3115

OPERATING INSTRUCTIONS

FIELD PLANT WATER STATUS CONSOLE

March 2017

Fig. 1 - Model 3115 Portable Plant Water Console shown with 22 c/f Compressed Gas Cylinder, 3072V22

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SOILMOISTURE

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Model 3115
Portable Plant Water Status Console
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1. *3115 Portable Plant Water Status Console*

The PPWS Console, Model 3115, is supplied in water and dust proof Pelican instrument case. The 3115 can be configured as a 25 or 40 bar (25 or 40 Mpa) platform with either the G4 or G2 specimen holder (for petioles and stems to ½" (125 mm), or blade leaves to 1" (254 mm) respectively. Choose either the standard 22 cu. ft. capacity or purchase the optional 33 cu. ft. capacity compressed gas bottle, for a small additional cost. The 3115 uses a quick-connect/disconnect, hose with stainless steel braids, and an external Pressure Regulator, preset at the factory for the maximum operating pressure of 40 bar (4.0 MPa) or 25 bar (2.5 MPa). (see Fig. 1)

Fig. 1 Portable Plant Water status console

The PPWS Console was thoroughly tested before shipment. When packed, it was in perfect working order. Unpack with care and remove all packing material. Follow the instructions carefully in order to assure long, trouble-free service.

Any damage found upon receipt should be reported immediately to the transport carrier for claim. It is important to save the shipping container and all evidence to support your claim. Be sure to read all operating instructions thoroughly before operating the unit.

Soilmoisture Equipment Corp. (SEC) warrants all products manufactured by SEC to be free from defects in materials and workmanship under normal use and service for twelve (12) months from the date of invoice subject to the following conditions:

SEC's obligation under this warranty is limited to repairing or replacing (at SEC's option) products which have been returned prepaid to SEC or SEC's agent in the user's country. SEC will return warranted equipment prepaid.

This warranty shall not apply to any SEC products which have been modified, misused, neglected, involved in accidents of nature, or sustained shipping damage. Under no circumstances will SEC reimburse the claimant for costs incurred in removing and/or reinstalling equipment. This warranty, and SEC's obligation thereunder, is in lieu of all other warranties, expressed or implied, including warranties of suitability and fitness for a particular purpose.

SEC is not responsible for incidental or consequential damages, actual or inferred, caused by misuse or improper handling of its products. SEC products are designed to be used solely as described in the product operating instructions by a prudent individual under normal conditions in applications intended for each product.

Products returned to SEC should have a Return Merchandise Authorization (RMA) number issued by SEC to expedite your repair. Merchandise received by SEC without an RMA number will likely experience a delay in processing due to a lack of information regarding the repair.

2. 3115 PPWS CONSOLE SPECIFICATIONS

2.1	Weight:	26 lbs (11.8 kgs) (including tank)
2.2	Dimensions:	18.5 x 14.5 x 7 inches
2.3	Pressure Vessel:	1/2 liter (internal); stainless steel, 4 internal cam locks
2.4	Gauges:	Test Gauge, 4.5 in, white face, 0-25 bar (300 psi) or 0-40 bar (600 psi), accurate to within 1/4 of 1% full scale. Source Tank test gauge, 1.5 in, white face (0-3000 psi), part of the 3074 Quick Connect pressure supply hose assembly.
2.5	Valves:	Female, CGA 580 main valve on Compressed Gas Cylinder; Metering Valve to adjust the inflow pressurization rate for uniform measurements; Three-Way Pressure Control Valve to pressurize or to exhaust gas in the pressure vessel.
2.6	Connecting Hose:	Stainless steel pressure hose with quick connect/disconnect at the PPW end and a male CGA 580 fitting on the compressed gas cylinder side.
2.7	Pressure Tank:	Either 33 cu.ft. Compressed Gas Cylinder, 6.9” diameter x 15.8” length (shipped empty) or 22 cu.ft. Compressed Gas Cylinder, 5.25” diameter x 16.3” length (shipped empty)
2.8	Specimen Holder:	Accepts either sealing sleeves or sealing grommets for leaves or stems using 3015G4 Specimen Holder, or use sealing plugs with the 3015G2 Specimen Holder for blade-type leaves . Has a stainless steel sealing knob and aluminum closing ring, stainless steel camlock with safety relief piston (to prevent build up in the pressure chamber unless the specimen holder is cam-locked in proper position).

