INSTRUCTION MANUAL

PRESSUREMETER

Model GAM-II

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

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1 GENERAL

1.1 DEFINITION AND PURPOSE OF TEST

The pressuremeter test is a load test carried out in-situ in a borehole. An inflatable cylindrical probe is set at testing depth in a pre-drilled borehole within a soil or rock mass or by direct driving into the mass. The method depends on the materials' characteristics.

The Pressuremeter uses a pneumatic/hydraulic control unit to load and monitor the tested material's response. The data collected defines the stress-strain relationship of soil and rock with depth.

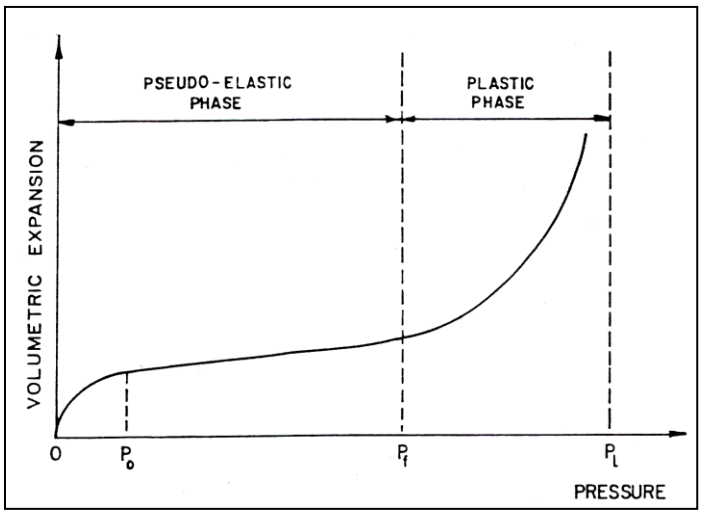
The pressuremeter test data is used to determine the limit pressure (10 MPa max) and pressuremeter modulus (5 GPa) max. The limit pressure is used to calculate the bearing capacity. The pressuremeter modulus is used to evaluate absolute and differential settlements for specific foundation designs.

1.2 PRINCIPLE OF TEST

The probe is set at the test depth using the method that will produce the least disturbance to the test material (Pressuremeter Borings Suggested Drilling Methods). Once in place, the probe is submitted to equal increments of increasing pressure. The probe volume changes are recorded 30 and 60 second from the time each pressure stage is reached. The pressure-volume data is plotted to determine the limit pressure P_L and the pressuremeter deformation modulus E. These values are used for foundation design using the methods suggested in the appendix "Note D-60-Interpretation and Application of Pressuremeter Results".

1.3 RESULTS AND THEIR USE

Figure below shows a typical pressure-volume curve obtained from a pressuremeter test.



Typical pressuremeter test curve

The curve can be divided into three parts:

i) From P = 0 to P = P_0

This portion of the curve corresponds to the probe seating against the borehole wall. The wall disturbance induced by drilling or driving the probe into place has considerable influence on this segment of the curve. The difference in borehole and probe diameters also affects this segment.

ii) From P = P_0 to P = P_f

This segment represents the pseudo-elastic behavior of the tested material. The probe is in contact with the borehole walls. The loading is uniform along the probe length. This segment is linear and defines E, the deformation modulus of the tested material. E, in turn is used to evaluate settlement. Should the probe be in contact with the borehole walls before applying pressure, the mass would exhibit pseudo-elastic behavior from the outset.

iii) From P = P_f to P = P_L

P_f by definition is the pressure at which the mass enters a plastic state. Above P_f, the loaded mass' deformation accelerates up to the complete failure point. The pressure that defines failure is the limit pressure P_L. This fundamental mechanical characteristic of the mass is used to evaluate the stability of foundations in accordance with pressuremeter methods.

2 TESTING EQUIPMENT

2.1 GENERAL

The pressuremeter apparatus consists of three distinct devices:

- The **probe**, the loading device, goes inside a borehole at the desired test elevation;
- The **control unit**, mounts on a tripod at surface, controls the test and displays test parameters and data. The pressure source, a compressed gas cylinder
- **The coaxial tubing** delivers pressurized gas and liquid from the control unit to and from the probe.

2.2 PROBE

The pressuremeter probe is a hollow metal cylinder threaded at both ends and designed to accept and seal the inner rubber membrane and the outer rubber or metallic sheath. The outer protective sheath mounts concentrically over the centrally located internal rubber membrane. The protective sheath extends over the total length of the probe. It is this sheath that is in direct contact with the borehole walls when the probe is pressurized. Figure below shows a longitudinal cross section of a pressuremeter probe.

The metallic sheath has longitudinal steel strips fixed to its outer surface. The strips overlap such that when inflated, the increased surface area of the sheath remains protected. The metallic sheath is the most frequently used. In certain soils, depending on the conditions, the pressuremeter tests are run with rubber sheaths.

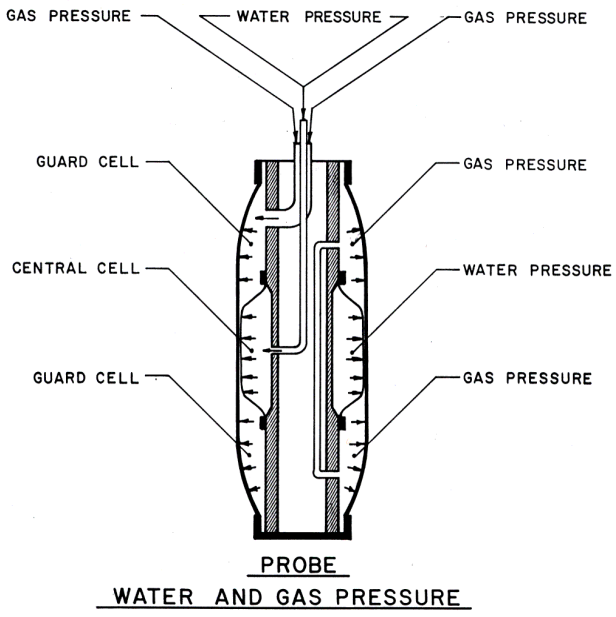
The central rubber membrane contains the pressurized water and is the probe's measuring cell. Its deformation mirror the soil's deformation under load. The loads are applied using the control unit. The sight tube indicates the volume change of the central measuring cell. Pressure and volume readings are plotted, as shown in Figure on page 1. P_L and E are the calculated values are applied to the foundation design.

As mentioned above, the inner rubber membrane in which water pressure is applied occupies the central parts of the probe. In the mathematics behind the interpretation of the results the assumption is made that the material loaded by the central cell is in a state of plane deformation. Practically, in order to obtain such a state of deformation it is necessary to extend the loaded zone on both sides of the central cell. This is accomplished by allowing gas pressure to be applied to the outer protective sheath which extends over the total length of the probe. Therefore to transmit load to the material tested the inner rubber membrane has to be in contact with the outer protective sheath. We then have three separate chambers under pressure: the central cell under water pressure and the two guard cells under gas pressure. Figures below schematically show the two pressure systems of the probe.

