INSTRUCTIONS MANUAL

FLEXIBLE DILATOMETER

Model DMP

© Roctest Limited, 2003, 2017, 2018, 2021, 2023, 2026. All rights reserved.

This product should be installed and operated only by qualified personnel. Its misuse is potentially dangerous. The Company makes no warranty as to the information furnished in this manual and assumes no liability for damages resulting from the installation or use of this product. The information herein is subject to change without notification.

Tel. : 1.450.465.1113 • 1.877.ROCTEST (Canada, USA) • 33 (1) 64.06.40.80 (Europe) • www.roctest.com • www.telemac.com

E10182-260128

TABLE OF CONTENTS

1 EQUIPMENT 2

2 OPERATING INSTRUCTIONS 3
2.1 Assembling the Equipment 3
2.2 Using the DP Box 4
2.2.1 Description 4
2.2.2 Installing the DP BOX READER APPS 5
2.2.3 Connecting and Turning on the DP Box 5
2.2.4 DP BOX READER APPS 6
2.3 Testing Procedure 12
2.4 Modulus Calculation 14

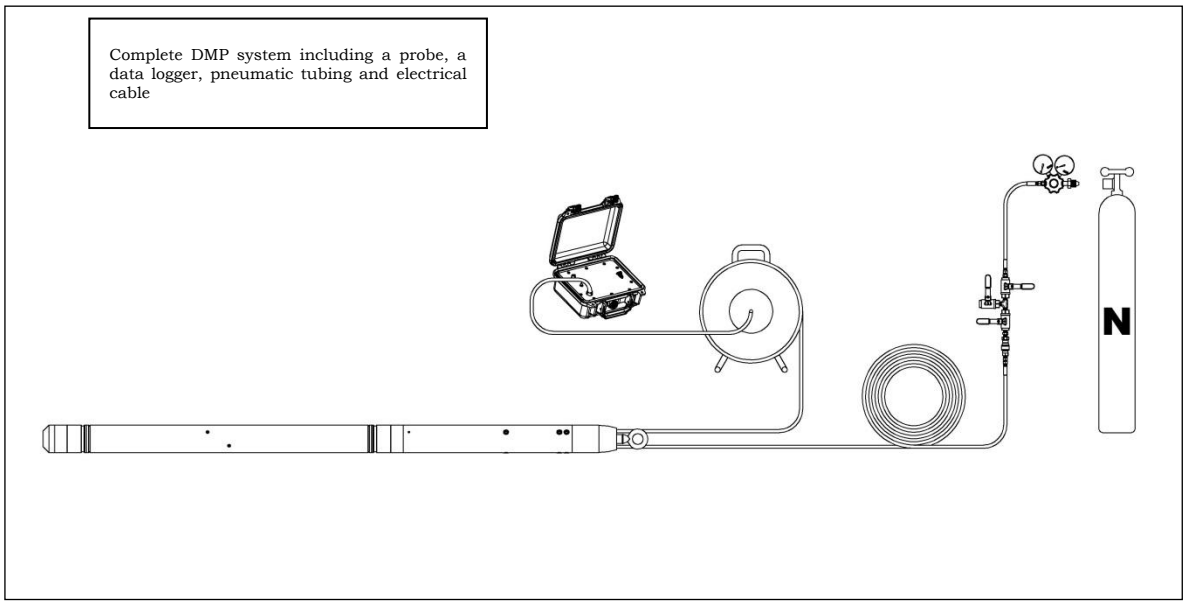
3 APPENDIXES 15
3.1 Typical Calibration Sheet 15
3.2 Assembling the Membrane 16
3.3 Disassembling the Membrane 18
3.4 Recommended Tools and Spare Parts 19
3.5 Evaluation of Measurement Accuracy 21

1 EQUIPMENT

The DMP is a Flexible Dilatometer designed for estimating in situ the rock mass deformability following the ISO 22476-5 Standard. It is available in two sizes: 95 mm for use in a 101-mm borehole, and 90 mm for use in a 96-mm borehole. A sediment collector is located on top of the probe. The probe is usually inflated with compressed gas. The borehole dilatometer test consists in loading the ground in progressive steps and to measuring the diametrical deformation resulting from this loading.

For running a test, the probe will be used with the following accessories:

- A Flexible Pneumatic Tubing with Connectors, a Pressure Regulator & Valves
- An Electrical Cable
- A Datalogger (DP Box)
- A Spare Membrane(s) and the membrane assembling tool (see appendix)



DMP System (Assembled)

The probe consists of a cylindrical body and includes:

- An inflatable membrane (rubber sleeve) equipped with three pairs of metallic inserts spaced at 120° intervals
- A split spring-ring and double cone membrane retaining system
- Three pairs of inductive displacement sensors with two measurement points each
- One reference displacement sensor for temperature compensation
- A pressure sensor allowing to measure pressure in the probe
- A sediment collector

DMP Probe

A	Eyebolt on a rod for connection to a wire or to rods
B	Sediment collector
C	Module integrating reference sensor, pressure sensor, and electronic circuit
D	Set of rings for holding the membrane in place
E	Expandable membrane
F	Displacement sensors' location
G	Bottom cap

The dilatometer probe has a total length of 1.8 m. The expandable part of the membrane is 1-m long. The probe is connected to a datalogger enabling reading of all sensors located in the probe. The raw readings are automatically converted in engineering units by the readout using the conversion factors determined during factory calibration.

2 OPERATING INSTRUCTIONS

2.1 ASSEMBLING THE EQUIPMENT

The equipment is assembled as follows:

- Connect the electrical cable between the probe and the DP Box readout. Turn on the DP Box and make sure that sensors in the probe are reading properly.
- Connect the pneumatic tubing between the probe and the valves. Install the pressure regulator on a tank filled with nitrogen, and connect the valves to it. Make sure gas pressure in the tank is sufficient for reaching maximum test pressure expected during the calibration & test. If possible, fix the valve kit to a table or to a piece of wood using C-clamps. This will make handling of these valves easier.
- If the membrane has to be replaced, please refer to the procedure given in appendix.

The equipment is now ready for use.

