INSTRUCTION MANUAL

PRESSUREMETER

Model PENCEL

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1 DESCRIPTION

The PENCEL pressuremeter is designed to perform pressuremeter tests using lightweight drilling equipment on sites where the use of heavy drill rigs are impractical. The probe is set in place by pressing it to the test depth or by direct driving from ground surface or from within a predrilled borehole.

The PENCEL consists of three main elements:

The probes

Hollow model:

The hollow mono-cellular probe is comprised of a zinc plated steel tube on which an inflatable metallic sheath is mounted. The sheath is held in place using two tapered metal rings and two lock nuts. The probe is fitted with a quick disconnect at its upper extremity and a saturation plug at its lower extremity. The quick connect accepts the tubing leading from the pressure-volume control unit. The plug is used for saturating the probe. A drive point screws onto the lower end of the probe and an adaptor, which accepts EW or AW drill rod screws onto the upper end of the probe. The total length of the probe is 580 mm and its maximum deflated diameter is 32.1 mm which is slightly less than the diameter of a standard static penetrometer cone. The hollow center probe can be used in series with the static cone penetrometer.

Solid model:

The mono-cellular probe is comprised of zinc plated steel tube on which an inflatable metallic sheath is mounted. The sheath is held in place using two tapered metal rings and two lock nuts. The probe is fitted with quick disconnects at both extremities. One accepts the tubing leading from the pressure-volume control unit and the other accepts the saturation tubing. A drive point screws onto the base of the probe. An adaptor which accepts EW or AW drill rod screws onto the top of the probe.

The Control Unit

The control unit consists of a ABS enclosure supported on an aluminium tripod and containing a piston cylinder assembly, pressure gage, volume counter, control valves and tubing connectors.

The Tubing

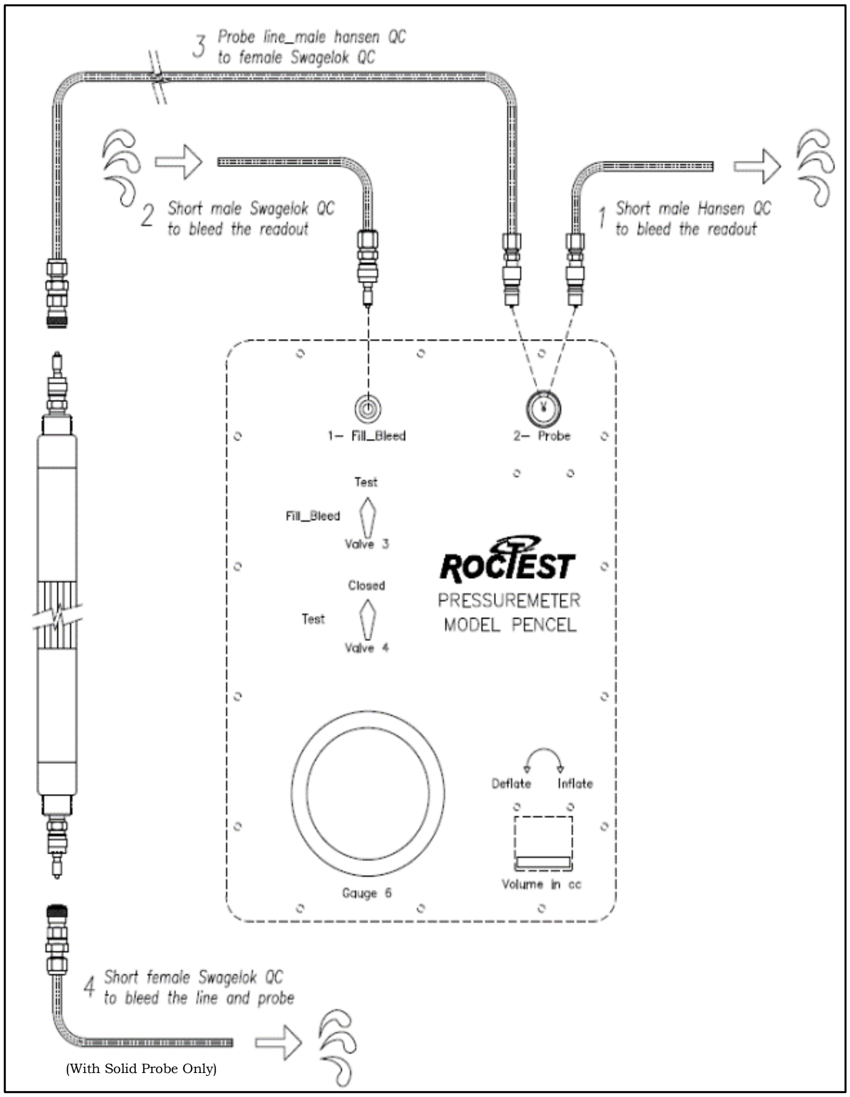
The tubing consists of a single conduit fitted with shut-off quick connectors at both ends, which allows the probe or tubing to be detached without de-saturating the circuit.

