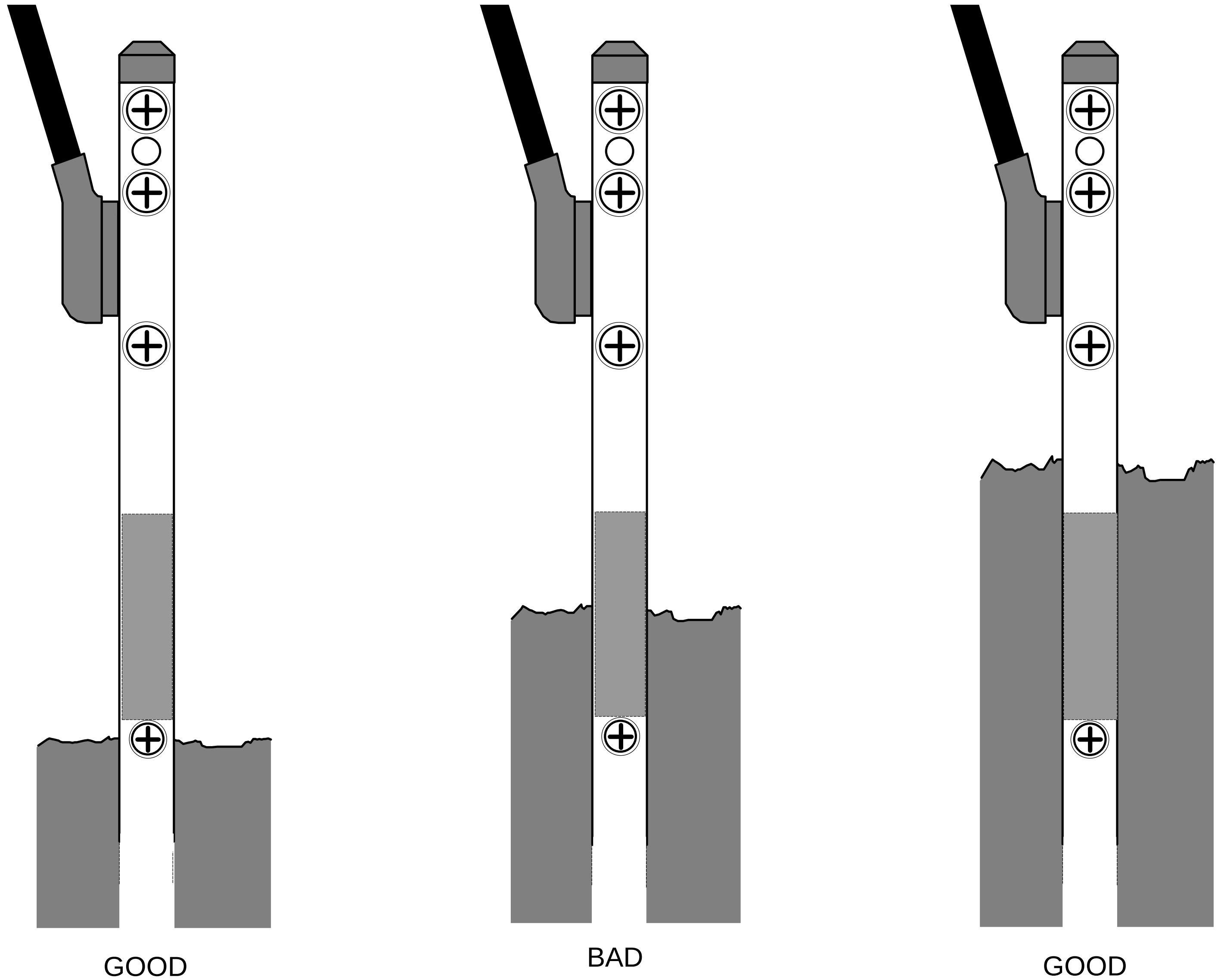
Depth of Probe Insertion



To obtain reliable moisture readings from the top segment of a profiling probe it is important to ensure that the probe is inserted to the proper depth. The soil/air boundary should be level with the upper screw of the top segment. There are two types of screws along the side of the probe. The sizes of these screw are 10-24 (large) and 6-32 (small). On all standard probes the uppermost 6-32 screw is the upper diode screw of the top segment.

The reason that care must be taken is that the soil/air boundary forms an impedance discontinuity. When the TDR signal reaches this discontinuity a reflection occurs. This reflection can interfere with the MP-917 data processing algorithm if the soil/air boundary lies anywhere within the hatched region above the upper screw of the top segment as shown in the figure to the left.

For standard profiling probes, inserting the probe so that the soil/air interface is more than 3.5 cm above the top screw of the upper segment means that the connector will be partially buried, and this is not recommended because of contamination problems with the connector. For some custom designed probes, the distance between the upper screw of the top segment and the connector can be as large as 30 cm, and for these probes it is possible to insert the probe so that the upper screw of the top segment is well below the soil/air boundary. In these instances the probe can be inserted as shown below.



Ease of Probe Insertion

The proper functioning of a profiling probe dictates certain restrictions on the mechanical design of the probe. These restrictions limit the mechanical strength of the probe. The limited mechanical strength of the probe, in turn, limits the methods with which the probe can be inserted into the soil. The recommended method prohibits pounding directly on the top of the probe. Instead, use of the extension shank is required. This shank distributes the shock loading from the probe driver evenly around the top of the probe.