2.2 USING THE DP BOX

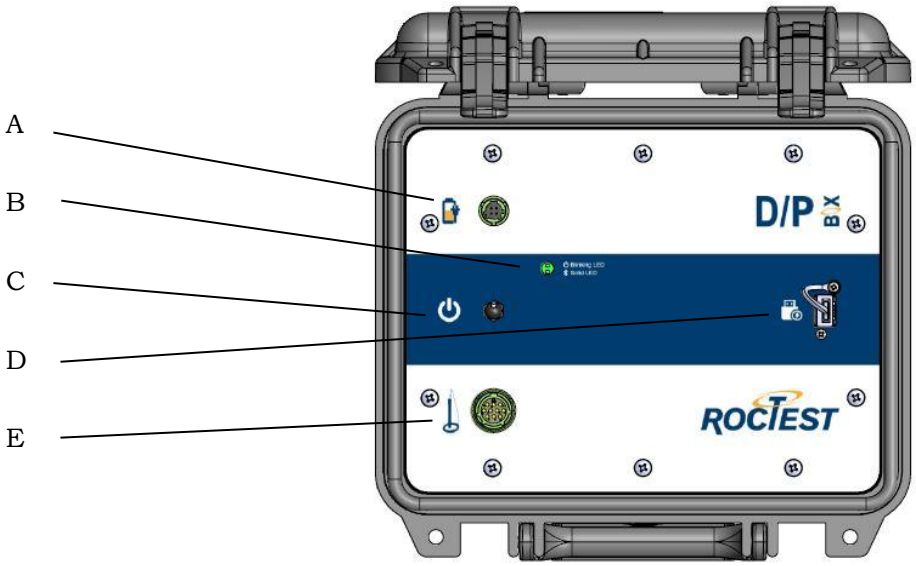
2.2.1 DESCRIPTION

DP BOX communicating with a tablet by Bluetooth

The DP BOX is designed for reading and logging measurements obtained from pressuremeters and dilatometers manufactured by Roctest (including models DMP, TEXAM and PROBEX). Thanks to the Bluetooth communication feature and to the DP Box READER Application, the DP Box can be used in conjunction with a tablet for reading the sensors, for configuring a calibration or a testing session, for visualizing the test results in real time, and for reviewing any test data. These test data can easily be uploaded to a laptop via USB communication. The DP Box comes in a convenient water proof enclosure and is fitted with two 12-V rechargeable batteries providing over 8 hours of autonomy in normal conditions. The DP Box also comes with cable Universal AC wall plug with US/Euro adapter + adapter cable for car (lighter) and for external battery. The battery should be charged every night. A charging circuit limits charge time to a certain level.

The front panel is splash proof allowing the use the equipment in wet conditions. However, do not let the readout with the cover lifted under the rain over extended period of time; otherwise water could get into the unit.

The DP Box is compatible with Android-based tablet model.



DP BOX Front Panel

SEE THE INSTRUCTION MANUAL SPECIFIC TO YOUR DP BOX FOR MORE DETAILS

A	Cannon connector for charging the DP Box batteries
B	LED indicating communication status The Bluetooth LED blinks slowly when the Bluetooth radio waits for a connection, then glows faster when the connection is established.
C	Switch for turning ON / OFF the unit
D	USB port
E	10-pin connector for connecting the dilatometer / pressuremeter

2.2.2 INSTALLING THE DP BOX READER APPS

Prior from using the DP Box, the DP Box READER Application should be first installed on a tablet. This apps can be downloaded from Roctest / Telemac web site.

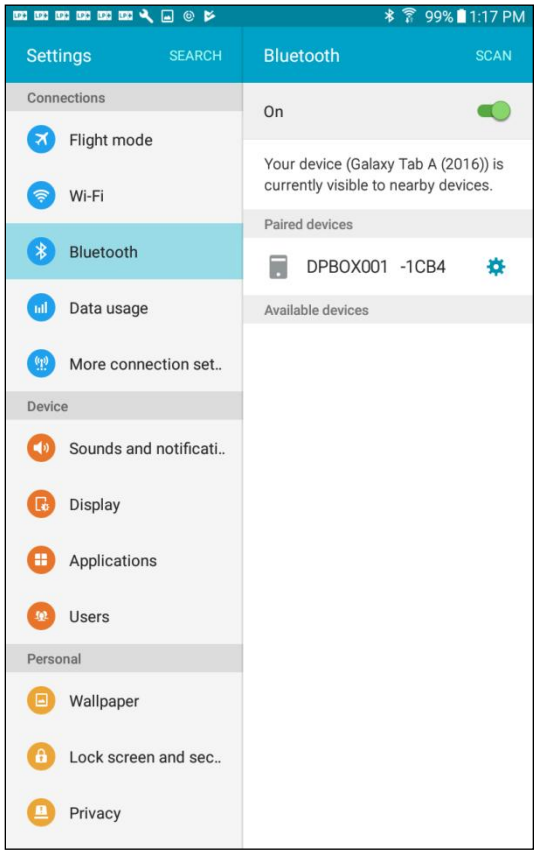
2.2.3 CONNECTING AND TURNING ON THE DP BOX

Connect the electrical cable of the testing equipment to the DP Box.

Turn on the DP Box. The LED on the front panel will then blink. Turn on the Tablet. Go in the Tablet Setup and make sure that the DP Box is available and paired with the tablet. If the tablet has been previously paired with another DP Box, you need first to erase the files automatically generated in *'Device Storage/DP BOXFiles/ConfigFile'*. Then you should be able to pair the tablet with another DP Box.

Set up the tablet as follows:

- Adjust the Display in 'Outdoor Mode' if necessary. But note that this will reduce the tablet autonomy.
- Adjust the screen timeout (typically 5 min)
- Make sure tablet is adjusted for dot-delimited numbers
- Make sure the battery voltage of the tablet is high enough for use.



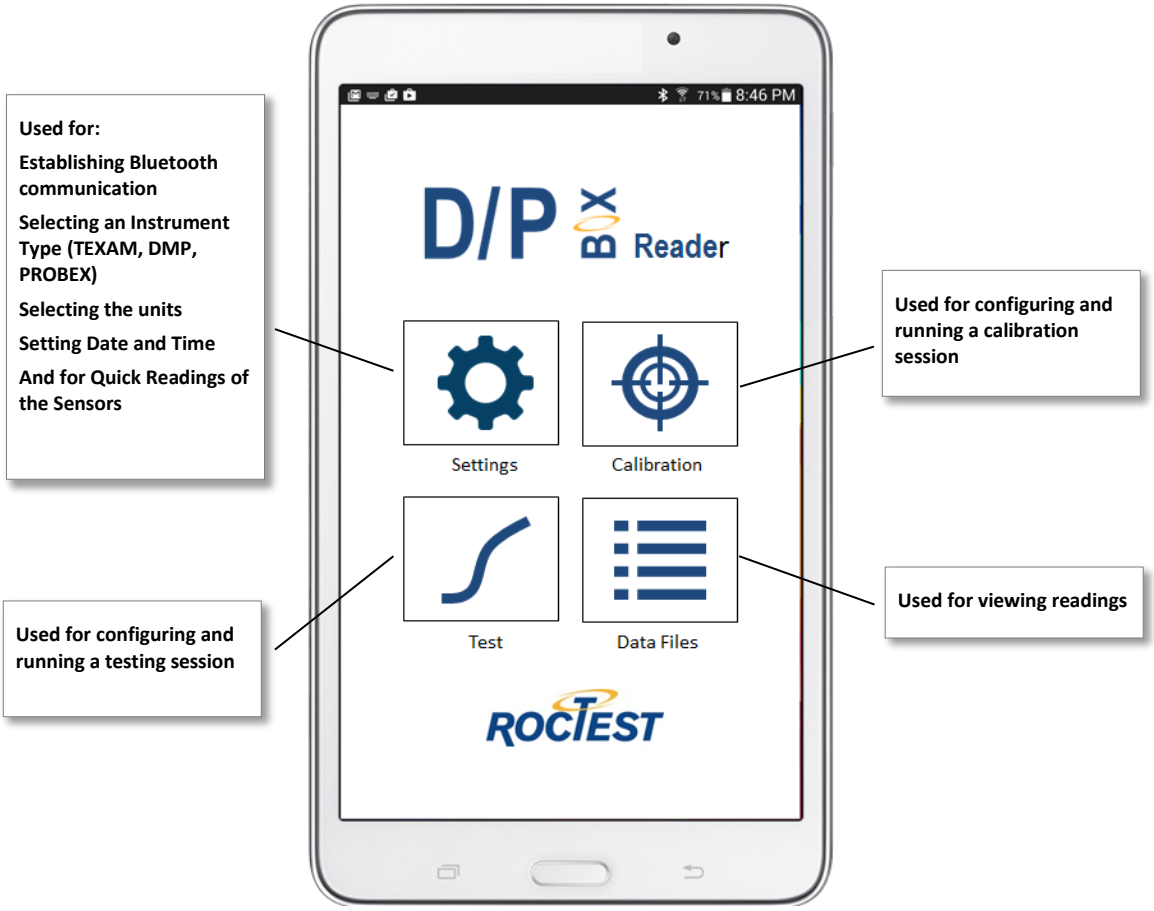
Open the DP Box Apps and go in 'Settings / Quick Reading' for establishing Bluetooth communication between the DP Box and the tablet, which will be confirmed when the DP box LED will blink quicker (see below for more information).