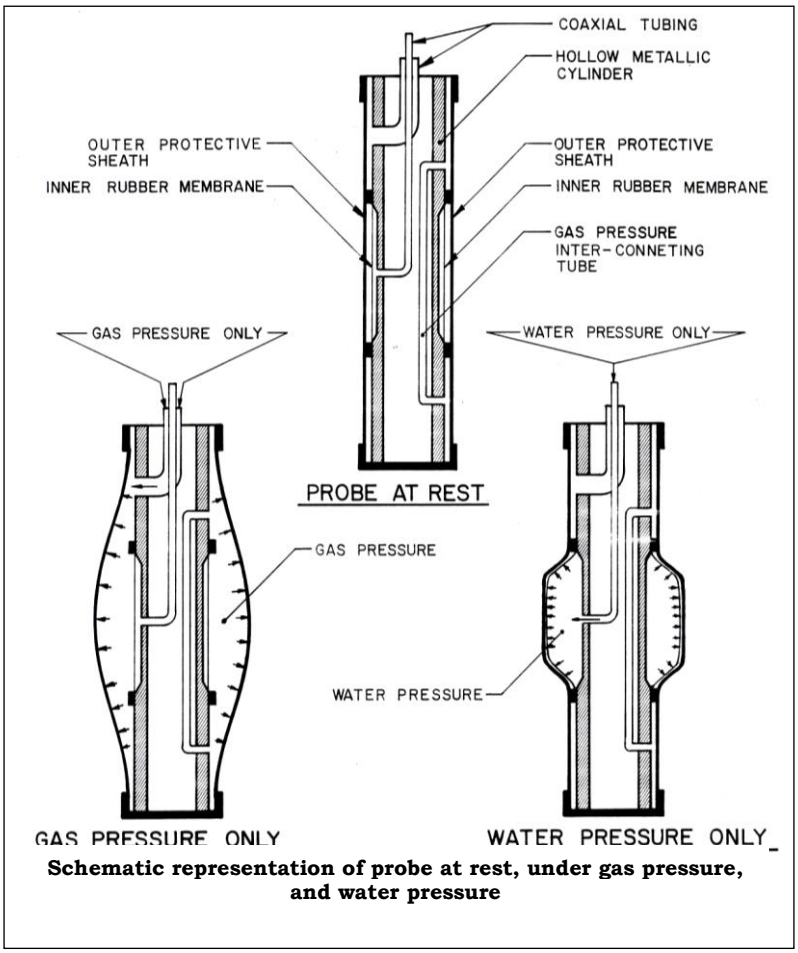
The GAM-II pressuremeter probe is available in three different sizes to fit the standard borehole diameters. Table below lists the available probes' diameters and their corresponding standard drill hole diameters. Table below also shows the acceptable tolerances on standard borehole sizes within which a satisfactory test can be expected.

DIAMETER OF MANUFACTURED PROBES vs. STANDARD BOREHOLES

DCMA Standard Hole	PROBE Diameter (mm)	BOREHOLE DIAMETER (mm)	
		Min.	Max.
A	44	46	53
B	58 (or 60)	60	70
N	74 (or 70)	76	89



Schematic representation of probe under water and gas pressure.



Schematic representation of probe at rest, under gas pressure, and water pressure

2.3 CONTROL UNIT

The control unit is the operator's interface with the probe. It is used to regulate and monitor hydraulic and pneumatic pressures and volumes during the calibrations and the test. The hardware is housed in a tripod mounted fiberglass case with a front panel. The controls, gages and valves required to run the test are located on the panel. The water supplied to central measuring cell is contained in a high-pressure cylinder located in the control unit. Volume variations during the test are read on a sight-tube. Volume is read on one of two scales: = -100 to +800 cc or -2 to +16 cc (high sensitivity). The control unit has two operating pressure ranges: 0-2500 kPa for most applications in soils, 0-10000 kPa for testing very dense soil and rock.

2.4 COAXIAL TUBING

The two tubes connecting the control unit to the probe are arranged coaxially. The tubing is a reinforced **Tecalan** sheathed high-pressure tubing (high pressure - working capacity > 10 MPa). The inner (co-axial) tube delivers the pressurized water to the central measuring cell. The pressurized gas is delivered in the annulus of the co-axial tubing assembly to the guard cells. The differential pressure between the water and gas tubing should be set at 100 kPa. The net result is that the tubing expands at a constant and small rate.

3 TEST PROCEDURE

3.1 GENERAL

The following sections lists the specific instructions for the different stages required to execute a successful pressuremeter test. They are, in chronological order:

- The probe assembly;
- The filling of the control unit and the saturation of the whole system, including the probe;
- The calibration test;
- And finally, the test itself.

Note: It is strongly suggested to use a bench vice and the probe-to-vice adaptor to hold the probe during the following operations.

3.2 THE PROBE ASSEMBLY AND DISASSEMBLY

The following description refers to the 44mm, 60mm and 74mm probes.

3.2.1 ASSEMBLY

Step 1 The two membrane internal tapered rings (32) are slid over the metal body (28) of the probe and are left in place at mid-section. The internal face of each ring is in the shape of a truncated cone and care must be taken so that the thickest extremity (the base) is oriented towards the center of the probe.

Step 2 Slide the membrane (31) over the body of the probe (28) and under the tapered rings (32). During this step keep the tapered rings at mid-section and center the rubber membrane (31) with respect to the beads (30a).

Step 3 Manually move the tapered rings (32) outward until the leading edge of the rings contacts the beads. Assemble the three shortest puller arms to the ring puller. The longer arms are used to remove the tapered rings.

Install the ring puller (36) at one extremity of the probe using the proper sized bushing to center the puller about the probe axis. Rotate the handle (37) backwards until it is parallel to the probe axis. This will set the tapered ring in the correct location. Release the puller by rotating the handle (37) forward. Repeat the operation for the other ring. When mounting the tapered rings verify that in doing so the rubber membrane is neither stretched beyond its natural length, nor bunched up between the two tapered rings. Place a layer of black electrical tape in order to cover most of tapered rings and a section of the rubber membrane sticking out from the outward edge of these rings. Do not tape over the opening that delivers the gas from the upper guard cell to the lower guard cell. Pressurize the measuring cell (100 kPa approx.) and verify for leaks.

Step 4 Place an o-ring (30b) in each of the two grooves. Spread a thin layer of molycoat or appropriate rubber grease over the probe core and membrane. Pay particular attention to coat the tape covering the inner tapered rings. Remove the temporary tape that covers each metallic sheath extremity. Slide, while rotating counter and clockwise, the outer protective sheath over the membrane (31) and the body of the probe. Push the sheath forward holding it at the far end from the probe. This will favor the opening of the sheath's leading edge and facilitate the installation.

Center the sheath with respect to the O-rings (30b). When centered, the sheath should cover a few of the inside threads at the probe extremities. **To ensure that the two o-rings remained in place, lift each end of the sheath up and physically inspect the location of each o-ring.** Replace the electrical tape at both extremities of the external sheath with the equivalent of 1 to 1.5 layers of electrical tape. Apply the lubricant to both outer sheath extremities. Check the inner membrane seal by inserting a 3X5 connector hooked up to position 10 on the control unit. Place valve on 6 and increase the pressure to 100 or 200 kPa. Close valve 10 and listen and look for leaks. The probe should remain inflated.

Slide the tapered retaining rings (Yellow Vulcolan or metallic rings) in place over the ends of the outer sheath. Orient the tapered rings such that the thickest extremity points outward. Screw the brass cover nuts (35) on to the body of the probe. This will advance the outer tapered sleeves inward providing a seal between the sheath and the o-rings. Continue to advance the brass nuts until same length of thread is exposed beyond both the nuts. When advancing the nuts verify that no relative movement between the sheath and probe body occurs. This can be achieved by holding the outer sheath in position with two screw clamps temporarily positioned on the outer sheath. Position one of the clamps near the inner edge of the vulcolan collar. Position the other clamp over the adjacent inner tapered ring. Tighten securely but do not overtighten to the point of cutting the inner rubber layers.

3.2.2 DISASSEMBLY

Step 1 Stand the probe up in a 5-gallon pail of water. Clean the probe thoroughly with a nylon bristle brush. Remove the probe shoe.

Step 2 Screw the probe to vice adaptor onto one extremity of the probe and clamp the adaptor in a bench vice.

Step 3 Using a strap wrench, unscrew the brass knurled nut (35) at the free end of the probe.

Step 4 Remove the external tapered ring (34).