2 FILLING AND SATURATING THE PRESSUREMETER

A 1000 cm3 capacity container filled with clean water is required for this operation. Should any risks of freezing occur, the water must be replaced by windshield washer. THE UNIT SHOULD BE CLEANED WITH FRESH WATER WHEN NOT USED.

Saturation of the Control Unit:

1. Pressure gage adjustment. The pressure gage should read 0. If not, use the following procedures to set the needle to zero.
   - Unscrew the knurled plug located at the upper back face of the pressure gage.
   - Set the pressure gage needle to zero using a small screwdriver.
   - Put back the knurled plug.



Front Panel of the 2500-kPa PENCEL Control Unit

2. Connect the short tubing fitted with the male quick connect to the **FILL-BLEED (1)** port on the front panel.

3. Place **VALVE 3** in the **FILL-BLEED** position and **VALVE 4** in the **CLOSED** position.

4. Submerge the plain end of the filling tube in the container filled with water or the antifreeze mixture.

5. Rotate the crank handle clockwise (i.e. in the **INFLATE** direction) to bring forward the piston in its foremost position within the cylinder. The numerical volume counter will indicate 138 +/- 1 cm^3 (or cc).

6. Rotate the crank handle in the **DEFLATE** direction at a maximum speed of one revolution per second until the volume counter indicates 0 cm^3. The cylinder is now full of liquid.

7. To remove air in the cylinder or in the tubing, transfer 100 cm^3 from the cylinder back into the container. To do so, rotate the crank handle in the **INFLATE** direction until the volume counter reads 100 cm^3.

8. Repeat step 6 to refill the cylinder.

9. Connect the short hose to the **PROBE (2)** quick connect on the front panel. Place **VALVES 3** and **4** in the **TEST** position. Rotate the crank handle in the **INFLATE** direction until air-free water flows out on the short hose. Disconnect the short hose from **PROBE (2),** and refill the unit following steps **3** and **6** above.

10. The control unit is now fully saturated. The user can now check it and saturate the 10-m tubing and probe as indicated below.

<u>Saturation of the Tubing & Probe:</u>

11. Connect the tubing to the probe. Lay out the drive rods side by side in the proper sequence for subsequent assembly. The rod couplings should alternate between male and female. The drill rod couplings should have been previously drilled out with an oversized hole of 16 mm in diameter to enable the passage of the male quick connect at the end of the tubing. Thread the tubing through the rod string beginning with the rod with a male coupling. Unscrew the drive point from the base of the probe. With the hollow probe, remove the cap on the saturation plug located at the base of the probe. With the solid probe, hook up the short tubing fitted with a female quick connect to the base of the probe.

12. Connect the tubing to the **PROBE (2)** quick connect on the front panel.

13. Place **VALVE 3** and **VALVE 4** in the **TEST** position. Rotate the crank handle in the **INFLATE** direction. During this operation, the probe must be held in an inverted vertical position with the center at the same height as the pressure gage of the control unit. In this position, the saturation plug points upward. A short hose should be connected to the solid Pencel probe for allowing water to flow out the probe – see image above. When using a hollow Pencel probe, simply remove the saturation plug at the tip of the probe.

14. Stop cranking when air-free water flows out the probe. Place **VALVE 4** in the **CLOSED** position and **VALVE 3** in the **FILL-BLEED** position. Refill the cylinder by rotating the crank handle in the **DEFLATE** direction with a maximum speed of one revolution per second until the volume counter indicates 0 cm^3, as described in step 6. Make sure that the free end of the filling tubing always remains submerged.

15. Repeat last two steps until no air bubbles emerges from the saturation plug or tubing.

16. For hollow probe: Screw the cap back onto the plug.
    For solid probe: Disconnect the short saturation tubing from the probe.
    Screw the drive point back onto the threads at the base of the probe.

17. Disconnect the probe tubing from the front panel **PROBE 2**. The probe and the tubing can then be transported in a saturated mode.