2.2.4 DP BOX READER APPS

The DP Box Application allows configuring the unit, reading and logging the data, and reviewing the results.

2.2.4.1 MAIN MENU

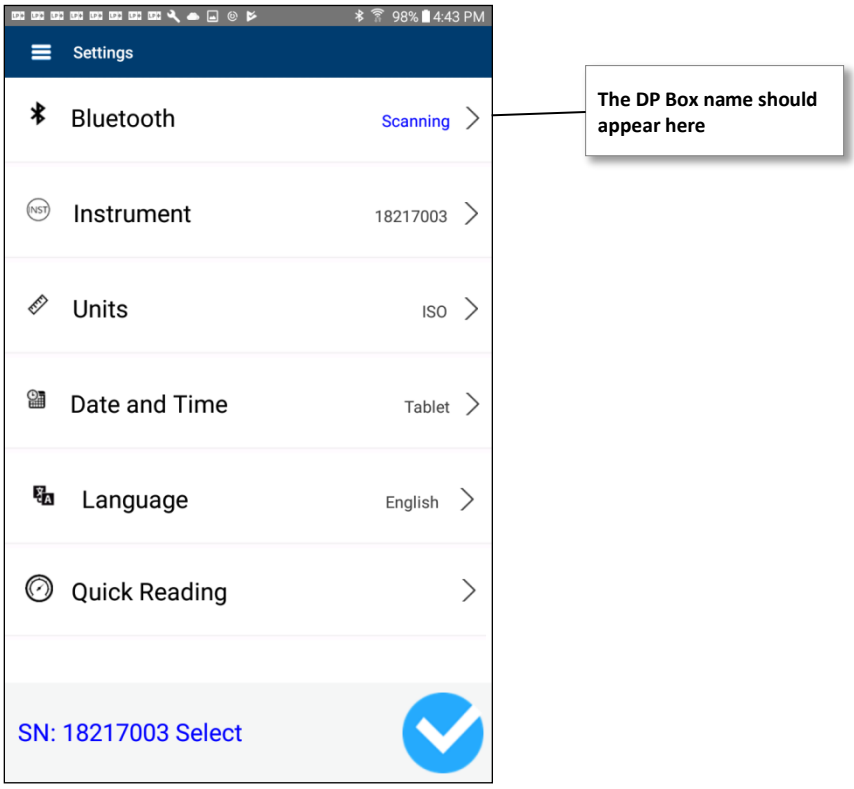
Main menu of the applications includes the following elements:



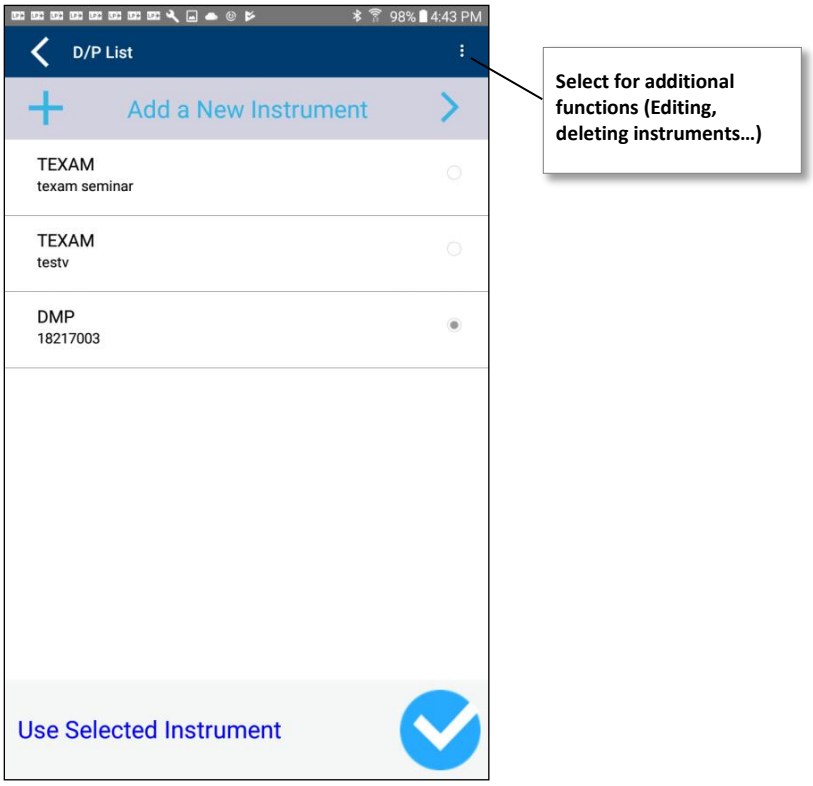
DP Box Apps Main Menu

2.2.4.2 USING THE DP BOX APPS WITH THE DMP

First Go in *'Settings'*. The APPS will automatically scan for establishing Bluetooth communication with the DP BOX which takes a few seconds. The name of the DP Box will then replace the 'Scanning' inscription.



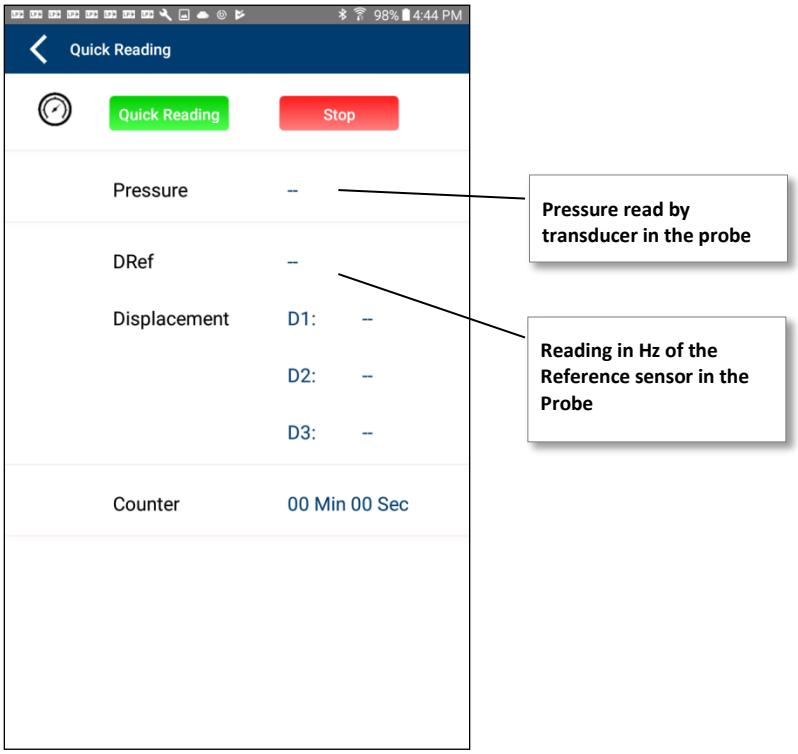
Go in *'Instrument/ Add a New Instrument'*, Select the Type of instrument (DMP) and enter the serial number of the probe (e.g. 18217003).