Vulcolan collars : Use the ring extractor provided. Place the two pins located on the inside of the extractor in the appropriate holes on the metal portion of the collar. Pull and rotate the extractor to remove the vulcolan collar. In difficult cases warm the metal ring and urethane. Heat until removal is facilitated. Remove the metal ring and the vulcolan collar in succession. Use a strap wrench for increased torque.

Metallic ring : Using a strap wrench, pull and rotate the ring. If necessary warm the ring slightly to facilitate its removal.

Step 5 Reverse the probe and repeat Steps 2, 3 and 4.

Step 6 Remove the outer sheath (33). If required remove the tape holding the strips at either extremity (replace with new tape upon reassembly).

Step 7 Remove the O-ring at the free end of the probe (30b).

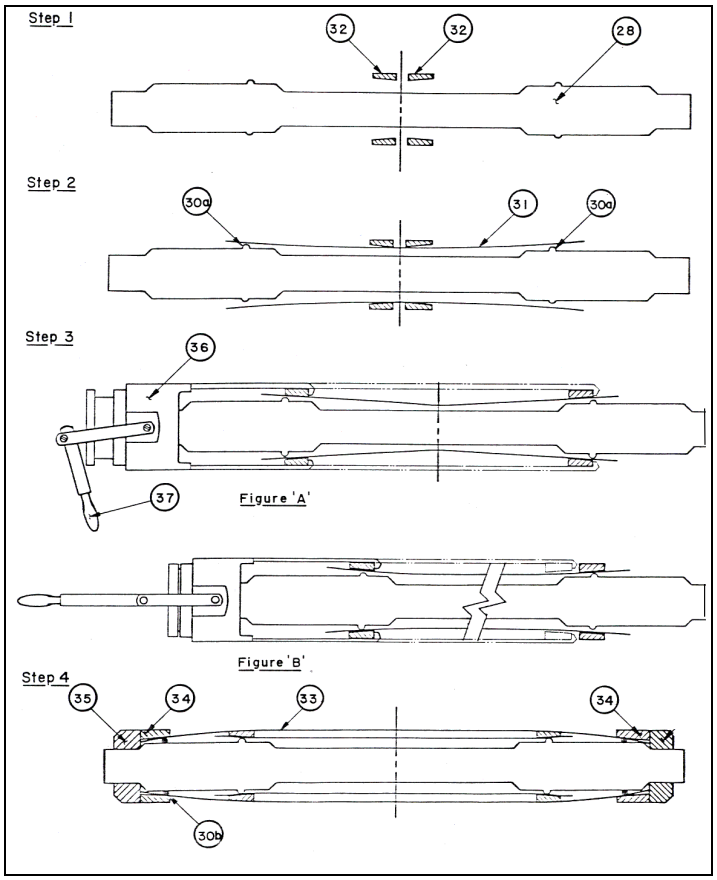
Step 8 Install the long extension arms and bushing appropriate to the probe size, on the puller.

Step 9 Place puller on the free extremity of the probe and grasp the membrane ring (32) with the 3 claws (Ref step 3, figure A). Rotate the puller handle backwards. This will free the membrane ring (Ref step 3, figure B).

Step 10 Reverse the probe and repeat Steps 7 and 9.

Step 11 Slide the membrane rings towards the center of the probe and remove the rubber membrane (31).

Step 12 Remove the two membrane rings (32).



Probe assembly and disassembly

3.3 FILLING THE CONTROL UNIT AND SATURATING OF SYSTEM

The first phase of the operation consists of filling and saturating the control unit and the central tube of the coaxial tubing. Filling is done at ground level.

When the control unit and central tube saturation are complete, proceed to the second phase which is the filling and saturation of the probe itself.

The step-by-step procedure related to the two phases of filling and saturation is described in detail in Section 4.

3.4 CALIBRATIONS

3.4.1 GENERAL

The deformability of the different materials submitted to a pressuremeter test varies over a wide range. Materials previously tested include soft and stiff soils, glacial till, soft rocks, ice, frozen ground and boulders.

Two types of calibration tests apply:

- The pressure calibration of the probe performed at ground level, beside the control unit, unconfined, to establish its own pressure-volume relationship. This is a measure of the probe inertia.

- The volume calibration of the complete system including the probe, coaxial tubing and control unit circuitry. The probe is confined by placing it in a steel casing. The pressure-volume relationship of the system is determined. This calibration is a measure of the intrinsic volumetric expansion of the components under pressure.

The first calibration is more significant when testing low to medium rigidity soils. The second calibration is more significant when testing highly rigid soils and soft rock.

In the first case a relatively low pressure (100 to 300 kPa) is necessary to inflate the probe to its maximum capacity. However, in the second case, high pressures (over 2500 kPa) are necessary. Small volumes of water are injected in the probe (from .07 to .15 cc/100 kPa). The value depends on the probe diameter and the tubing length; an 80 meter tubing length with the N-size probe is between .12 to .15 cc/100 kPa. Should the volume coefficient lie significantly (>50%) above the specified range, it generally signals a faulty system.

The significance of the volume coefficient and the repeatability of measurement of the system expansion increase exponentially with increasing modulus values. Ultimately the system deformation approaches the tested material's deformation limiting the instrument to moduli of 5 GPa (700 000 psi).

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

- If a membrane and/or protective sheath are replaced. In this case, before proceeding with the inertia calibration it is advisable to inflate the probe several times.
- If the same membrane and protective sheath have been used for a large number of tests, the calibration should be checked.
- If the coaxial tubing has to be changed.

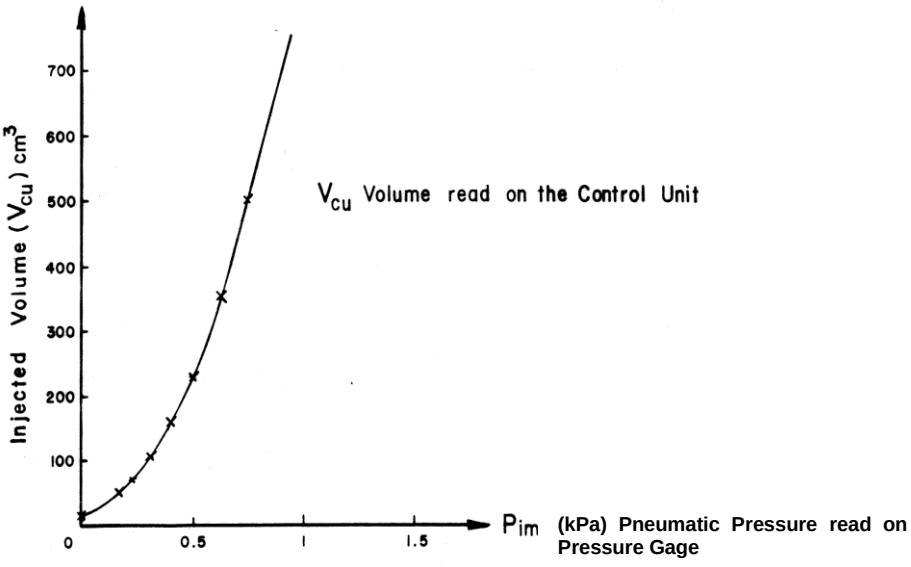
- If the ambient temperature at the test location or in the borehole is substantially different than the temperature that prevailed during the last calibration.

- It is recommended to repeat a volume calibration every day the equipment is used for checking good fuctionning (no leak) of the equipment

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

3.4.2 PROBE INERTIA CALIBRATION

As mentioned previously the probe inertia calibration is done with the probe at ground level, beside the control unit and unconfined. The calibration is carried out following the instructions in Section 4 under low pressure calibration. The probe is inflated in 25 kPa increments to a volume of approximately 75% of Vo. The pressure-volume relationship is plotted for the pressure read on the pressure gage. Figure below shows a typical pressure-volume data plot obtained from an inertia calibration. This curve is subsequently used for data interpretation.



