Pressure Cell for Soil Cores[1]

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Abstract

A design is presented for a small and economical pressure cell which can be used to determine the moisture characteristic of soil core samples contained in brass cylinders. By weighing the entire cell assembly after disconnecting it from a pressurized, regulated air supply, the moisture content of the sample can be determined to the nearest 0.03 g or ± 0.0004 volume fraction in a total volume of about 70 cm^3.

The cells are suitable for pressures up to 1 bar and are made of lucite and aluminum. Details on construction and operation are supplied and examples are given of reproducibility of results and of time of equilibration. Errors caused by evaporation losses are eliminated and positive contact between soil and retainer plate is maintained at all times.

The miniature pressure cell should be particularly adaptable for routine investigations where information on moisture characteristics is required on field soils.

The moisture characteristic of field soils, particularly at pressure potentials[3] slightly less than zero, should be determined using samples that have not been appreciably disturbed (3, page 225). Such samples are commonly obtained with some sort of cylinder sampler (core sampler), and equipment is required whereby the changing moisture content of the core sample can be measured as the pressure potential is varied.

The pressure cell principle as first proposed by Richards (2) is suitable and practical for such a purpose. It must be remembered that the equilibration time of a soil column in a pressure cell is dependent upon its height, Gardner (1), and for the procedure to be practical, column heights in excess of 4 or 5 cm are undesirable, thus limiting the size of the core sample to modest proportions. To find the time of equilibration and the final moisture content of the core sample, weighing is least conducive to errors. However, it is not practical to remove the core from its support for this purpose because of the difficulty of re-establishing good hydraulic contact between sample and porous plate.

Therefore, a small and simple pressure cell was designed that could be weighed in its entirety with adequate precision. Also, a piece of equipment that would be economically suitable for use in testing laboratories was desired.

Materials and Methods

Figure 1 shows the dimensions and assembly of the pressure cell. It is designed for the use of brass retainer cylinders as used in the soil sampler specified by the U. S. Salinity Laboratory (4). These cylinders are made of 19 gauge brass (0.11 cm), 1.180 inches (3.00 cm) high, and 2.250 inches (5.72 cm) outside diameter. For other sizes of retainer cylinders, the proper dimensions have to be worked out.

The porous plate is supported on the lucite bottom part, which is grooved for drainage. An O-ring prevents entry of air into the part of the cell below the porous plate. The top part of the cell, also made of lucite, is clamped to the bottom part with wing nuts, thus securing the retainer cylinder to the porous plate and insuring the O-ring seal between plate and bottom. Two types of porous plates are used, ceramic and monel. Ceramic plates are used where the moisture characteristic of a soil core from zero to -1000 millibars (mb) is desired, as the ceramic has a bubbling pressure of about 1400 mb. If, however, the moisture characteristic from zero to -200 mb is desired, monel plates are used, since the equilibration time is much less than with the ceramic plate. O-rings in the side of both the top and the bottom part secure the retainer ring sideways and prevent escape of air when the cell is pressurized. A list of materials needed in construction is given in Table 1.

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It is essential to fully saturate and deaerate the porous plate before placing the cell in operation. This is best accomplished by saturating the plate in a vacuum desiccator with deaerated distilled water. Following this, the drain tube of the cell is connected to a leveling bulb, the height of water in the bulb being at the same height as the bottom of the cell, and the porous plate is installed. Once the plate is in place, the leveling bulb is raised so the water level is just at the top of the porous plate. There should be no free water on the plate.

Next, the soil core in its retainer ring is placed in the bottom part; this is done by first gently twisting the retainer ring as it is being pushed down past the O-ring, and then firmly pressing the core onto the porous plate to insure good contact.

The core can now be saturated with water by means of the leveling bulb left at the height previously mentioned. The time required for saturation depends on the conductivity of the soil and of the porous plate. Once the core has been saturated, the top part of the cell is installed and the wing nuts tightened. The cell is now connected by means of a flexible rubber hose to a source of air of regulated and known pressure.