Make sure the conversion factors associated to this instrument have been entered. Refer to the calibration certificate. For doing so, go in *'Settings/ Calibration/ Review Factory Calibration'*. For changing these factors, select *'Change factory calibration'*, make the appropriate changes and select 'Save new factory calibration' at the bottom of the screen.

Set the units (typically ISO), then set the date and time of the tablet if necessary.

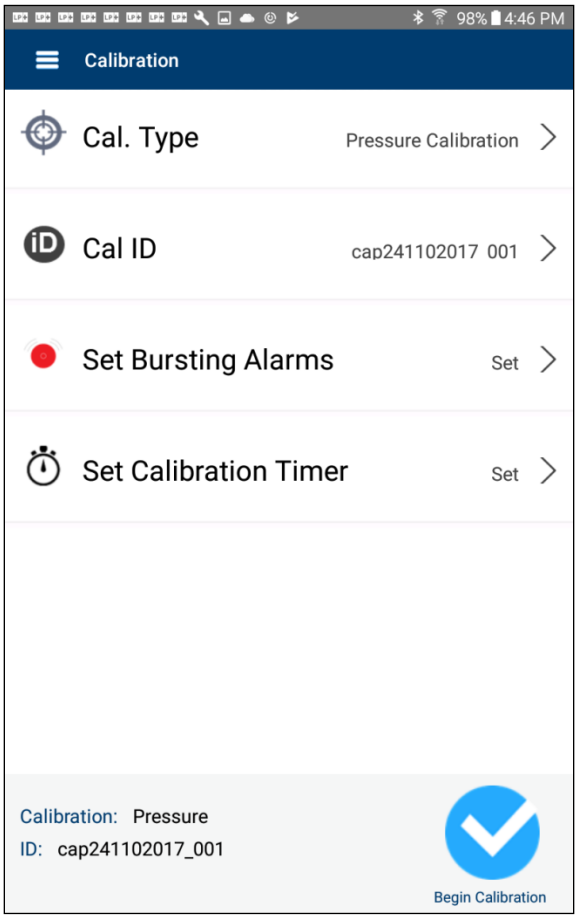
Go in *'Quick Readings'* and press the green button *'Quick Reading'*.



Two types of calibrations can be done, one with the probe unconfined *('Pressure Calibration'*) and one with the probe confined *('Displacement Calibration')*. See next section for more details.

For configuring a calibration, go *to 'Calibration'*, select the type, give a calibration ID, and set the calibration timer. For configuring a test, go to *'Test'* and proceed the same way.

Note : Never include any special characters (#,%,\...) in a Calibration or Test ID.



Typical set up:

	ID [1]	Bursting Alarm (mm) [2]	Timer (sec)
Pressure loss calibration	*'CAP*+Date'	Level 1: 15 Level 2: 20	Contact: 10 Regular: 10
Displacement calibration	*'CAD*+Date'	Level 1: 14 Level 2: 18	Contact: 10 Regular: 30
Test	*'TE*+Date'	Level 1: 14 Level 2: 18	Contact: 10 Regular: 30

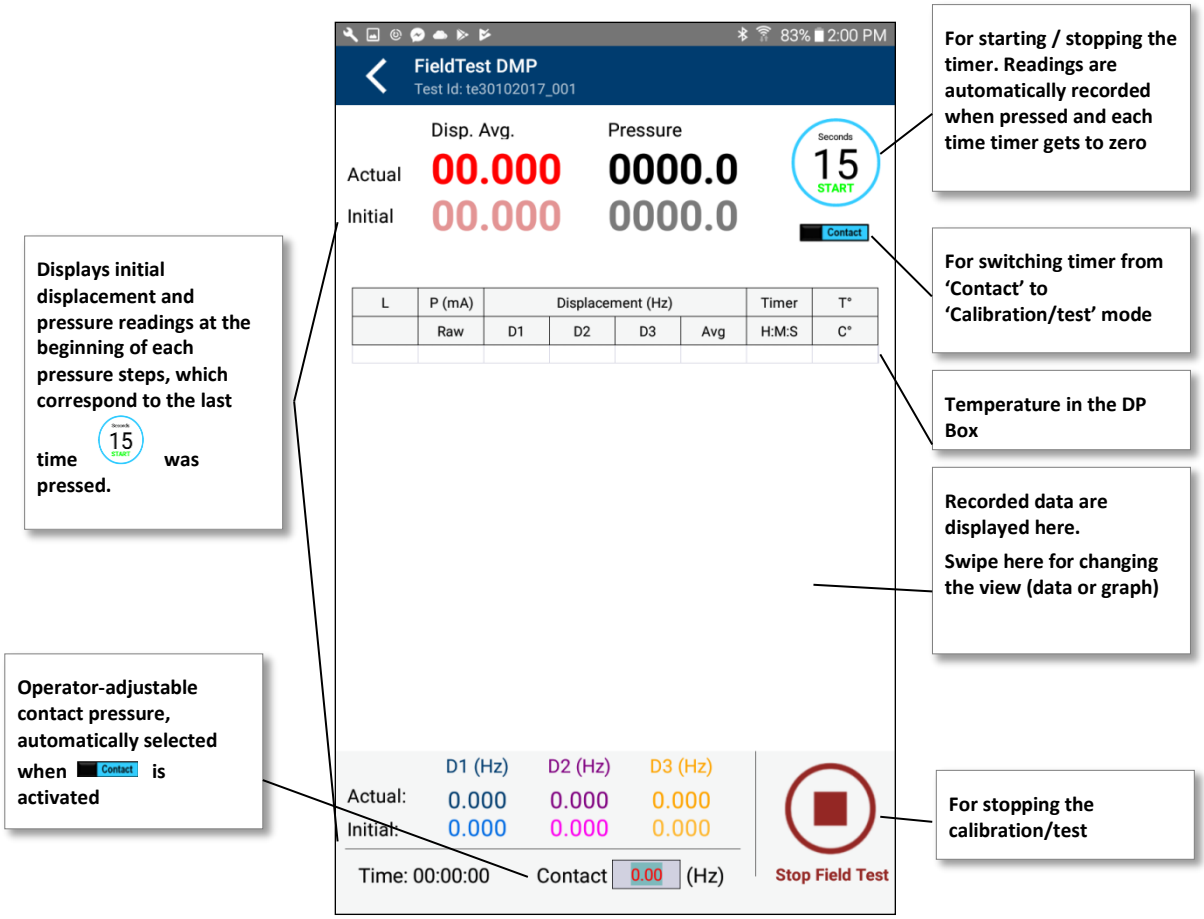
[1] *The Apps will automatically increment selected ID*

[2] *The Apps will stop to read when level 2 is reached*

Once setup is completed, select : '*Begin Calibration / Test'* to start.