Typical pressure-volume curve from a probe inertia calibration.

3.4.3 CALIBRATION DUE TO INTRINSIC VOLUME EXPANSION OF COMPLETE SYSTEM

When a pressuremeter test is performed, the volume variations measured on the control unit are a combination of the volume changes due to the materials' deformation, to the slight deformation undergone by the coaxial tubing, to the expansion of the control unit circuits and finally, to the compressibility of the rubber membrane and the protective sheath. In high-pressure testing performed on stiff soils or rock, the former represent a significant proportion of the total deformation.

A high pressure volume change calibration is necessary, to determine the system's intrinsic expansion. The calibration is performed with the probe inside a steel casing. The instructions are detailed in Section 4 under high-pressure calibration.

3.5 EXECUTION OF THE PRESSUREMETER TEST

3.5.1 GENERAL

The GAM-II pressuremeter has two standard pressure ranges. They are:

- 0-2500 kPa for most applications in soil testing.
- 0-10 000 kPa for very dense soils or soft rock testing.

3.5.2 LOW PRESSURE TESTING (0-2500 KPA)

The limit pressure is first estimated to relate expected limit pressure to a known soil parameter. Eight to 12 pressure levels are required to adequately define the pressuremeter curve and parameters for the tested material. To determine the pressure increment size divide the estimated limit pressure by 10. The pressure is increased incrementally approaching the pressure from below and maintained for 1 minute. The ramp up period between intervals is from15 to 30 seconds increasing with the pressure increment size. The volume readings are recorded 30 and 60 seconds after reaching the pressure level. The volume scale is in cm^3 or .02 cm^3 when knob under sight tube is screwed and valve 4 is set at high sensitivity. This knob is located under the water reservoir. One may get access to this knob after opening front panel. The "high sensitivity" position increases the volume readings' resolution. This is generally necessary when testing rock at pressures above 3000 kPa.

Once the 60 second reading is recorded, the pressure is increased by one increment and the sequence repeated. It is important, so as not to disturb the differential pressure, not to decrease pressure once the pressure setting is reached. Instead record the actual pressure level and the corresponding volume.

The test is stopped when the suggested limiting combination of values for pressure and volume are reached.

3.5.3 HIGH PRESSURE TESTING (0-10000 KPA)

The high pressure range is required to test from very stiff soil deposits to soft rock. It is not uncommon for the glacial till or an over consolidated sand to show a limit pressure "P_L" above 5000 kPa. The pressure is increased in 500 kPa increments. Readings are recorded 30 and 60 seconds after the pressure level is reached or when the readings have stabilized, whichever comes first.

3.5.4 MEASURING CELL AND GUARD CELL PRESSURE SYSTEMS

To accurately measure the deformation of the material under test:

1. The central measuring cell rubber membrane must always be in full contact with the metallic sheath liner.
2. The membrane must not exhibit relative axial deformation with increasing pressure.

These conditions are met if the pressure in the measuring cell less the cell membrane's inertia exceeds the gas pressure in the guard cells by a constant differential pressure.

This differential pressure must remain constant over the total test pressure range.

The pressure applied to the material by the central measuring cell at the probe level is comprised of:

i. The gas pressure applied to the water reservoir in the control unit and readout on gages 5, 6 or 17.
ii. The water pressure exerted by the water column between the probe center and the ground surface elevations.
iii. The pressure decrease due to inertia of the probe. This pressure P_i, determined by the unconfined pressure loss calibration, decreases the net pressure applied to the test material.

$$\mathbf{P_{net\ applied} = P_{gage\ 5,\ 6\ or\ 17} + \delta h - P_{i\ measuring}}$$

Where
$P_{net\ applied\ measuring}$ = the pressure applied to the soil or rock
$P_{gage\ 5,\ 6\ or\ 17}$ = the gas pressure reading at gage 5, 6 or 17 on the control panel
δ = the water density
h = the difference in elevation between the center of the probe and the center of the control unit.

The gas pressure applied to the guard cells to the tested material above and below the measuring cell is equal to:

i. The pressure readout on gages 7 or 16.
ii. The pressure decrease due to the inertia of the probe as described above, assuming that the inertia is the same for the guard and measuring cells.

$$\mathbf{P_{net\ applied\ guard} = P_{gage\ 7\ or\ 16} - P_{i\ guard}}$$

Where
$P_{net\ applied}$ = the pressure applied to the soil or rock
$P_{gage\ 7\ or\ 16}$ = the gas pressure reading at gage 7 or 16 on the control panel

3.5.5 DIFFERENTIAL PRESSURE

The differential pressure across the measuring cell membrane between the guard cell and the measuring cell must remain constant. This pressure is set at 100 kPa for testing in soils. These values were chosen to ensure that the measuring cell is always in contact with the inner wall of the metallic sheath. They are a function of the maximum error between the pressure gages with the same range.

The differential pressure can be gradually increased up to 200 kPa (max) in these special situations:

- During tests at high pressure (over 5000 kPa)
- For deep tests (over 40 m)
- When the temperature drops below 0 degrees Celsius

With the probe at 1 meter below ground surface and a total differential pressure required of 100 kPa, the pneumatic component of the differential pressure is +92 kPa. That is gage 5 must be set to lead gage 7 by 92 kPa. For each meter additional meter of probe depth the pneumatic component of the differential decrease by 9.8 kilopascals.

At 10 meters depth, the pneumatic differential is 0 and the differential pressure at the probe level is 100 kPa.

For all depths beyond 10 m, valve 3 is rotated to position > 10 meters.

4 OPERATIONS

4.1 CHOICE OF GAGES

The control panel is delivered with the following gages :

- On the water circuit : a 0-2500 kPa, 0-6000 kPa, and 0-10000 kPa gage. A lower range gage, for example 0-600 kPa, can be fitted to quick connector 17 to give more accurate readings at these lower pressures for soils with weak stress-strain properties.

- On the gas circuit : a 0-2500 kPa, and 0-10000 kPa gage. In the same manner, inlet 16 can be used to add lower pressure range gages.

WARNING : The gages plugged to quick connectors 16 and 17 are active no matter what the position of valves 14 and 15 are. Take care to close these valves or remove gages with low pressure ranges whenever necessary.

Once the gages have been chosen, check that they are set to zero, if not use the knurled buttons or the screws on the gages to do so.

4.2 FILLING THE PRESSUREMETER

Connect the small funnel into inlet 13 on top of the control panel, turn valve 2 to "Water", then fill the volumeter so that the water level just reaches the colored zone in the sight tube. Do not let the level go any higher to avoid filling the gas circuit with water. Remove the funnel and turn valve 2 to "Test". Use clean water or anti-freeze solution to fill the equipment.

To drain the control panel, connect the filler funnel to outlet 12e. Turn valve 2 to "Water". The water in the control panel empties out by gravity.

4.3 SATURATION OF TUBING AND PROBE

- Unscrew pressure regulator completely.
- Connect pressure supply.
- Slowly open valve on gas bottle.
- Pressure is indicated on gage 10.
- Thread the rod connector through tubing.
- Connect coaxial tubing (push quick-connects in completely until clicking sound is heard).
- Valve 1 on close to avoid expansion of the guard cell.
- Valve 4 on test.
- Valve 2 on test.
- Valve 3 on 0-10 m.
- Apply 200 kPa on gage 5 by screwing in pressure regulator.
- Water will flow from quick connect into the central tube.
- When water flowing out the end of the central tube contains no air bubbles, hook up the 4 x 4 connector to the probe.