Verifiaction of the Control Unit:

18. Disconnect all tubing from the control unit. Place **VALVE 3** and **VALVE 4** in the **TEST** position.

19. Pressurize the cylinder until the pressure gauge reaches the maximum range. This is done by turning the crank in the **INFLATE** direction. Verify that the volume necessary for this operation is less than 5 cm^3, and also that after about two minutes, the pressure stabilizes.

20. If the volume necessary to carry previous step is more than 5 cm^3, the saturation of the system is inadequate. It is then necessary to bring back the pressure to zero and to repeat the saturation operations.

21. If the pressure cannot be stabilized, there is a leak in the internal circuitry. Open the unit by removing the front panel and locate the leak by pressurizing the cylinder. Repair as required. The saturation must be repeated from the beginning and the volume counter must be brought back to 0.

3 CALIBRATION

Two calibrations are required. One is the **Pressure Loss Calibration** and the other is the **Volume Loss Calibration**. The calibrations have the following purposes:

1. To determine the pressure correction necessary to annul the inertia of the membrane. The inertia is the pressure required to dilate the probe to a specific volume when the probe is confined only by atmospheric pressure.

2. To determine the volume correction caused by the parasitic expansion in the tesing unit. This is the small difference between the injected volume that is read on the meter and the real increase in volume of the probe.

3.1 PRESSURE LOSS CALIBRATION (PRESSURE CORRECTION)

The pressure correction curve is also called the inertia curve of the probe membrane. To determine the pressure correction curve, proceed as follows:

Make sure the whole system is saturated. Connect the probe to the control unit and place it vertically at ground level next to the unit. Place **VALVE 3** and **VALVE 4** in the **TEST** position, inflate and deflate the probe five times by injecting 90 cm^3 in order to knead a new membrane. When deflating the probe do not rotate faster than one rotation per second.

1. Rotate the crank handle clockwise at a rate of one revolution every 9 seconds, until 5 cm^3 have been injected.
2. Stop the injection, wait 30 seconds and record the pressure, which corresponds to 5 cm^3 injection.
3. Continue this procedure until 90 cm^3 is injected.
4. Slowly rotate the crank handle counter clockwise to bring the piston to its initial position. The volume counter should indicate 0 cm^3.

The inertia curve is the plot of the pressure versus the injected volume. It is required for interpretation of the test data and must be established for each new membrane mounted on a probe. The inertia should also be verified at the beginning of a test and at regular intervals during testing procedures.

3.2 VOLUME LOSS CALIBRATION (VOLUME CORRECTION)

The volume correction is required to correct the injected volume as read on the counter for the volume losses due to the system's intrinsic deformation under pressure. To determine the correction proceed as follows:

1. Place **VALVE 3** and **VALVE 4** in the **TEST** position. Make sure the whole system is saturated. Connect the probe to the control unit and place it in a calibration tube such as the one supplied. The calibration can be any thick wall tube with an inside diameter of around 34 mm.
2. Inflate the probe (in the tube) by injecting water in increments of 200 kPa. After a waiting period of 1 minute, record the pressure and volume for each increment. Continue to inject and record pressure up to 2000 kPa.
3. Deflate the probe by bringing the volume counter back to zero.
4. Plot Volume Calibration curve.

Either one or both of the calibration tests described above should be performed when any one of the following conditions are met:

- If a protective sheath is replaced.
- If the same protective sheath has been used for a large number of tests, the calibration should be checked.
- If the tubing has to be changed.
- If the ambient temperature at the test location or in the borehole is substantially different from the temperature that prevailed during the last calibration.

It should be emphasized that calibration tests are important if one wants to arrive at representative results. It is recommended to calibrate regularly.

4 PROBE INSERTION

The PENCEL probe is set in place by pushing or light hammering. In this case, the probe is connected to hollow EW drill rods with an external diameter of 34.9 mm. **The standard inside diameter of the coupling is reamed from 12.7 mm to 16 mm.** The tubing beginning with the upper end, which connects to the control panel, is threaded from bottom to top through the rods. The diameter of the quick connect at the upper end of the tubing is 15 mm.

Rods with an inside diameter of at least 16 mm may be used instead of EW rods. An EW male coupling must be fabricated for the connection to the probe. A slotted anvil adapted for the pushing or driving systems is screwed to the upper end of the rods. The slot allows the passage of the tubing.
Do not forget to put a locking ring on the quick connector between the probe and the tubing for avoiding accidental disconnection of the probe in the ground.

Another option consists in making the test cavity by driving a 35-mm OD steel rod. The rod is then removed and the probe is inserted.