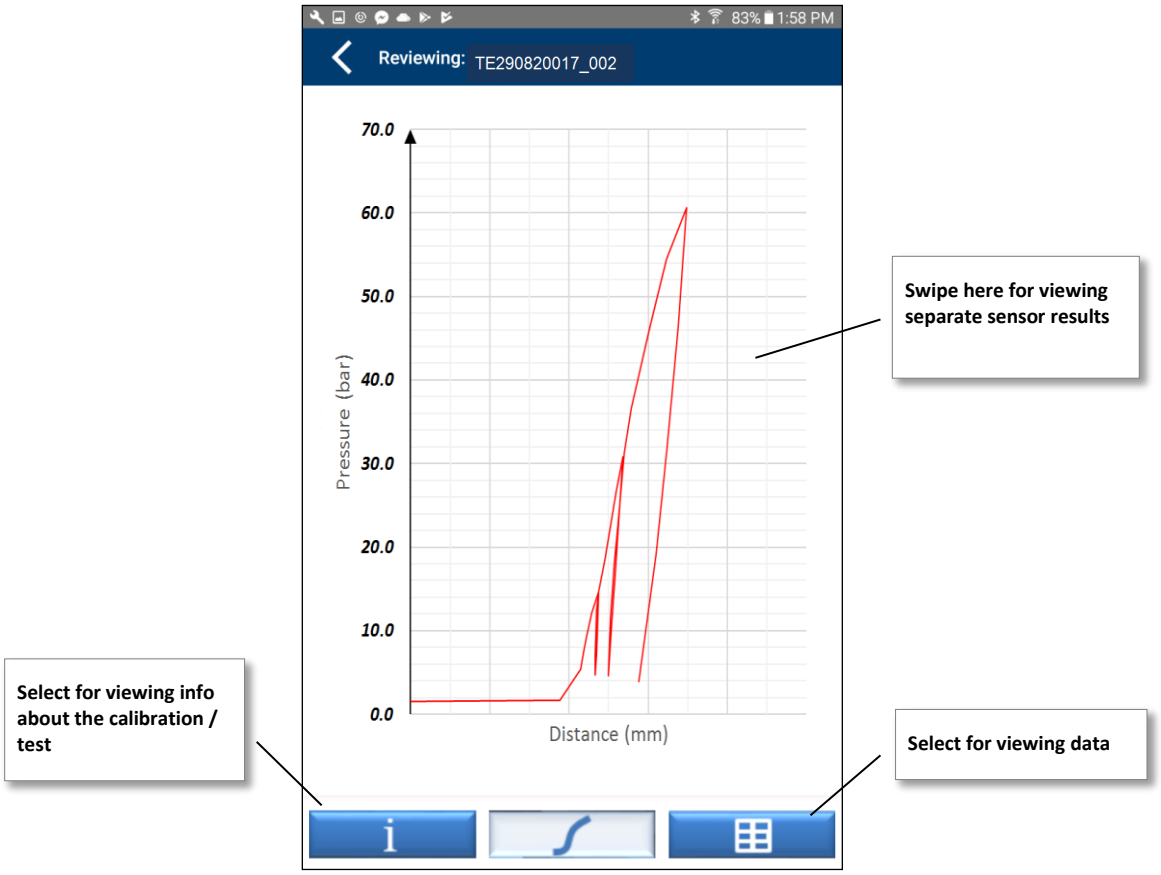
Once calibration or testing is started, a window like the one below will be displayed.

After saving the initial readings, the operator should press *'Start'* for initiating the timer. When ready to increase pressure to the next pressure step, press *'Stop'*, increase pressure and press *'Start'*. After reaching the contact pressure, press *'Contact'*. This will switch the timer from the *'Contact'* mode to the *'Calibration or test'* mode.



When the calibration or test is over, press on :

For reviewing results, go to *'Data Files'*, the select *'Calibration'* or *'Field Test'*. Then select the specific file you want to see.



2.3 TESTING PROCEDURE

Some general testing procedure guidelines are given below but for specific details, please refer to the procedures described in the ISO 22476-5 : 2012 Standard.

The DMP should be periodically checked and calibrated to show that it provides reliable and accurate measurements. A Pressure Loss Calibration performed with the probe unconfined will show a membrane resistance typically between 200 and 300 kPa at 15 mm of diametrical expansion. A Displacement Calibration consists in pressurizing the probe in a thick steel tube (6 mm min) and making sure that displacements are negligible i.e. similar to the steel tube expected expansion. A 96-mm ID casing is recommended for the DMP90, and a 101-mm ID casing is recommended for the DMP 95.

Tests are done in a 96 or 101 mm drill Core diameter borehole depending on the model of DMP used. The Dilatometer probe is lowered down in the borehole at the desired depth using a string of rods. The test begins by inflating the probe in little pressure steps (about 20, 50,150, 200 & 500 kPa) to determine the contact pressure i.e. the pressure at which the membrane of the probe gets in contact with the borehole walls. This will allow determining exact diameter of the borehole.

Then loading of the rock can be done following one of the procedures described in the ISO 22476-5 : 2012 Standard. The pressure is increased and decreased by steps. At each of these steps, pressure is maintained during 1-3 minutes during which diametrical measurements will be measured. Typically, three progressive load-unload cycles will be done. A complete test will typically last about 4 hours.

Risk of bursting the membrane

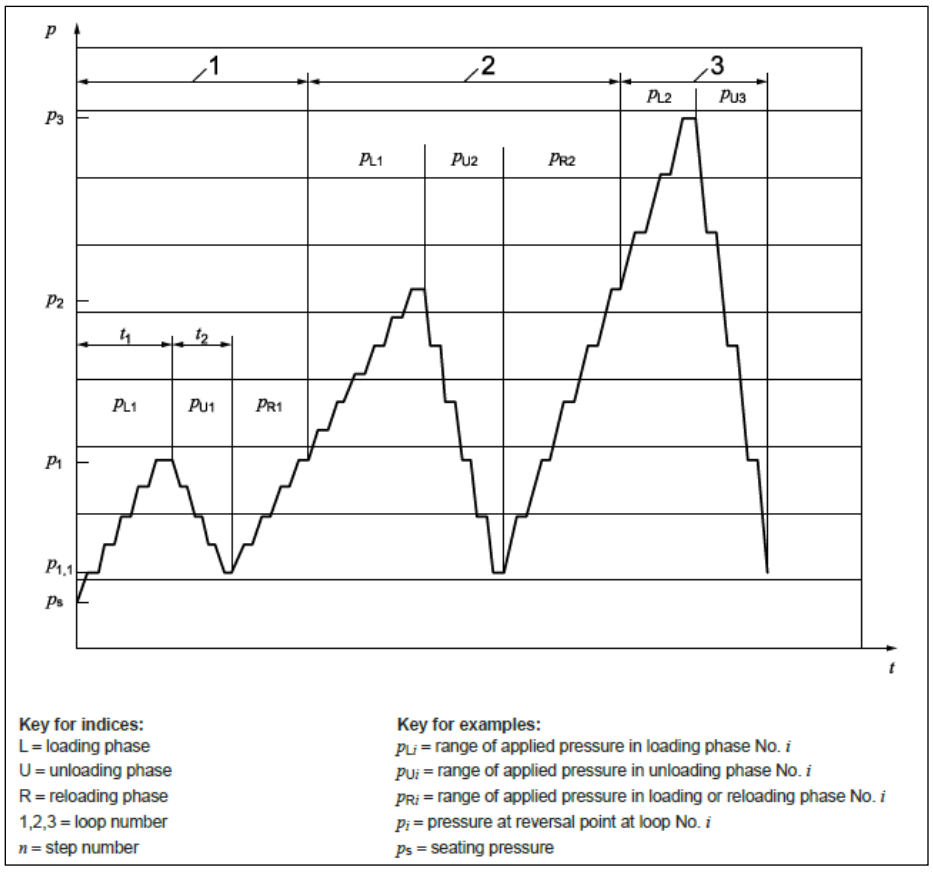
It is suggested to never exceed the following values during a test:

- 15 mm at 5000 kPa
- 10 mm at 10 000 kPa
- 8 mm at 15 000 kPa

These values apply in a tight borehole i.e. when contact with the borehole wall is made under 6 mm.