- When 200 cc of water have been injected in the probe, disconnect the 4 x 4 connector from probe; water will be expulsed from probe with air bubbles. Repeat this operation until the water ejected from the probe contains no air bubbles; then reconnect 4 x 4 to probe.
- In the execution of the latter phase, care should be taken not to let the water in the reservoir drop below the 800 cc level. Otherwise, gas bubbles will get into water circuit. In that case, refill the control panel, then saturate tubing and probe again.

The saturation being completed:

- Pressure regulator to off.
- Set valve 2 on "water" and "gas" for a few seconds, then set it back on test.
- Set valve 4 on closed.
- Connect air line of the coaxial tubing to the probe by screwing 10 mm nut on the tubing to the probe.
- Refill water reservoir as per section 4.2

4.4 DIFFERENTIAL PRESSURE VALVE ADJUSTMENT

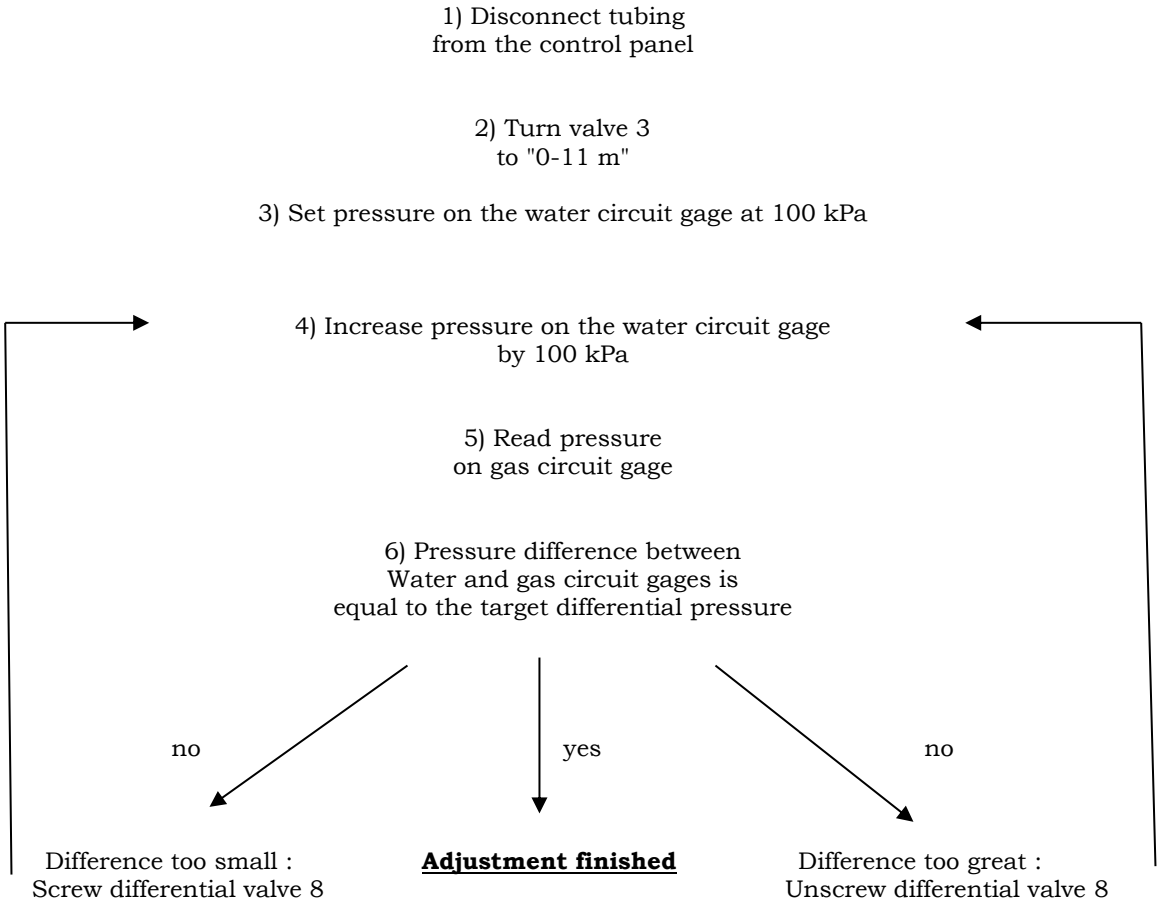
For a test at a depth less than 10 meters, for example 5 meters :

1. Disconnect the probe hose from the control panel.
2. Turn valves 1, 2 and 4 on test and valve 3 onto "0-11" m
3. Use main pressure regulator 9 to obtain a reading of 100 kPa on gages 5 and 6.
4. Read the pressure indicated on gage 7.
5. If P_{diff} > 50 kPa (for example 70 kPa), go to step 6.
   If P_{diff} = 50 kPa, the differential pressure is set correctly.
   If P_{diff} < 50 kPa (for example 30 kPa), go to step 10.
6. Unscrew differential valve 8 slightly (counterclockwise)
7. Increase pressure on gage 6 by 100 kPa.
8. Read the new pressure on gage 7.
9. Go back to step 5.
10. Screw in the differential valve 8 slightly (clockwise).
11. Increase pressure on gage 6 by 100 kPa.
12. Read the pressure on gage 7.
13. Go back to step 5.

At the end of the procedure, unscrew pressure regulator 9. Bleed the pressure in each circuit with valve 2, and then reconnect the probe tubing onto the control panel. The quick connectors are designed to prevent any air from entering the tubing.

SURFACE DIFFERENTIAL PRESSURE VALUES vs DEPTH		
DEPTH OF TEST IN METERS	POSITION OF VALVE 3	PRESSURE DIFFERENCE(kPa) BETWEEN THE GAGES
1	0-10 m Pressure on water circuit gage is greater than pressure on gas circuit gage.	90
2		80
3		70
4		60
5		50
6		40
7		30
8		20
9		10
10		**0**
11	*>10m Pressure on gas circuit gage is greater than pressure on water circuit gage*	*10*
12		*20*
20		*100*
25		*150*
30		*200*
50		*300 - 400*
70		*500 - 600*

For a test at 10 m and less :



Flow chart for adjusting differential pressure
(test between 1 and 10 meters)

4.5 CALIBRATION LOW PRESSURE 0-2500 KPA

- Place probe at ground level.
- Connect probe tubing.
- Differential pressure must have been adjusted for a test at a depth of 0 meter
- Valve 3 on 0-11 m
- Valves 2 and 4 on test. Valve 1 closed.
- Make sure appropriate manometers are selected (valves 14 & 15).
- With the pressure regulator, apply 25 kPa pressure to the central cell.
- Note volume readings 60 seconds after the pressure step is reached.
- Progressively increase the pressure by increments of 25 kPa taking volume readings after 60 seconds for each pressure step.
- Stop the injection around 75% of Vo to avoid undue risk of bursting the probe.

- Reduce pressure to zero with regulator.
- Valve 3 set horizontally (on "bleed" i.e. > 11m).
- Bleed the pressure in each circuit with valve 2
- Let all water go back in the water reservoir; gas pressure can be used to speed up the process
- The inertia is the pressure required to inject 100% of Vo and is obtained by extrapolation of the pressure-volume curve obtained from the calibration.

4.6 TESTING

- Valve 4 on closed.
- Lower probe to the required elevation.
- Adjust the pressure differential.
- Valves 1 and 2 on test.
- Make sure appropriate manometers are selected (valves 14 & 15).
- Valve 3 on 0-11 m or >11 m according to test depth table
- Valve 4 on test.
- Water will flow by gravity from the reservoir into the probe.
- Note the volume reading once the level in sight tube has stabilized.
- With the pressure regulator, adjust the central cell pressure gage to the first pressure step (one tenth of the expected limit pressure).
- Note volumes reading 30 seconds and 60 seconds after the pressure step has been reached.
- The pressure is increased by equal increments to the limit pressure. To avoid bursting the probe, it is recommended to stop injection around 75% of Vo.