In dense soils, the probe could be damaged by the driving. A pilot hole of 35 mm Ø can be drilled.

5 TESTING PROCEDURES

5.1 VOLUME CONTROLLED TEST

Once the probe has been set at the test depth and **VALVE 3** and **VALVE 4** are in the **TEST** position, the testing can then be carried out in increments of equal volume. The increment of increasing volume is 5 cm^3 and the corresponding pressure is noted 30 seconds after having injected the 5 cm^3. The maximum volume injected is 90 cm^3. This results in a test with 18 volume increments and test duration of about 10 minutes.

It is possible to carry on cyclic load cycles during a test, by injecting and then withdrawing a preselected volume of liquid (by deflating the probe).

When the test is complete, prior to either removing the probe from the hole or pushing it to a lower level the probe must be deflated by returning the water to the cylinder.

5.2 STRESS CONTROLLED TEST

This method is more difficult to execute. It may be used for tests in over consolidated soil or during creep test.

1. Lower the probe to the test depth.

2. Place **VALVE 3** and **VALVE 4** in the **TEST** position.

3. Using the crank handle, set the pressure gage reading to the first pressure step corresponding to less than 1/10 of the estimated limit pressure.

4. Maintain the pressure at this value and record the counter readings, 30 seconds, 60 seconds after the pressure step has been reached.

5. When the loading phase of the test is completed, return the piston to its initial position by turning the crank handle counter clockwise at a slow rate until the counter indicates 0 cm^3.

6 INTERPRETATION

The first step of the interpretation consists in plotting the raw pressuremeter curve (pressure vs volume) as well as the corrected pressuremeter curve. For each point on the raw curve there corresponds a point on the corrected curve with coordinates of corrected pressure and corrected volume. The corrected point is obtained by subtracting the volume correction and the pressure correction from the raw pressure and volume data. The corrected pressure must also include the hydrostatic pressure equivalent to the head of liquid between the pressure gauge and the center of the probe.

Thus:

V corrected = V read - V calibration
P corrected = P read - P calibration + P hydrostatic

Calculations can be done based on the normal pressuremeter procedures. This gives:

The limit pressure P_l
The deformation modulus E

NOTE: ASK ROCTEST FOR A FREE COPY OF *PENCELCOMPANION* : A SPREADSHEET FOR DATA REDUCTION

6.1 LIMIT PRESSURE

The limit pressure is not necessarily modified by remoulding of the ground due to the driving of the probe. Theoretically the limit pressure corresponds to that required to double the initial volume Vo of the probe, which in the case of the PENCEL probe corresponds to a theoretical volume of 192 cm^3 and an inflated diameter of 45 mm. The limit pressure is obtained by extrapolating the corrected pressuremeter curve beyond the injected volume of 90 cm^3.

6.2 DEFORMATION MODULUS

The modulus E is calculated in the pseudo-elastic phase of the test. This corresponds to the quasi-linear part of the pressuremeter curve.

$$E = \frac{2\,(1 + \mu)\,(Vo + Vm)\,(P2 - P1)}{(V2 - V1)}$$

where:

µ	=	Poisson's ratio = 0.33
Vo	=	initial probe volume = 192 cm^3
Vm	=	the mean volume injected at midpoint of the linear part of the curve for which the modulus is calculated.
P2-P1	=	increase of pressure P corresponding to the increase of volume V2-V1

Example:
If the curve is linear between 30 and 60 cm^3 and the values are as follows:

V1 = 30 cc   P1 = 200 kPa
V2 = 60 cc   P2 = 1000 kPa

Then:

$$Vm = \frac{V1 + V2}{2} = 45\ cm^3 \quad V2\text{-}V1 = 30\ cc \quad P2\text{-}P1 = 800\ kPa$$

$$E = \frac{2.66\ (192 + 45)\ 800}{30} = 16\ 819\ kPa$$

Due to soil disturbance, the modulus value obtained with a driven probe may be slightly different from a value obtained by placing the probe in a drilled hole. For example, the values obtained in saturated granular materials at depths greater than 10 meters are either the same or less than those obtained in drill holes.

For more information about the test itself and the treatment of the modulus and limit pressure values, the reader is referred to the different manuals and books bearing the subject, especially the ASTM standard D4719–00 and the Note D.60.AN available from Roctest.

7 PENCEL PROBE MEMBRANE REPLACEMENT

1. Unscrew the two brass knurled nuts.

2. Place the threaded end of the probe in the bench vice adapter or grasp with plastic covered jaws in order to prevent damage to the thread.