The risks of membrane failure will be reduced if the above values are not exceeded. However, it will not provide a 100% protection.

In all cases, never exceed 19 or 20 mm with any of the sensors during a test. Otherwise, sensors could move out from the probe's body.



Typical loading phases of a Flexible Dilatometer Test
(Extract from ISO 22476-5 : 2012 Standard)

2.4 MODULUS CALCULATION

The pressure vs diametrical deformation should be plotted for each sensor, but more importantly for the average of these three sensors.

Then Shear (G) or Flexible Dilatometer (E) Moduli will be calculated on various sections of the load-unload cycles using the following formulae.

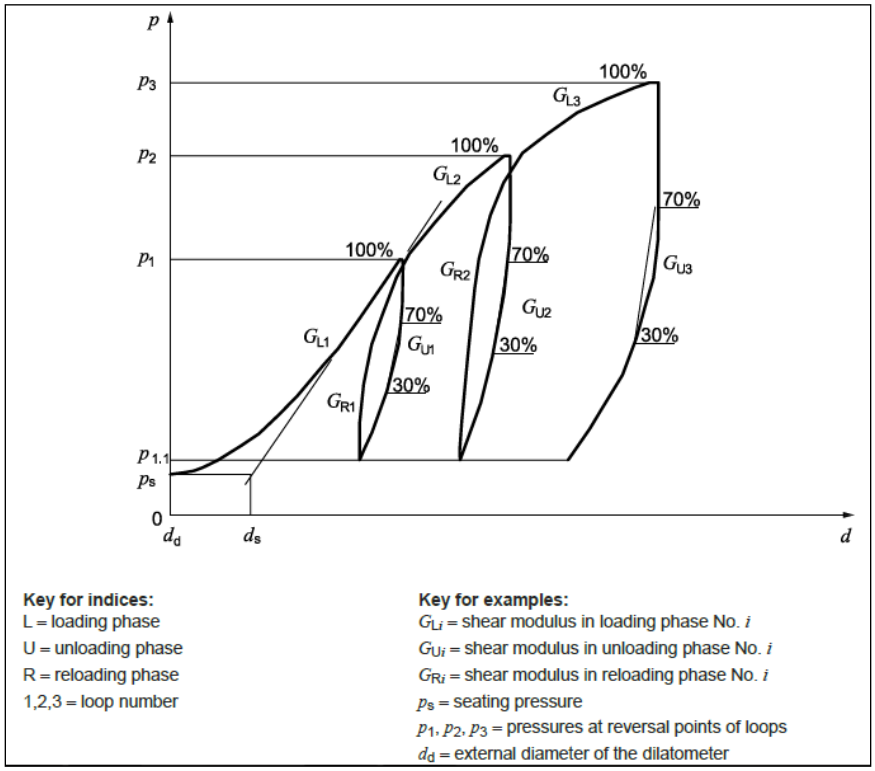
$$G = 0.5 \, \emptyset \, P/d$$

$$E = (1 + \nu) \, \emptyset \, P/d$$

with :

- ν : Poisson factor of rock (often taken equal to 0.25 or 0.30)
- ∅ : initial diameter of the borehole (mm)
- P : pressure (MPa)
- d : diametrical deformation (mm)

See ISO 22476-5 Standard for more details



Typical Pressure-Deformation (average) of a Flexible Dilatometer Test

(Extract from ISO 22476-5 Standard)

3 APPENDIXES

3.1 TYPICAL CALIBRATION SHEET

TELEMAC

www.telemac.com • www.roctest.com

Calibration Sheet : RTT-18/004

Customer :	Telemac	Type :	DMP 95	S. N. :	18201800004

Displacement	Reading unit			Relative Displacement			Absolute Error			Linearity *		
	Sensor 1	Sensor 2	Sensor 3	Sensor 1	Sensor 2	Sensor 3	Sensor 1	Capt.2	Sensor 3	Sensor 1	Sensor 2	Sensor 3
(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
0	0.058	0.072	0.083									
1	1.021	1.145	1.022	0.963	1.073	0.939	-0.037	0.073	-0.061	-0.185%	0.365%	-0.306%
2	2.007	2.142	1.992	0.986	0.997	0.970	-0.014	-0.003	-0.030	-0.070%	-0.015%	-0.151%
3	2.987	3.109	2.961	0.980	0.967	0.969	-0.020	-0.033	-0.031	-0.100%	-0.165%	-0.156%
4	3.989	4.083	3.952	1.002	0.974	0.991	0.002	-0.026	-0.009	0.010%	-0.130%	-0.045%
5	5.006	5.073	4.983	1.017	0.990	1.031	0.017	-0.010	0.031	0.085%	-0.050%	0.156%
6	6.025	6.089	6.017	1.019	1.016	1.034	0.019	0.016	0.034	0.095%	0.080%	0.171%
7	7.038	7.096	7.037	1.013	1.007	1.020	0.013	0.007	0.020	0.065%	0.035%	0.100%
8	8.051	8.101	8.058	1.013	1.005	1.021	0.013	0.005	0.021	0.065%	0.025%	0.105%
9	9.049	9.107	9.050	0.998	1.006	0.992	-0.002	0.006	-0.008	-0.010%	0.030%	-0.040%
10	10.039	10.103	10.032	0.990	0.996	0.982	-0.010	-0.004	-0.018	-0.050%	-0.020%	-0.090%
11	11.021	11.097	11.007	0.982	0.994	0.975	-0.018	-0.006	-0.025	-0.090%	-0.030%	-0.126%
12	12.010	12.088	11.980	0.989	0.991	0.973	-0.011	-0.009	-0.027	-0.055%	-0.045%	-0.136%
13	12.993	13.078	12.965	0.983	0.990	0.985	-0.017	-0.010	-0.015	-0.085%	-0.050%	-0.075%
14	14.002	14.074	13.957	1.009	0.996	0.992	0.009	-0.004	-0.008	0.045%	-0.020%	-0.040%
15	15.013	15.074	14.965	1.011	1.000	1.008	0.011	0.000	0.008	0.055%	0.000%	0.040%
16	16.023	16.082	15.993	1.010	1.008	1.028	0.010	0.008	0.028	0.050%	0.040%	0.141%
17	17.041	17.092	17.020	1.018	1.010	1.027	0.018	0.010	0.027	0.090%	0.050%	0.136%
18	18.056	18.106	18.043	1.015	1.014	1.023	0.015	0.014	0.023	0.075%	0.070%	0.116%
19	19.036	19.110	19.042	0.980	1.004	0.999	-0.020	0.004	-0.001	-0.100%	0.020%	-0.005%
20	20.034	20.097	19.992	0.998	0.987	0.950	-0.002	-0.013	-0.050	-0.010%	-0.065%	-0.251%

Conversion Factors

Sens. 1 (S1) (Hz/mm)

-5.07437090E-17	(K4)	a
1.53291718E-11	(K3)	b
-1.73417304E-06	(K2)	c
8.79857286E-02	(K1)	d
-1.68851350E+03	(K0)	e

Sens. 2 (S2) (Hz/mm)