The ease with which a probe is inserted into the soil has a bearing on the reliability of the probe. As the soil becomes harder, more force is required to tap the probe into the soil. There comes a point where the force needed to insert the probe into the soil becomes so great that there is a large risk of damaging the probe during insertion. Two of locations in North America have been identified by users where the soil is so hard that following the recommended insertion method runs a significant risk of damaging the probes. When hard soil is encountered it is recommended that an alternative insertion method be used.

Alternate Insertion Methods

Giddings Rig

A Giddings rig is a hydraulic ram that is usually mounted on the back of a pickup truck. These rigs are normally used to collect core samples of soil by pushing a hollow tube into the soil and then extracting the tube containing the core sample. A Giddings rig may be used, instead of the TK-917, to insert profiling probes into the soil. The smooth, continuous motion of the Giddings rig produces peak mechanical forces on the probe that are far lower than the shock loads produced by the probe driver for a given soil condition. Because of the reduced loading on the probe, the use of a Giddings rig is preferred over the use of a TK-917.

A TK-117 is needed, instead of a TK-917, when a Giddings rig is used.. The TK-117 tool kit is a subset of the TK-917 consisting of a pilot rod, coupling link, and pin set. The user is responsible for acquiring an adapter that will attach to the driving end of the ram and allow the rig to push probes into the ground. This adapter must also couple with the coupling link in order to extract the probe/pilot rod.

When using a Giddings rig, it is still recommended that the pilot rod be used to make a pilot hole and that the profiling probe be inserted into this pilot hole.

Augering Before Insertion

One method of reducing the forces experienced by the probe during insertion is to auger a hole before inserting the pilot rod. This process removes soil from the hole and reduces soil compression when the probe is inserted into the hole. The reduced compression, in turn, reduces the amount of work required to insert the probe into the soil. The reduced soil compression also reduces the changes in moisture behavior of the soil (see the section below Effects of Soil Compression Due to Probe Insertion).

This method requires a 1/2 inch diameter auger. The length of most commercially available augers is not sufficient to drill a 120 cm deep hole (required for a type A probe). Normally, an extension rod needs to be welded to the drive end of the auger to make it long enough. A battery powered hand drill is very useful for driving the auger during field operations.

Mount the auger (or more precisely, the extension rod welded to the driving end of the auger) in the chuck of the drill. Place the drilling end of the auger on the ground where the probe is to be inserted. Ensure that the auger/extension bar is vertical. Then start the drill and push down on the auger until it starts cutting into the soil. Let the auger drill to a depth of approximately 15 cm. While the auger is still spinning pull it out of the hole. This will clear the flutes of the auger of soil. Resume drilling with the auger, clearing the auger by pulling it out of the hole at least once for every addition 15 cm of depth drilled. As the hole gets deeper the auger may need to be cleared more often. Each time the auger is cleared, care must be taken to ensure that it remains vertical during the clearing motions. Once the hole is as deep as required, the auger may be extracted from the hole. The recommended insertion method should now be followed.

The auger method can also be used if it is desired to install the probes at an angle to the vertical. USDA-ARS scientists from the University of Nebraska have successfully employed this approach.

Coring and Backfilling

If the ground is very hard or contains a large percentage of rocks, following the recommended insertion method could damage a profiling probe. In these cases it is recommended that a large hole be cored from the soil, the probe placed in the hole and the hole back filled.

There is a tradeoff associated with this method of inserting the probe. The advantage is that the probe is placed in the soil with the least amount of force and, therefore, the smallest risk of probe damage. The disadvantage of this insertion method is that the soil surrounding the probe is not the same as the soil into which the large hole was bored. The bulk density of the soil used for the backfill will be different that of the parent material. If the soil is heavily layered, the layers will be disturbed as well. The soil used for backfilling the hole will have different hydrological properties than the parent soil. The net effect is that the volumetric water content in the back fill soil will differ from that of the parent material under dynamic as well as equilibrium conditions.

The disadvantages can be reduced somewhat if care is taken to pack the backfill soil around the probe sufficiently. If the soil is heavily layered, taking care to pack the layers appropriately is beneficial. As beneficial as these measures are, they only reduce the effect of disturbing the soil. There will always be some soil disturbance and therefore the backfill soil will always have different hydrological properties. In making the decision to use this method to insert the probes, the disadvantage of disturbing the soil around the probe must be evaluated on a case by case basis, and weighed against the advantage of not damaging the probe during insertion.

Effect of Soil Compression Due to Probe Insertion

When a probe is inserted into undisturbed soil, the probe displaces soil downward and sideways and in the process, compresses the soil near the probe. This compression can cause a small error in the moisture reading. The magnitude of this error will be greatest just after the probe insertion and will diminish as time passes. For best accuracy, it is desirable to wait about one week after insertion to allow the water content adjacent to the probe to reach equilibrium with the water content of the surrounding soil.

After equilibrium has been achieved, the ability to measure changes in the water content (resolution) and the ability to obtain repeatable data (repeatability) are unaffected by these compressions within the limits of the accuracy and resolution stated for moisture point profiling probes. One published calculation (Hook & Livingston, 1996) shows the TDR water content error due to changes in soil density to be small with respect to other instrument error sources.

For most agricultural applications the compression effects can be ignored. To date, there is little field evidence that compression is a problem even for sophisticated soil science applications. Furthermore, there is some field data to support the idea that spatial variability of water content in field applications can be as large as 0.15 m^3/m^3 . Therefore, in any field applications spatial variability is likely to cause errors much larger than those caused by compression. In any event, if compression effects are a concern to the user, the auger method of insertion may be employed to reduce these effects.