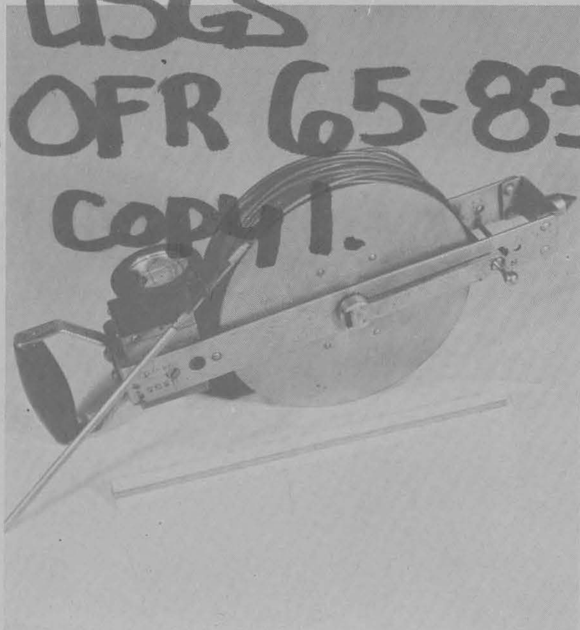


UNITED STATES

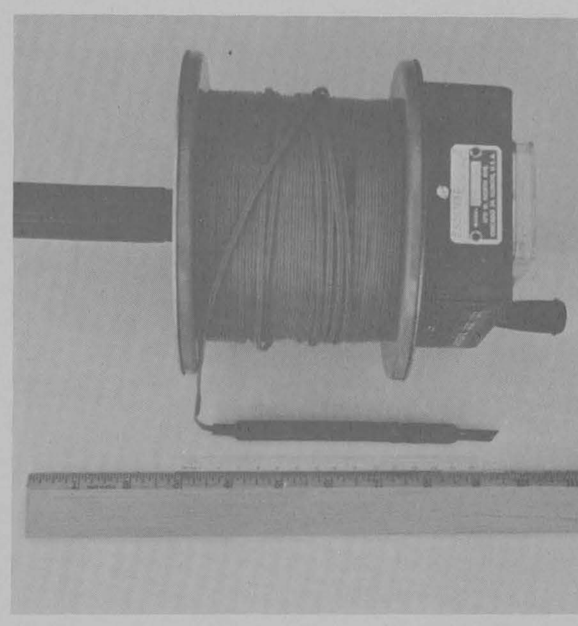
DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

PIEZOMETERS FOR PORE-PRESSURE MEASUREMENTS IN FINE-TEXTURED SOILS

WATER RESOURCES DIVISION

Denver, Colorado



Cover Photographs

Top: Livingston depth-to-water reel for small-diameter piezometers. A California-type reel is used to hold up to 300 feet of 0.08-inch-diameter armored cable. (See Livingston, Penn, and Bridges, T. W., 1936, Ground-water resources of Kleberg County, Tex.: U.S. Geol. Survey Water-Supply Paper 773, p. 197-232.)

Bottom: Depth-to-water reel sold by a laboratory-supply firm. Meter on reel indicates contact with water surface; 300 feet of cable connects to small-diameter electrical contact probe.

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Compiled by A. I. Johnson

U.S. Geological Survey
Open-File Report

Denver, Colorado
1965

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INTRODUCTION

When ground-water observations are desired over a period of time at one particular location, some kind of observation well or piezometer usually is installed at the location. For protracted and detailed observations of ground-water levels or pressures in fine-textured, low-permeability soils, a special type of piezometer installation may be necessary.

The purpose of this brief report is to bring to the attention of hydrologists a simple piezometer using a porous ceramic tube for filter point. This piezometer is more sensitive to ground-water fluctuations in fine-textured materials and is more resistant to plugging of the point by fine particles than the conventional sand-point observation well for which it substitutes.

To the best knowledge of the author, this piezometer was first developed and used about 1946 by Arthur Casagrande in his studies of pore pressure in the foundation clays at Logan International Airport in Boston (Casagrande, written communication, 1946). Casagrande (1949), Gould (1949), and the U.S. Corps of Engineers (1951) subsequently described some results obtained by field use of these piezometers. Those studies show that the time interval for 95 percent equalization 3 months after installation was about 3 hours.

The following description is compiled primarily from the personal notes of Casagrande (1946), who kindly gave his permission for use of his material. His cooperation is gratefully acknowledged. This report was prepared originally in 1958 as a training aid and now is released in the present form to provide greater availability to hydrologists in the field.