3. Remove the plain tapered ring at the free end of the probe by rotating the ring clockwise while pulling at the same time. If not possible to do by hand, wrap a strap wrench around the knurled part of the ring. A pipe tube wrench should not be used, due of the danger of deforming the ring.

4. Repeat the same operation on the ring at the other end of the probe.

5. Remove the membrane.

6. Place a new membrane and center it over the body of the probe.

7. Tighten a hose clamp at a distance of 2 cm from the end of the metallic strips to enable the tapered ring to slide over the beginning of the strips.

8. Grease the inside of the tapered ring and the tape covering the end of the metallic strips with a very small amount of silicone base grease.

9. Push the tapered ring over the end of the metallic strips until the threads on the probe are visible. Thread the brass-knurled nut onto the end of the probe.

10. Repeat steps 7, 8 and 9 for the other end of the probe.

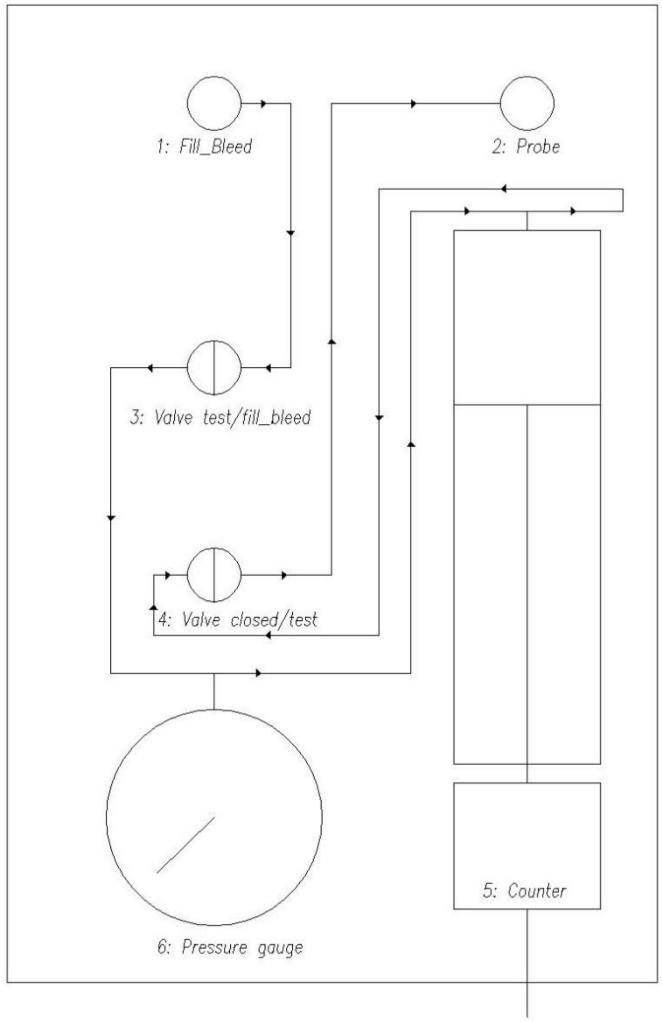
11. Check that the membrane is well centred lengthwise over the probe. Position the tapered rings as required to center the membrane by screwing the brass nuts inwards or outwards.

12. Screw in the brass nuts with a strapped wrench in equal amounts until the distance between the inside edge of the steel rings is 24 cm. At this point about 2.5 cm of thread will be showing at both ends of the probe.

13. The probe is now ready for calibration.

8 APPENDIX

Probe Components and Accessories		
A	Probe to AW rod adapter	20-1026002032
B	Probe to EW rod adapter	20-1026002039
C	Hollow PENCEL Probe 2500 kPa (assembled)	FR-1026050300
D	Saturation Plug for the Hollow PENCEL Probe	05-R03LA3C
E	Quick Connect Locking Ring	20-1026002033
F	Tubing with fittings to connect solid probe to control unit, 10 m length	40-1026040700
G	PENCEL solid probe 2500 kPa (assembled)	FR-1026050200
H	Drive Point for hollow/solid probe	20-1026002030/38
I	Probe to bench vice adaptor	20-1026002040
J	PENCEL solid probe 2500 kPa Body with Swagelok quick connector	20-1026002035
K	Pencel Metallic sheath	40-1026040600
L	Sheath external Ring for 2500 kPa probe	20-1026002034
M	Cover Nut for probe	20-1026002037



PENCEL SCHEMATIC DIAGRAM