Immediately before the cell is weighed for the first time, any air present below the plate is expelled with a syringe filled with water. For this purpose, the cell is held upside down and water injected in the drainage tube. Some tilting of the cell and repeated shots of water are usually required. This filling procedure may be necessary before each weighing, so that the weight of the water in the bottom of the cells is constant. Inverting the cell seems to have no effect on the equilibrium status of the sample. The weight of the cell can be determined at any time by wiping off any droplet hanging from the drain tube and inserting a rubber policeman over the drainage tube to prevent air from being pulled through the drain tube into the drainage grooves when the air supply hose is disconnected and the cell is weighed. When using a porous plate of low conductivity, the rubber policeman may not have to be used. Weighing is done on an automatic, direct-reading balance[4] with a capacity of 800 g and a sensitivity of 0.03 g. The total weight of a cell with soil is around 500 g.

Pressure regulation and measurement can he done in several satisfactory ways. In our laboratory we use a regulator[5] for 0 to 1,000 mb operating range with a precision of about 2 mb. A central supply of compressed air is available. Pressure is measured with a precision gauge[6] with divisions for every 5 mb and a sensitivity of 2.5 mb. A small supply of water is kept in the regulated pressure line to prevent desiccation of the sample by back diffusion.

Any number of core samples may be handled simultaneously with as many pressure cells using a suitable manifold.

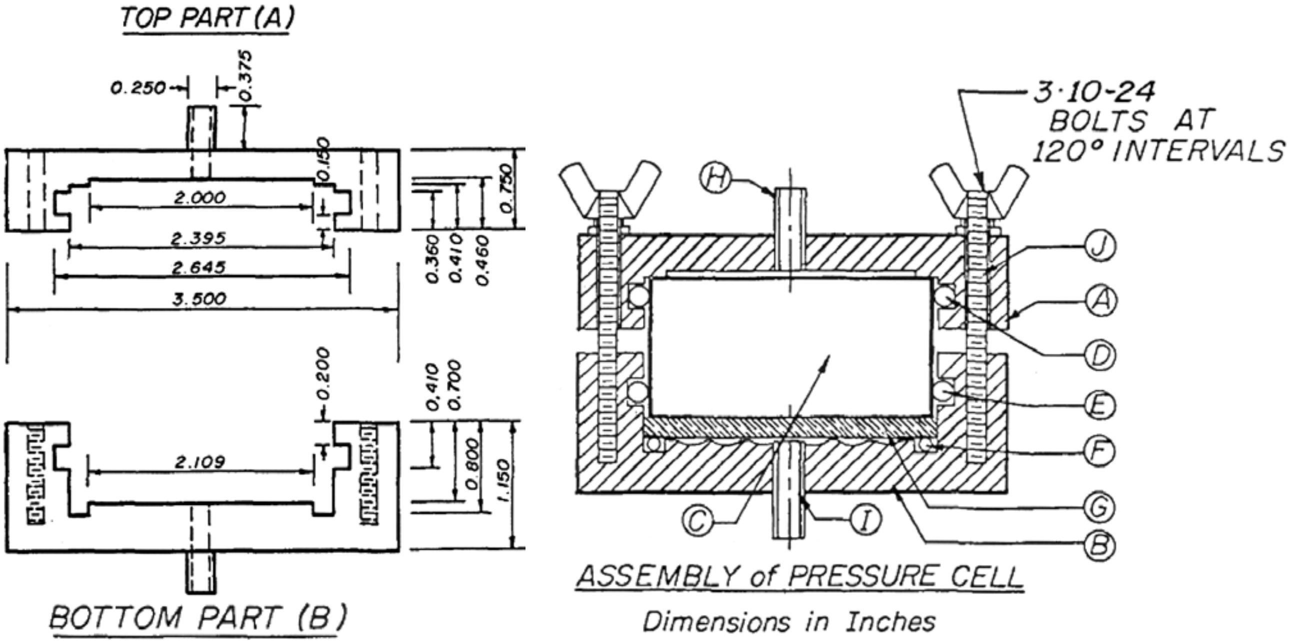

Figure 1. Dimensions and assembly of pressure cell.