DESIGN AND CONSTRUCTION

Porous Point

The porous point consists of a 2-foot length of fine grade alundum or carborundum porous tube, 1.5-inch outside diameter by 1-inch inside diameter. One end of this tube is plugged with a No. 5 rubber stopper, and into the other end is installed an appropriate length of ½-inch-outside-diameter plastic[1] tubing, held in place by a soft rubber bushing. A cross section of this point is shown in figure 1. The length of plastic tubing is determined by the depth of the point below the elevation where the water-level is desired.

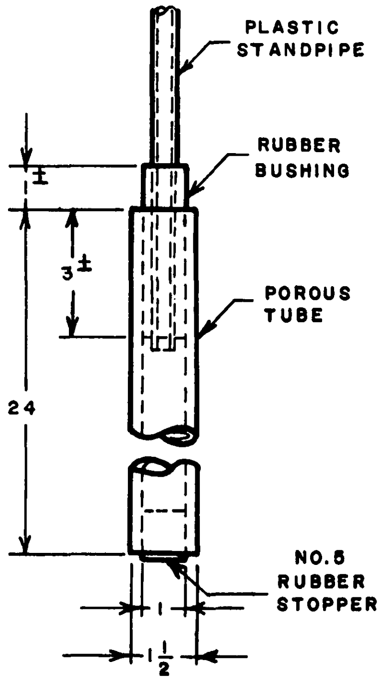

Figure 1.--Assembled porous point; all dimensions are shown in inches (After Casagrande, 1946).

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[1] Vinylidene chloride plastic tubing was recommended originally by Casagrande (written communication, 1946) but polyethylene tubing now is recommended (Casagrande, written communication, 1955).

The procedure for installation of the length of plastic tubing is as follows: (a) A 4-inch length of 3/8-inch inside diameter by 5/16-inch wall Neoprene or rubber bushing is cut from a length of tubing; (b) one end of the ½-inch-outside-diameter plastic standpipe is bevelled on the outside with a knife and lubricated with water; (c) this lubricated end of the plastic tube is inserted about 1 inch into the Neoprene or rubber bushing; (d) the Neoprene or rubber bushing is next inserted into one end of the porous tube as far as possible (approximately 3 inches); (e) with a twisting motion, the plastic tubing is forced 3 inches further into the Neoprene or rubber bushing (this distance can be determined by placing a mark 4 inches from the end of the plastic tube prior to assembly).

If properly installed, it is impossible for one man to pull this joint apart with his hands. It requires considerable effort to force the plastic tube into the Neoprene bushing and it is advisable to make a strap wrench for gripping the plastic tube. An improvised strap wrench can be made with strong twine and a piece of wood. If the ends of the twine are held tightly and the wooden handle is turned in the right direction, the twine tightens on the plastic tubing and acts as a wrench.

Tamping Hammer

The hammer is made of a 3-foot length of tubular steel, 1-5/8-inch outside diameter and 5/8-inch inside diameter to fit the 2-inch casing and the ½-inch plastic tubing (fig. 2). The hammer is provided with a

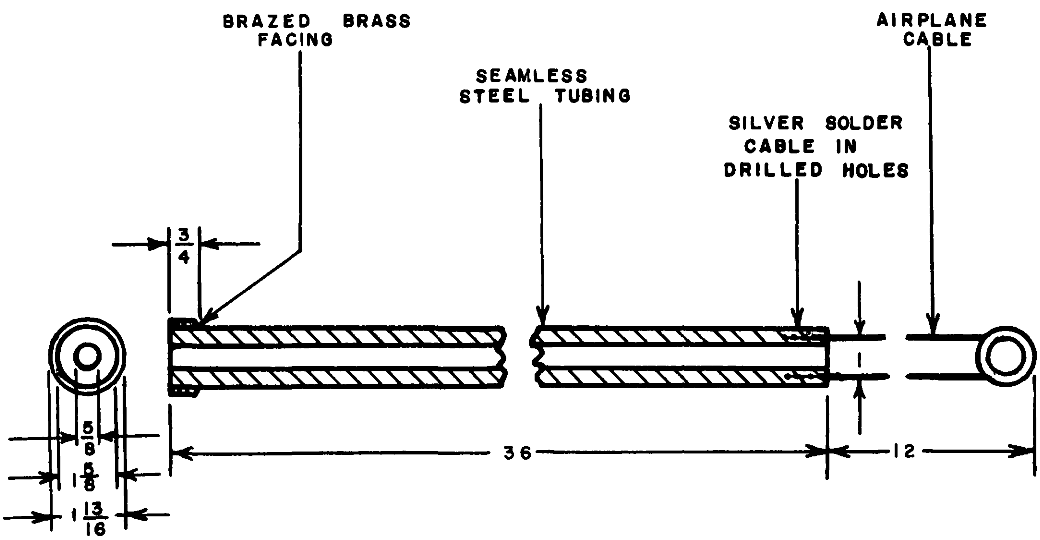

Figure 2.--Tamping hammer for piezometer installation; all dimensions are shown in inches (After Casagrande, 1946).