To depressurize the system:

- Reduce pressure to zero with regulator 9.
- Valve 3 set horizontally (on "bleed" i.e. > 11m).
- Valve 2 set slowly on "water"
- When manometer 7 (or 16) displays about 500 kPa, set valve 1 on closed.
- When all water is back in water reservoir, set valve 4 on close, valve 2 on "gas" and at the same time valve 1 on "test"
- Inflation of the probe must be done slowly to minimize risks of bursting the sheath

4.7 CONVERSION TO HIGH PRESSURE (10 000 KPA)

To use the pressuremeter above 2500 kPa, the following modifications must be made.

4.7.1 PRESSURE GAGE

- Connect the 0-10 000 kPa pressure gages and set valves 14 and 15 at gage 16 and 17.

4.7.2 PRESSURE REGULATOR SPRING

To change the spring of the main regulator 9, proceed as follows:

- Remove chrome cap from control knob.
- Remove circlip with special pliers and remove control knob.
- Unscrew bonnet (1 3/4" flats) and remove load spring.
- Select the silver colored load spring (0-10000 kPa). The olive colored spring has a range of 0-3500 kPa.
- Insert load spring into bonnet.
- Complete the reassembly.

4.8 CALIBRATION HIGH PRESSURE (0-10000 KPA)

For tests in soft rock, the dilatation of the pressuremeter-tubing-probe system under pressure is determined by calibrating the system with the probe placed in a rigid steel casing. The procedure is as follows:

- Fill and saturate pressuremeter and probe.
- Adjust pressure differential to 100 kPa.
- Valve 15 on gage 16.
- Valve 14 on gage 17.
- Put high pressure spring in the pressure regulator.
- Valve 3 on 0-11 m.
- Place probe in steel casing:
  - 44 mm dia. probe - A size casing
  - 60 mm dia. probe - B size casing
  - 70 mm dia. probe - N size casing
- Valve 1, 2 and 4 on test.
- With pressure regulator, apply 500 kPa pressure to the central cell.
- Note the volume reading when the water level in the sight tube has stabilized.
- Increase pressure by 500 kPa increments taking volume readings when the water level has stabilized.
- When the volume changes become imperceptible, screw knurled knob located underneath the sight tube and set valve 4 on " high sensitivity".
- In this position, the volume changes are amplified 50 times (i.e. 1 scale unit - .02 cc).
- Continue increasing the pressure up to at least the maximum pressure that will be reached during the test (2500 kPa min) in 500 kPa increments taking volume readings at each step.
- When calibration is completed, position set valve 4 on test and unscrew knurled knob. The factor of correction due to dilatation of the pressuremeter system is a = dv/dp.

To depressurize the system:

- Reduce pressure to zero with regulator.
- Valve 3 set horizontally (on "bleed" i.e. > 11m).
- Bleed the pressure in each circuit with valve 2
- Let all water go back in the water reservoir; gas pressure can be used to speed up the process

4.9 TESTING HIGH PRESSURE (0-10000 KPA)

- Lower the probe to the test elevation.
- Adjust the pressure differential.
- Leave valve 3 in the position used to adjust pressure differential (refer to the table at p.16)
- Valves 1 and 2 on test.
- Valves 14, 15 on gage 16 and gage 17.
- Valves 4 on test.
- Water will flow by gravity from the reservoir into the probe.
- Note the volume reading once the level has stabilized.
- With the pressure regulator, adjust the central cell pressure gage to 500 kPa.
- Note the volume reading once the level has stabilized completely.
- Increase the pressure in 500 kPa increments taking volume readings at each pressure step after stabilization.
- When the volume changes become imperceptible, screw knurled knob located underneeath the sight tube and set valve 4 on " high sensitivity".
- In this position, the volume changes are amplified 50 times (i.e. 1 scale unit - .02 cc).
- Continue to increase the pressure to 10 000 kPa or less depending on borehole size. To avoid the risk of bursting, maximum volume injected at 10 000 kPa should not exceed 325 cc.
- When the test is completed, position valve 4 on test and unscrew knurled knob

To depressurize the system:

- Reduce pressure to zero with regulator.
- Valve 3 set horizontally (on "bleed" i.e. > 11m).
- Valve 2 set slowly on "water"
- When manometer 7 (or 16) displays about 500 kPa, set valve 1 on closed.
- When all water is back in water reservoir, set valve 4 on close, valve 2 on "gas" and at the same time valve 1 on "test"
- Prior to moving the probe in the borehole, allow sufficient time for the probe to deflate completely.

4.10 CYCLIC TEST

To unload-reload:

- Reduce pressure on main regulator to 0
- When test depth exceeds 10 m, bleed valve to 'water'
- When test depth is less than 10 m, bleed valve to 'gas'
- Bleed pressure to the desired level, and take readings after 30 and 60 seconds
- For increasing pressure, put pressure back to the regulator
- Continue with test

4.11 WINTER USE

During winter, it is necessary to use an antifreeze liquid instead of water. The use of windshield washer liquid is recommended. But this liquid may induce deposits that could block tubing and fittings. It is then recommended to flush the equipment with fresh water after its use for cleaning it.

When the control unit is used at very low temperatures, the Whitey valves with Teflon seal may leak. To stop the leakage, remove the black handle of the valve with a 3/32" Allen key and slightly screw the packing bolt with the special two-pin tool provided (tightening tool) in 1/8th turn increments. Usually, the first 1/8th turn will prove sufficient.

4.12 TESTS AT GREAT DEPTHS

The spring in the differential valve has a 500-kPa range approximately. Consequently, for tests in soil at depths exceeding 60 m, an additional differential valve must be mounted in series in order to increase range of differential pressure. The additional differential valve is installed between the main pressure regulator and the differential valve on the control panel.

The borehole MUST be filled with drilling mud to limit the expansion of the probe before the test starts.

The tubing and the probe must be perfectly saturated and be filled with specially de-aired water to prevent air bubbles rising in the tubing. This would alter the value of the hydrostatic pressure at in the probe.

Regulate the differential pressure before lowering the probe down the borehole, the hose being disconnected.

Close water circuit valve 4 to prevent any expansion as the probe is lowered down the hole with the risk of jamming it above the designated test depth. Re-open this valve just before the start of the test.

Pressure increments must be obtained slowly. The readings at 30 and 60 seconds should only be taken after the pressure reading on the gage has stabilized.

5 READINGS AND INTERPRETATION

The readings are taken manually. Then the pressuremeter test curve can be plotted, either manually or using a software. Roctest offers a free 'PressioCompanion' Excel spreadsheet. Available on our web site.

The theoretical V_o values are as follows:

44 mm diameter probe - V_o = 535 cc
60 mm diameter probe - V_o = 535 cc
74 mm diameter probe - V_o = 786 cc

A more representative effective V_0 value can be determined as per ASTM D4719-20.

The limit pressure P_L corresponds theoretically to the pressure required to double the volume of the initial cavity. The total injected volume is then equal to V_o plus twice the volume injected in order that the probe contacts the walls of the borehole. This value is generally obtained by extrapolation.

Readings interpretation can be done referring to the following documents:

ASTM (2020). 2020 Annual Book of ASTM Standards, Section 4: Construction, Vol. 04.08 : Soil and Rock (1) : D4719-20, p. 898 – 906.

Frank R., Cuira F., Burlon S. (2021) 'Design of Shallow and Deep Foundations', CRC Press, 232 p.

Menard L., Rousseau J., Gambin M., (1975 rev. 2018), 'D.60 Brochure : The Menard Pressuremeter: Interpretation and application of Pressuremeter test Results to Foundation Design', Sols Soils no. 26, Ed. Apageo

Additional information can be found on the web site of the Internationnal Committee of Pressuremeter :
www. icp-pressuremeter.com/

6 MAINTENANCE

6.1 FILTER

Filter in the control panel prevent water and gas circuits from becoming contaminated with foreign particles. This filter should be cleaned and changed periodically.