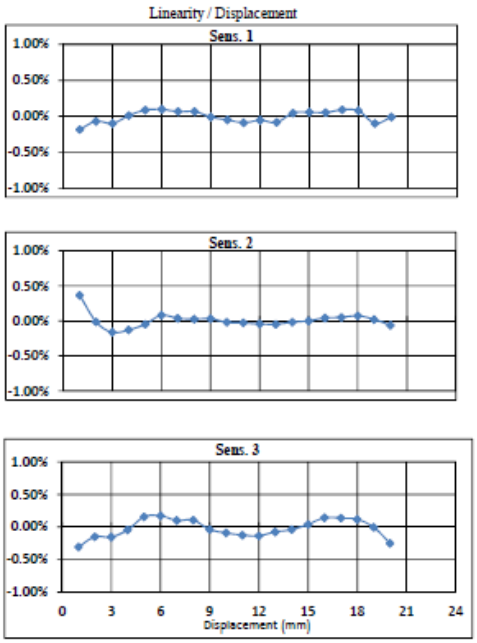
-1.28285837E-17	(K4)	a
4.71004532E-12	(K3)	b
-6.21140097E-07	(K2)	c
3.62647657E-02	(K1)	d
-7.90548858E+02	(K0)	e

Sens. 3 (S3) (Hz/mm)

-1.18370051E-16	(K4)	a
3.44871378E-11	(K3)	b
-3.76654818E-06	(K2)	c
1.83707885E-01	(K1)	d
-3.37780933E+03	(K0)	e

Pressure sensor (kPa/mA)

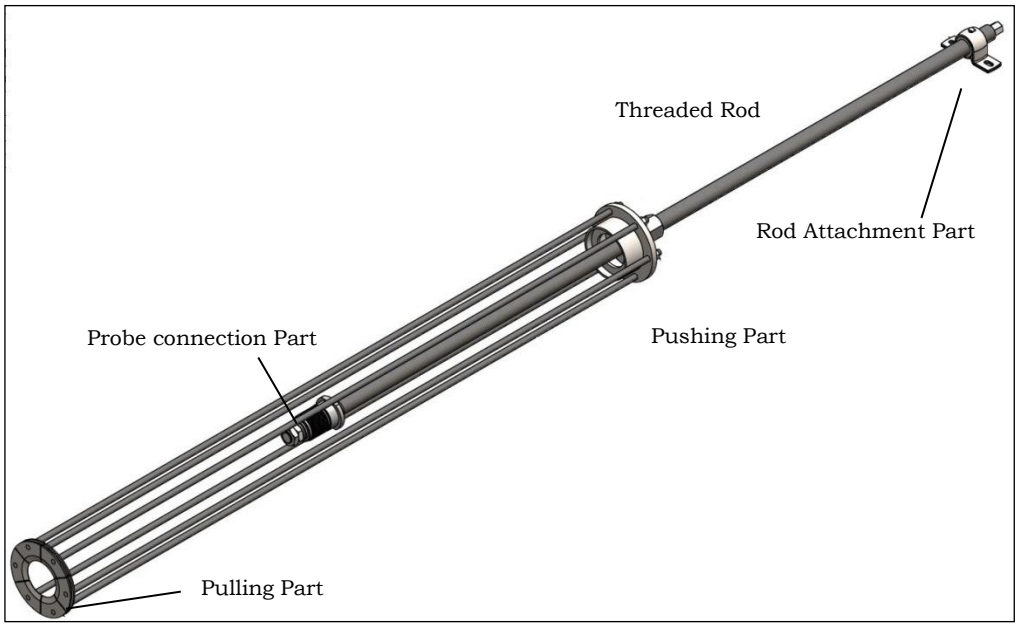
1293.8	(K1)
-5169.9	(K0)



Traceability no: TR-12-19	Atmospheric pressure: 101.3 kPa / Temp: 22 °C
Filename: 18201800004.xlsx	
Calibrated by : Jean-François Demers	Calibration Date : 2018-09-07

3.2 ASSEMBLING THE MEMBRANE

The DMP is normally provided with a membrane installation tool (see image below)

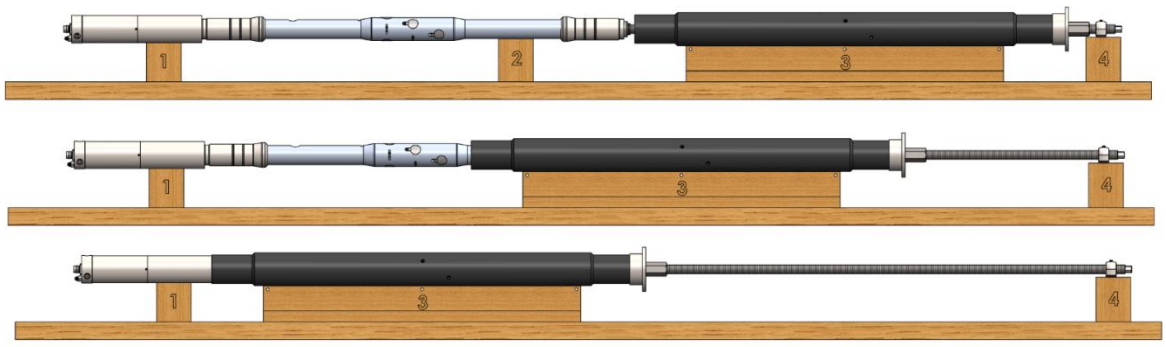


Membrane installation tool (assembled)

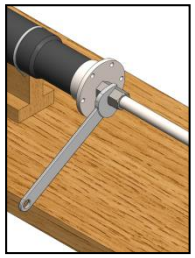
A

B

C



A) Put the probe's body and the membrane on wooden blocks as shown above. The suggested height (mm) of these wooden blocks should be approximately: 125.5 (block 1), 124 (block 2), 105 (block 3), and 129 (block 4). Screw the 'Rod Attachment Part' on a wooden block and insert the 'Threaded Rod' through the membrane and the 'Pushing part'. Make sure that the probe's bottom cap is removed from the probe and screw the 'Probe Connection Part' to it.

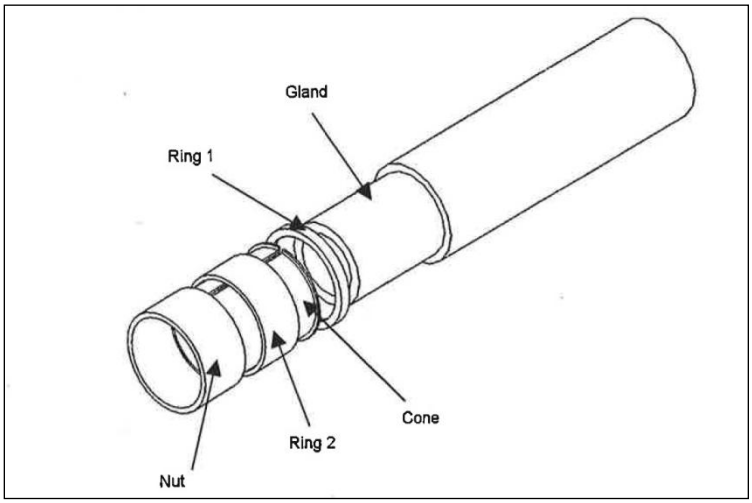


B) Using a marker pen, make a dot on each of the sensor on the probe's body. Using a wrench, block the nut next to the 'Pushing Part'. Using another wrench or a hand drill fitted with the proper socket, rotate the 'Threaded Rod' counter clockwise. This will push the 'Pushing part' and membrane forward. Slightly insert

the membrane over the probe's body while making sure that the sensors on the probe and the holes on the membrane are well aligned.