flat tamping face 3/16-inch larger in diameter than the hammer body. The hammer is rigged by means of a single loop and thimble through the grooved ring (fig. 2) to a 1/8-inch 7 by 19 galvanized preformed airplane cable passing through a snatch block over the casing to a hand reel. It is important that all parts of the hammer that may touch the plastic tubing be smooth and the edges rounded.

The purpose of the hammer is two fold: (a) To tamp the bentonite seal into place, and (b) to center the plastic standpipe while the seal is being tamped into place.

INSTALLATION

A cased hole is advanced to the elevation planned for the bottom of the piezometer. Two-inch-diameter pipe is recommended for the casing (Casagrande, 1946). The first section of casing should be at least 10 feet long, and it should not be provided with a coupling (or drive shoe) at its lower end. As the last 10 feet of casing is being driven, no washing should be done in advance of the bottom of the casing. This technique will assure a tight contact between the bottom 10 feet of casing and the surrounding soil.

The inside of the casing is washed clean to the bottom, then the wash water is entirely replaced by clear water. For a jetted hole, this is done by reversing the flow of the jetting pump and using the jet pipe--with its lower end a few inches above the bottom--as the intake. The casing is kept filled by the clear water being poured in until all the cloudy water is pumped out. For a drilled hole, clean water is circulated through the bit until the discharge is clear.

The casing is then pulled up 2 feet. This may be done by jacking or by a slip weight against a top coupling. It should be done just prior to backfilling with sand. After the casing is raised, saturated sand is poured in to fill about 2 feet at the bottom of the open hole, or to the bottom elevation of the porous point (fig. 3). Any washed and screened sand between No. 20 and No. 35 mesh may be used for this purpose. The sand must be thoroughly saturated before pouring it into the hole. The volume needed should be computed and closely controlled. Care should be taken to keep the sand from arching within the casing. This arching would render it impossible to get the porous point down below the bottom of the casing. It is recommended that the tamping hammer be used to check the height of the sand in the hole.

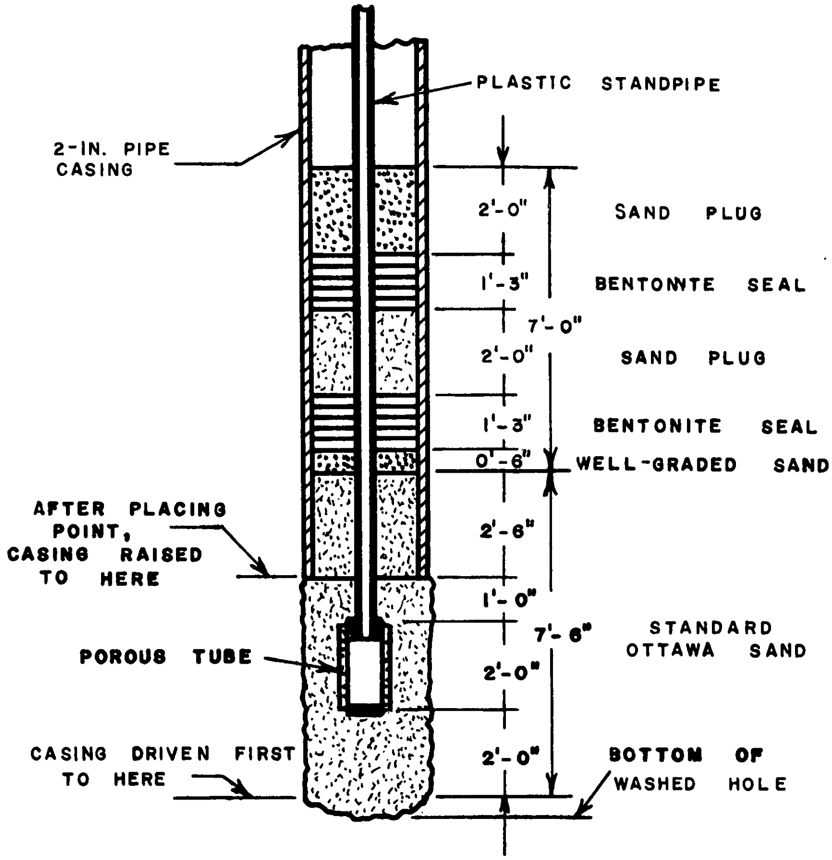

Figure 3.--Piezometer installation (After Casagrande, 1946).