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Table 1. Materials list (refer to figure 1).

A.	Top part of cell	3.5-inch cast clear plastic rod
B.	Bottom part of cell	3.5-inch cast clear plastic rod
C.	Brass sample retainer	Seamless brass tubing, 19 gauge, 2.250 O.D., height 1.180 inches
D.	Buna-N O-ring	O.D. 2.645 Inches, width 0.210 Inch, Parker No. 2-331
E.	Buna-N O-ring	O.D. 2.645 Inches, width 0.210 inch, Parker No. 2-331
F.	Buna-N O-ring	O.D. 2.387 Inches, width 0.139 Inch, Parker No. 2-227
G.	Circular porous plate*	Diameter 2.375 inches, thickness 0.200 inch or 0.125 inch
H.	Air connection	1/4-inch clear plastic tubing
I.	Drainage Tube	1/4-inch clear plastic tubing
J.	Clamp Bolts	10-24 by 2 inches brace machine screw and wing nut

* Ceramic Plates ≈ 1400 mb, bubbling pressure, No. 750 porous plate, Coors Porcelain Company, Golden, Colo. The circular ceramic plates are cut from a large rectangular plate; a disc is cut to approximate size on a cut-off machine and then desired diameter is obtained by turning the disc down on a lathe. Correct thickness is obtained by sanding. Care must be taken to insure that both sides of the disc are parallel. Monel Plates ≈ 200 mb, bubbling pressure, 1/8-inch Purolator Products, Rahway, N. J.

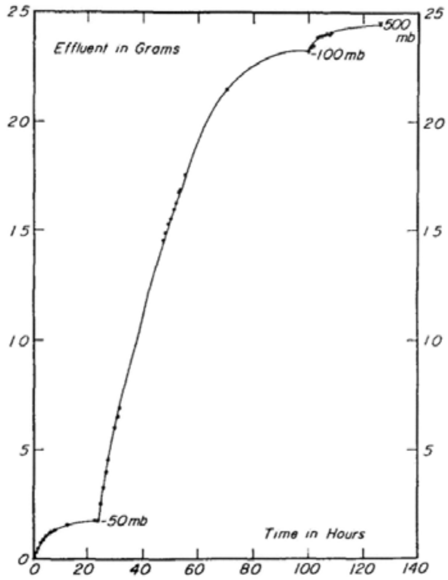

Figure 2. Amount of water released at three pressure potentials vs. time for 50–500µ sand using ceramic plate in cell.

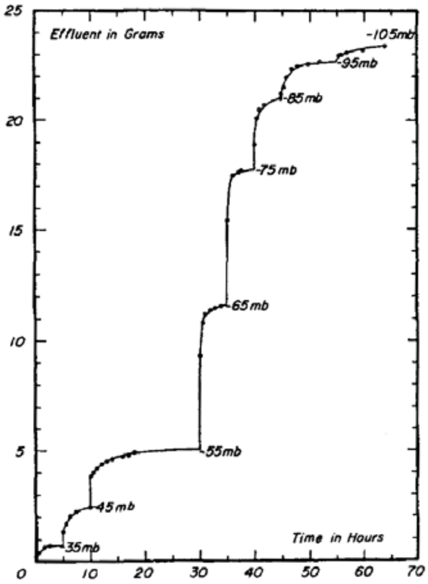

Figure 3. Amount of water released at eight pressure potentials vs. time for 50–500µ sand using monel plate in cell.

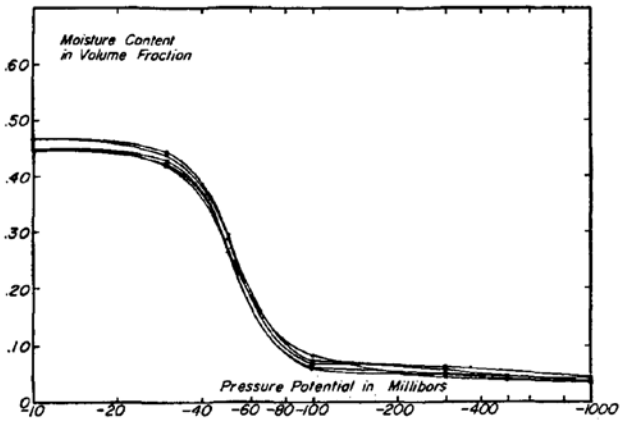

Figure 4. Moisture characteristic of 50–500µ sand. Five replicates are shown.