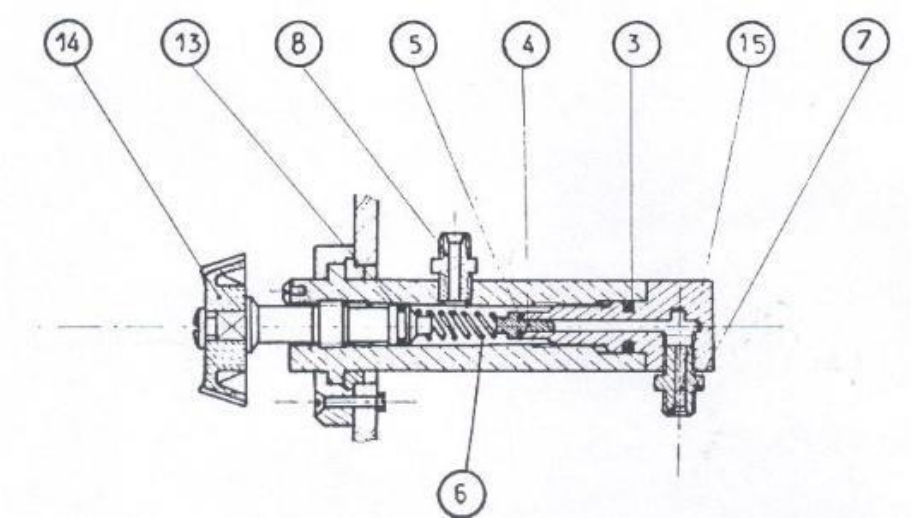
6.2 PRESSURE REGULATOR

Please note the the pressure regulator included with the GAM-II is a **non-vented** model. This model is equivalent to the one shown at the end of this manual. This type of presseure regulator requires much less efforts than the vented type in terms of servicing.

6.3 DIFFERENTIAL VALVE

Problem: *Unstable differential pressure*

Unscrew back of differential valve 8, remove valve 4, and clean off the fine dust that might have stuck to it, preventing seal 5 to tighten down correctly.
Reassemble the valve.



Differential Pressure Valve

3	seating seal	7	Inlet connector with filter
4	valve	8	outlet connector*
5	valve seal	13	Valve screw seal
6	spring	14	knob

* the outlet connector is similar to the inlet connector without filter (6 1/8 connector).

6.4 TROUBLE SHOOTING

When performing necessary corrective action in the following operations, refer to procedures described above.

Problem: *Differential pressure is not maintained.*

1. Make sure that differential pressure valve is clean.
2. Make sure valve 3 is not leaking

Problem: *The regulated pressure continues to increase after lock-up and without change in control knob position.*

Possible cause:

Pressure regulator assembly needs cleaning and seal replacement.

Problem: *Water does not come back to zero after a test.*

Possible cause:

The inside of the probe or tubing must be cleaned.

Problem: *Water got into the gas circuit.*

Bleed thoroughly gas circuit, including differential valve and pressure regulator.

Problem: *A valve is leaking*

1. Tighten slightly packing.
2. If necessary, replace valve itself.
3. Packing replacement is a delicate operation and requires proper tools

Problem: *Broken sight tube*

Take-off the polycarbonate protection strip in front of the sight tube 21, unscrew the 2 nuts 36, remove sight tube 21 if faulty and replace it with the spare tube kept in the control panel container. Re-assemble in the reverse order. Do not over tighten nuts 36.

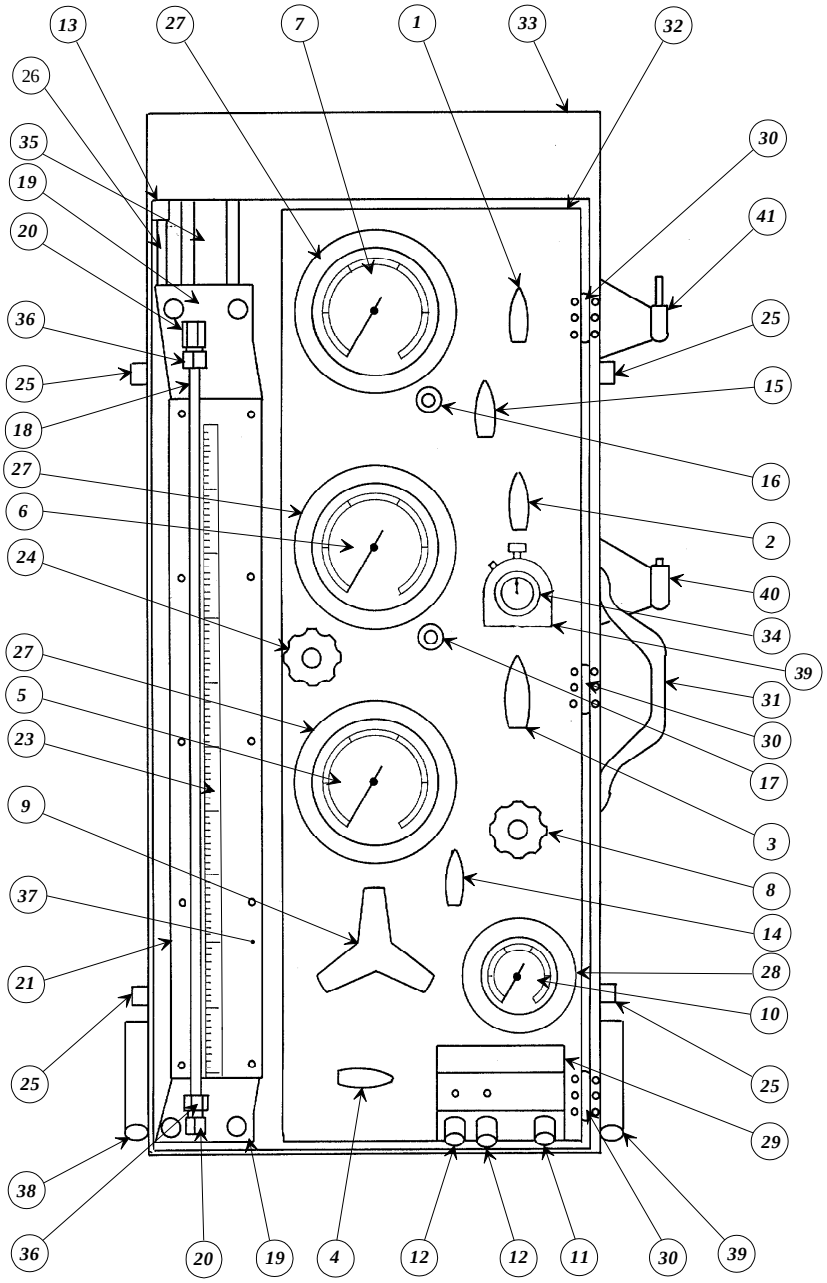
Problem: *Leaking bleed valve 2*

Remove the knob from the valve with a BTR 5/64 spanner and tighten the packing washer less than 1/8th of a turn with an 8 mm flat spanner.