The standpipe of the assembled piezometer is attached to a small tank. The point is immersed a few feet below the water surface in the casing and a vacuum is applied to the tank. The piezometer is filled in this way and a small reservoir of water is obtained in the tank. Saturation of the porous filter point may be expedited by soaking in warm water or by boiling in water prior to installation. While lowering the point to the bottom, a small excess head is maintained in the point to assure that a small amount of water will flow out of the point.

The elevation of the top of the point must be accurately determined during its installation by lowering the hammer and measuring the length of cable when the hammer is just resting on top of the point. For this purpose, it is convenient to have the cable marked off in 5-foot intervals by strips of tape, starting with zero feet at the working face of the hammer. The depth to, or elevation of, the porous filter point should be recorded to the nearest 0.1 foot.

With the point resting on the sand in the bottom of the hole, the casing is pulled up an additional 2 feet, corresponding to the desired elevation of the top of the point. Then saturated sand is poured in to fill the space around the point. The volume of sand needed for this operation easily can be computed and controlled. While pulling the casing up to its final position--or 1 foot above the top of the porous point--the open hole is backfilled with more saturated sand. Enough sand is poured into the casing to fill approximately the bottom 3 feet of the casing and then tamped by means of 10 blows of the hammer dropped 6 inches.

Bentonite is prepared to a putty-like state and formed into balls about three-eighths inches in diameter. The bentonite balls then are dropped through the water to the bottom of the casing. Five 3-inch layers, each one well tamped, provide an effective seal. To determine how many bentonite balls should be dropped into the casing to make one 3-inch layer, the water level in the casing is lowered until it is 3 inches from the top, and then enough balls are dropped down to raise the water level again to the top. Then, a 3/4-inch-thick layer of approximately 3/8-inch-diameter rounded pebbles is dropped on top of the bentonite layer to prevent the hammer from sticking. The hammer is next lowered onto the pebbles and 20 blows are applied by raising the hammer about 6 inches and allowing it to drop freely. This process is repeated until the five layers of bentonite are in place.[2]

A plug of graded sand, about 2 feet in length, is then added and tamped into place. As an additional precaution against leaking, another seal of five 3-inch layers of tamped bentonite should be placed on top of the sand plug (fig. 3). This second bentonite seal is placed as described above. The second bentonite seal should be capped with about 3 feet of sand, and the remainder of the hole may be left open if desired. Once construction is complete, the elevation of the top of the piezometer should be determined to the nearest 0.01 foot.

MEASUREMENT OF WATER LEVEL

The water level in the piezometer standpipe, when below the elevation permitting direct readings, is found by a simple electrical sounding device (Casagrande, 1946). A drawing of a contact tip and a sketch of the circuit are shown in figure 4.

A pair of No. 22 B and S Neoprene insulated 7/32 stranded wires are taped together and marked off for measuring.[3] The lower end of the sounding wire is weighted by wrapping with sheet lead (about 1/32-inch thick) in short sections. The sections should be about 1 inch long and spaced 1 inch apart. Fifteen such weights will keep the wire taut. Each weight should not be more than one-fourth inch in diameter and the sharp corners on it should be filed smooth. In putting the weights on the wire, care must be excerised that the insulation is not damaged.

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[2] Lambe (1959) describes a method for sealing the piezometers by use of a clay-chemical grout. The method proved to be much faster and more economical than the clay-ball method described here.

[3] Number 1248 shielded alpha microphone cable is recommended as more satisfactory to feed into the plastic tubing but requires a modified contact point (Casagrande, 1955).