Results and Discussion

The time for equilibrium is determined by the conductance of the porous plate or of the soil core, whichever is smaller. The ceramic plate has a conductance of 0.025 g hr^{-1} mb^{-1} and a conductivity of about 5×10^{-4} cm hr^{-1}; thus, at pressure potentials near zero the plate will limit the outflow rate for many soils. However, the conductance of the porous monel plate is 68.9 g hr^{-1} mb^{-1}, while its conductivity is 0.7 cm hr^{-1}. The monel will probably not affect significantly the outflow rate of most soils even at pressure potentials near zero.

Using a ceramic plate in the cell, an example of the dependence of outflow upon time for sand (50 to 500µ) is given in figure 2. The sand drains most of the water held between -30 and -100 mb pressure potential with corresponding moisture contents of 0.430 and 0.070, respectively. From the 0 to -50 mb pressure potential interval which corresponds to a moisture content change of about 0.03 volume fraction, equilibrium requires more than 24 hours.

By substituting a porous monel plate for the ceramic plate, the equilibrium time is reduced considerably as seen in figure 3. From the 0 to -45 mb pressure potential interval which again corresponds to a moisture content change of about 0.03 volume fraction, equilibrium requires about 10 hours or less than half the time required by the ceramic.

It was stated before, however, that the bubbling pressure of the monel is about 200 mb while that of the ceramic material is about 1,400 mb. Therefore, the range of the moisture characteristic one is interested in will dictate the type of porous plate that is to be used.

An example of reproducibility is shown in figure 4, giving moisture characteristics of five samples of the same batch of 50 to 500µ sand. It appears that the apparatus gives consistent values.

Literature Cited

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2. Richards, L. A. Porous plate apparatus for measuring moisture retention and transmission by soil. Soil Sci. 66:105-110. 1948.
3. _______, and Weaver, L. R. Moisture retention by some irrigated soils as related to soil moisture tension. J. Agr. Res. 69:215-235. 1944.
4. U. S. Salinity Laboratory Staff. Diagnosis and improvement of saline and alkali soils. USDA Handbook 60. p. 159. 1954.

Footnotes

1 Contribution from Soil and Water Conservation Research Division, ARS, USDA. Presented before Div. I, Soil Science Society of America, Dec. 7, 1960, at Chicago, Ill. Received Feb. 11, 1961. Approved June 16, 1961.

2 Soil Scientist and Chief Soil Scientist, respectively, U. S. Water Conservation Laboratory, Southwest Branch, SWCRD, ARS, USDA, Tempe, Ariz.

3 The pressure potential of soil water, as used in this paper, is defined as the difference between the pressure of bulk water that is in hydraulic, chemical, and thermal equilibrium with the soil water at identical elevations across a boundary permeable only to water and solutes, and the pressure of the gas phase that is in contact with the soil water. Since, conventionally, flow is defined as taking place from points of high potential to points of low potential, the pressure potential should be progressively lower as soil moisture content decreases. The pressure potential, commonly measured in centimeters of water, bars, or atmospheres, can be measured conveniently, when positive, with a piezometer and, when negative but not less than -0.8 bar, with a tensiometer.

4 Balance: 800 g capacity, ±0.03 g accuracy, Mettler Instrument Company, Hightstown N. J.

5 Pressure Regulator: 0 to 15 psi, #40-15, Moore Products Company, Philadelphia 24, Pennsylvania.

6 Pressure Gauge: 0 to 1,000 mb, FH 141700, Wallace and Tiernan, Inc., 25 Main Street, Belleville N.J.

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