7 PART LIST AND ILLUSTRATIONS

PRESSUREMETER GAM-II – PARTS	
ITEM	**DESCRIPTION**
	Control Panel
1	Valve for gas
2	Bleed valve for both water and gas circuits
3	4-way valve
4	Valve for water
5	0-2500 kPa pressure gage - central cell
6	0-6000 kPa pressure gage - central cell
7	0-2500 kPa pressure gage - guard cells
8	Differential valve
9	Main pressure regulator
10	0-200000 kPa pressure gage
11	Gas supply connector
12e	Water outlet connector
12g	Gas outlet connector
13	Volumeter inlet
14	Central cell gage selector valve
15	Guard cell gage selector valve
16	Female quick connector for optional gage on gas circuit
17	Female quick connector for optional gage on water circuit
18	Filter
20	Volumeter
21	Sight tube
	High Pressure Coaxial Tubing (HP)
1	Rilsan tubing 5 mm X 3 mm
2	Tecalan tubing
3	Tecalan connector ass'y
4	10 mm Nut
5	10 mm Ferrule HP
6	4 x 3 connector
7	O-ring øi: 0.087" X w: 0.031"(Bunan)
	Coupling for Two Tubings
1	Double connector
2	Internal tube

Front panel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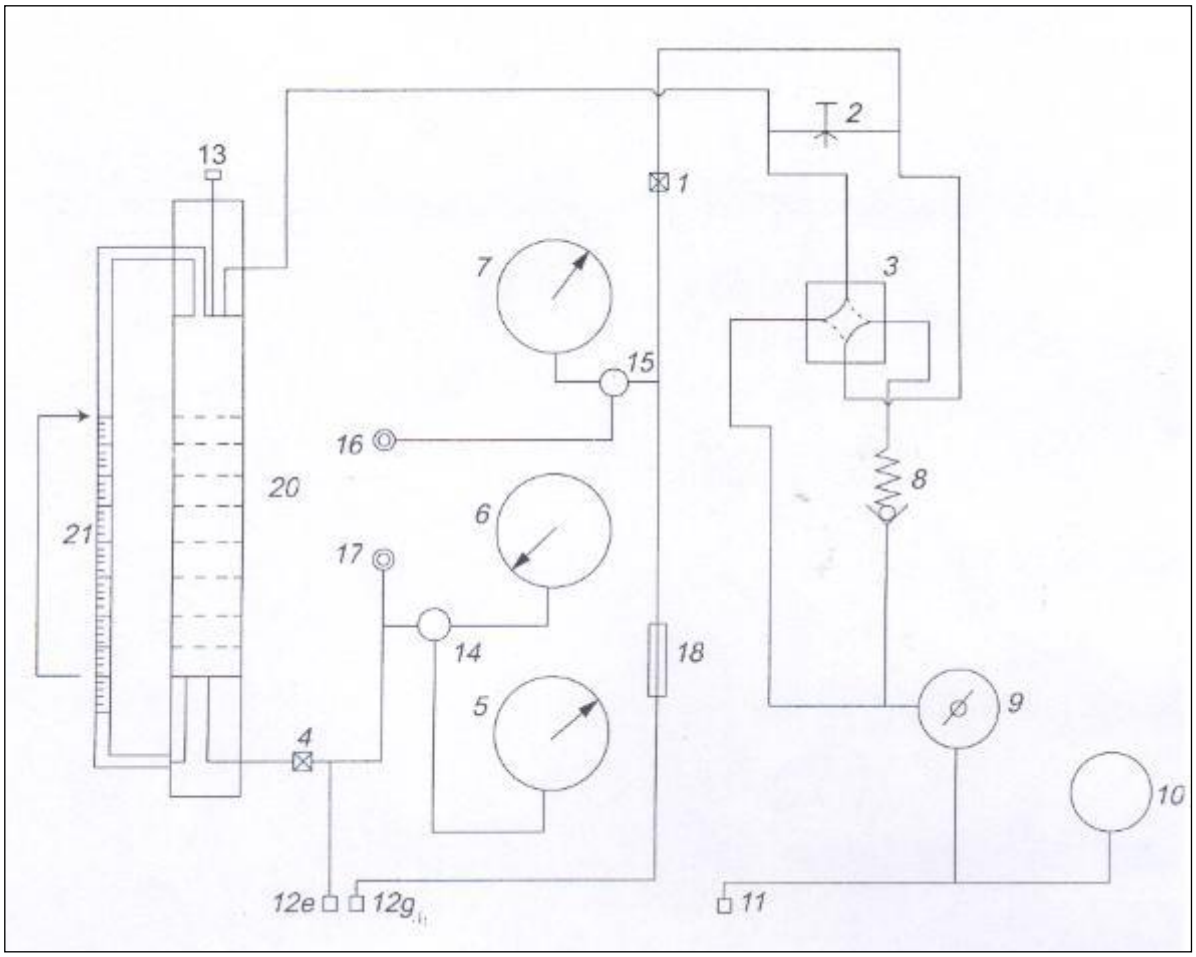
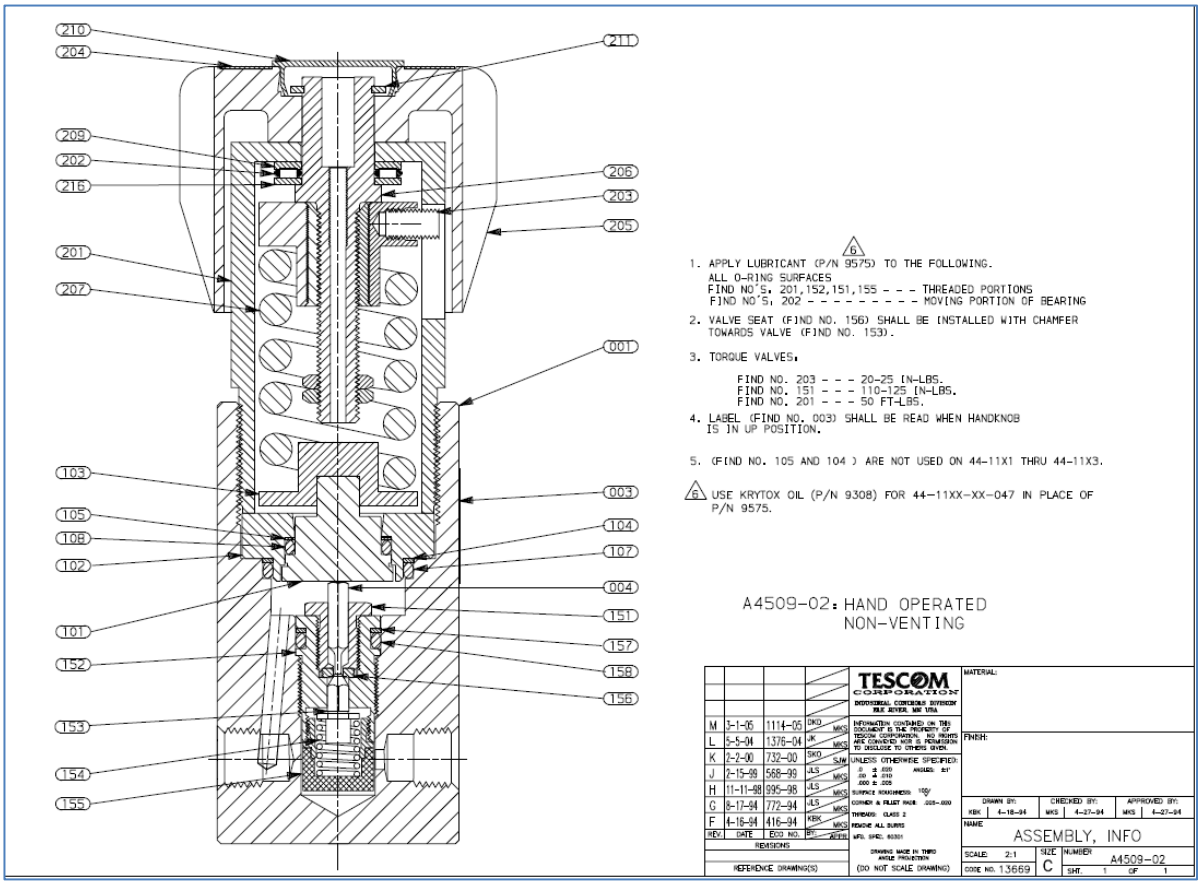
Circuit Schematic Diagram



Pressure Regulator