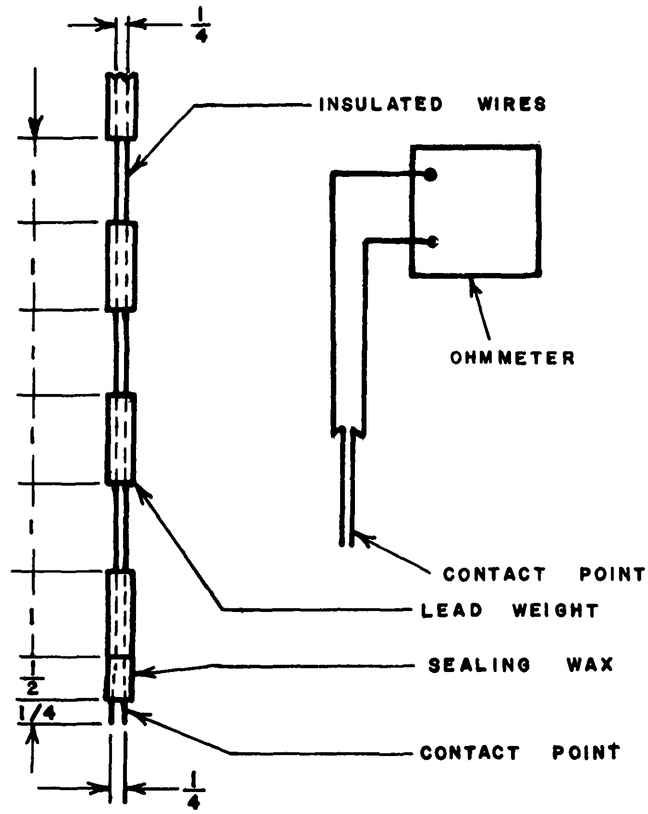

Figure 4.--Contact-point assembly; all dimensions are shown in inches (After Casagrande, 1946).

The contact point is made by baring the ends for about one-fourth inch and leaving a little less than one-fourth inch of space between them. Sealing wax applied above the bared ends will keep the contact points in shape.

This sounding wire is connected to a suitable ohmmeter and lowered to the water surface. When the bare ends touch the water, the hand on the ohmmeter is deflected, indicating that the circuit is closed. Resistance in such a circuit is relatively low, whereas it is infinite when not in contact with water.

The operator of this sounding device should note that as the points approach the water surface (possibly within 2 feet of it) often there is a slight movement of the hand on the ohmmeter. This probably is due to a thin film of water on the inside of the standpipe. However, if the points are gradually lowered further, there is a distinct jump of the hand as the points make contact with the water surface.

The entire tip (sealing wax and sides of the bared wires) should be covered with a film of grease at all times. If this is not done, the water will not always break free on withdrawing the contact point, and it may not be possible to check a reading by making and breaking the water contact several times in succession.

This device has been developed empirically (Casagrande, 1946) and is known to give satisfactory results. Deviations in construction may cause difficulties and should be tried before they are used. Several electrical water-level sounding devices are available commercially if the hydrologist does not prefer to construct his own.

If the pore pressure is so great that water is forced out of the top of the standpipe, the excess pressure can be measured by means of a Bourdon-gage installation. The details of such an installation are shown in figure 5.

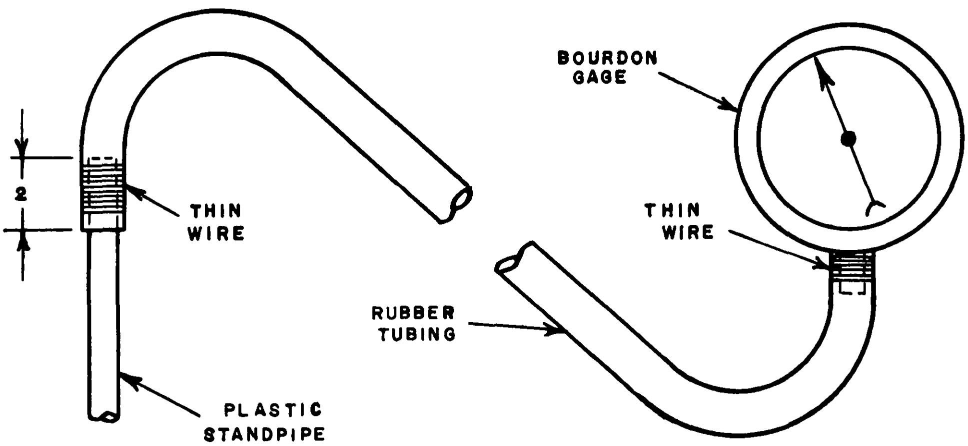

Figure 5.--Bourdon-gage installation
(After Casagrande, 1946).

With the water level at the top of the plastic standpipe, a 2-foot length of 3/8-inch-inside-diameter rubber pressure tubing is attached to the end of the standpipe. The threads on the connection to the Bourdon gage are filled with some adhesive to prevent leaking around the threads, and then the other end of the rubber tube is placed over this connection to the Bourdon gage. The ends of the rubber tube are made fast and leakproof to the standpipe and Bourdon gage by wrapping them tightly with soft copper wire.

The Bourdon gage then is fastened to a wall or stand in such a way that the center of the gage is not higher than the top of the standpipe. Whenever the pressure in the gage drops to zero, the Bourdon gage should be detached from the standpipe and readings made directly.

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