C) Slowly advance the membrane. WARNING: REDUCE ROTATION SPEED OF THE ROD BY USING A MANUAL WRENCH WHEN THE HOLES ON THE MEMBRANE GET CLOSE TO THE SENSORS ON THE PROBE. STOP IF YOU FEEL IMPORTANT RESISTANCE. Keep up advancing the membrane until it covers entirely the probe's body. Make sure that the holes on the membrane are well aligned with the dots on the sensors

D) Remove the installation tool.



E) Place Ring 1 on the membrane on the bottom of the dilatometer probe. The round part of Ring 1 must be facing the center of the membrane. Due to manufacturing tolerances, often the membrane diameter is too large or too small. It will then be necessary to increase this diameter by adding a layer or two of electrical tape, or to reduce the diameter using sand paper or small grinder.

F) Place the Tightening Cone on the membrane as shown above. To ensure proper tightness of the membrane, the opening on the Cone has to be between 3 and 4 mm. If it is not the case, rectify the membrane's diameter by adding electrical tape or by sandblasting the membrane.

G) Put Ring 2 in place. This Ring is conical too. Make sure its thinner side is facing the membrane.

H) Repeat operations E, F, and G on the other end of the membrane.

I) Using strap wrench, screw the Retaining Nut on the 'Tightening Cone'. This Nut is also conical. Make sure its thinner side is facing the membrane. Proceed simultaneously on each side of the membrane.

J) At the end of this operation, the opening on the 'Tightening Cone' should be very small but not entirely closed

K) Take the 6 Screws Feelers and make sure that each o-ring is in place and not damaged. Then put these Screws on the membrane.

L) Install the probe's bottom cap.

Note: Put lubricant on the rod's thread, Tightening Cone, Ring 2, and Retaining Nut. Use a lubricant that is not corrosive for the membrane (e.g. silicone-based grease).

3.3 DISASSEMBLING THE MEMBRANE

A) Remove the bottom cap, Retaining Nuts, Rings and Cones

B) Remove the 6 screws feelers off the membrane

C) Install the (Dis) Installation tool as shown below. After putting in place the first of the six parts of the 'Pulling Part', tape the little rod next to it around the membrane. Repeat that after installing each of the six parts. This will hold everything in place – see image below.

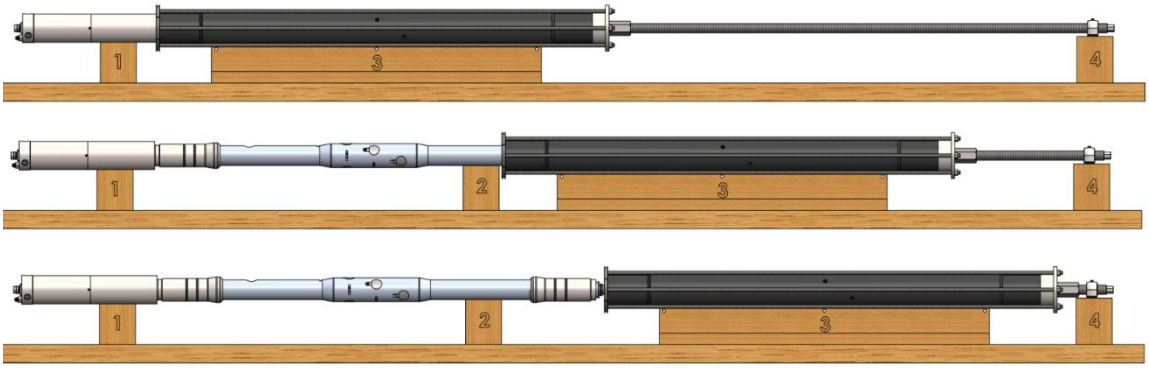
D) Using a wrench or a hand drill fitted with the proper socket, rotate the threaded rod clockwise. This will pull the 'Pulling Part' and membrane off the probe's body. Proceed slowly when reaching the protuberances of the probe's body. Readjust the 'Pulling Part' if necessary. Also, using your fingers, hold and slowly open each of the spring-loaded sensors when reaching them.

E) Disassembling is complete

C

D

E



3.4 RECOMMENDED TOOLS AND SPARE PARTS

RECOMMENDED TOOLS/ACCESSORIES	COMMENTS
Angle grinder with fiber discs	To reduce the membrane's thickness and thus facilitate the installation of the rings
1 wide electrical tape	On the other hand, it is sometimes necessary to add thickness under the rings to ensure watertightness
2 pipe wrenches	To tighten and loosen the rings
Lever arm	Sometimes it is necessary to add a lever arm to the pipe wrench
2 strap wrenches	To adjust the position of the membrane (inserts holes) in relation to the sensor
1 thick-blade chisel	To enlarge the opening on the cone (sometimes screwdrivers are also used)
1 large hammer	To adjust the position of the rings. Do not tap directly on the rings. Use a wooden or plastic wedge.
1 cutter	To cut out the damaged membrane. Saves time for removal

1 set of hexagonal keys 8 – 19mm	For the connection of the cable and tubing
Allen keys	For screwing on the membrane / sensor insert and the sediment tube
Silicone grease	Grease adapted to rubber, facilitates the installation of the membrane
WD-40 Lubricant	For mechanical parts
1 teflon tape	In case of leakage at the level of the tubing connections and screws membrane/sensor
1 chain wrench	For screwing and unscrewing the mechanical parts like the sediment tube
Screwdriver with torque > 100Nm, with 17 mm hexagon socket	For the TELEMAC assembly/disassembly tool

1 marker	To put a reference point on the sensors when mounting the membrane
RECOMMENDED SPARE PARTS	
4 o-rings for the probe body	
6 screws & o-rings (inserts)	

3.5 EVALUATION OF MEASUREMENT ACCURACY

Several factors can affect the measured modulus value. These include the characteristics of the rock mass (rock composition, fracturing level, heterogeneity, stress, dip, etc.), the conditions under which the probe is installed and loaded (remolding, drilling quality, contact between the inserts and the rock wall, etc.), and the proper functioning of the probe. These factors must be considered when analyzing the representativeness of the measurements.

In practice, the metrological performance of the sensors is much higher than the actual accuracy resulting from the use of the rubber sleeve, the geometric definition of the contact between the metal inserts and the borehole wall, etc.

As mentioned in section 2.3, the proper functioning of the equipment must be checked regularly by the user by pressurizing the probe in a rigid tube and ensuring that a repeatable, linear response is obtained, essentially illustrating the deformation of the tube.

The deformation of the steel tube can be estimated using high-precision calipers or evaluated theoretically. Thus, a 101 x 114 steel tube should deform only very slightly (2-4 microns/MPa).

The deformation of the tube can be estimated theoretically using:

$$\epsilon=(1/Et)(Pi((Ro^2+Ri^2)/(Ro^2-Ri^2)+Pi))$$

Where :

ϵ is the circumferential internal deformation

Et is the Young's modulus of the tube's material

Pi is the applied pressure

Ro is the external radius

Ri is the internal radius

For example, a diametral deformation of 100 microns measured in a 100 mm borehole over a range of 10 MPa will produce a dilatometric modulus of 12.5 GPa (Poisson's ratio of 0.25) i.e. E = (1+0.25) x100 mm x 10 MPa/0.1 mm. If the error on this measurement is +/- 20% (i.e. +/-20 microns), the relative error on the modulus will be +/-20%.

It is suggested that loading cycles be performed to maximize diametrical deformation.