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3. *Accquaint yourself with Model 3115 Product Features:*

3.1 PPWConsole Carrying Case:

The PPWS Console is housed in a water-tight, dust-tight, briefcase-style Pelican Case®. When securely latched, it may be hand carried in the field (at 16 lbs less the bottle), or stored in low profile for future use. (Fig. 2).

Fig. 2 Carrying case

3.2 Specimen Holder Assembly:

3115 comes with the standard Specimen Holder Assembly (3015G4) for leaf petioles and stems to ½" diameter, or choose the 3015G2 Specimen Holder for blade-type leaves to 1" width. (See Fig. 3a). The Specimen Holder Assembly is removed by placing your hand on the closing cap and turning counterclockwise 45°, then pulling the Specimen Holder upward (Fig. 3b).

Fig. 3a Standard specimen holder

Fig. 3b Specimen holder for blade type leaves

Uses our unique cam lock cap-to-vessel security cap lock system (see Fig. 3c). Four cams and a stop pin provide a rapid cap-to-vessel assembly (see Fig 3d).

Fig. 3c Security cap lock system

Fig. 3d Rapid cap-to-vessel assembly

Also the Specimen Holder Assembly has a safety relief piston (Fig. 3e) that will not allow the Pressure Vessel to pressurize unless the cam locks have fully seated.

Fig. 3e Specimen holder with saftey relief piston

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3.3 Sealing Sleeves, Grommets, and Support Washers:

A full range of sealing sleeves, grommets and support washers are available to accomodate a wide range of leaf petioles and stems (see Fig. 4). Or please see our web site www.soilmoisture.com and select Product Information, then select Plant Water Status.

Fig. 4 Sealing sleeves, etc

3.4 Gauges

The Model 3115 can be configured for high pressure research applications to 40 bar, using the 0 to 4.0 MPa test gauge. Or configure the 3115 for lower pressure, routine irrigation scheduling (0 to 25 bar) with the 0 to 2.5 MPa gauge.

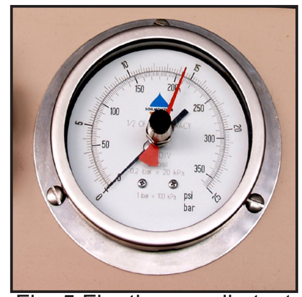

Fig. 5 Floating needle test gauge

(Fig. 5), shows the PPWS Console with the standard 41/2-inch, white-faced, stainless-steel housed, maximum pressure floating needle Test Gauge (0 to 600 psi, 0 to 40 bar); the gauge displays leaf or xylem water potential in psi or bars (1 bar = 100 kPa). Or the PPWS Console may be configured to read to 25 bar with a 0 – 350 psi (0-25 bar) Test Gauge. Either test gauge is accurate to ½ of 1% full scale.

Fig. 6 Pressure regulator

3.5 Pressure Regulator

The 1-1/4” external Regulator and Pressure Gauge is set at the factory to the specifications of the Console: 0 to 4.0 MPa (0 to 40 bar) for the standard model 3115, or the regulator will be set to 0 to 2.5 MPa for the lower pressure console. The Pressure Regulator is external to the PPWS Console and mounts to the Portable Gas bottle as part of the high pressure braided stainless steel Quick Connect/disconnect hose. (See Fig. 6).

Fig. 7 Metering valve

3.6 Metering Valve

A precision Metering Valve, (Fig. 7), allows the user to adjust the inflow rate to pressurize the vessel in accordance with the tissues monitor. A precision metering valve is an important consideration for making consistent plant water potential measurements.

3.7 3-Way Pressure Control Valve

A Three-Way Pressure Control Valve, (Fig. 8) allows: regulated and metered gas pressure to enter the Pressure Chamber; Pressure Chamber exhaust; and gas pressure shut-off to the Pressure Chamber.

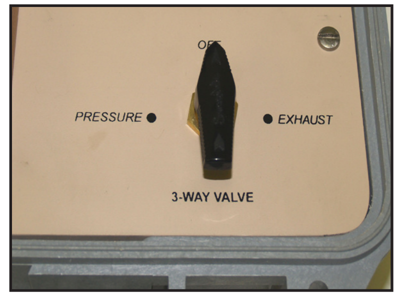

Fig. 8 Pressure control valve

3.8 Sample Preparation Board

A hardwood Sample Preparation Board, (Fig. 9a), holds the specimen holder conveniently on it's side to allow easy insertion of the plant specimen petiole or stem into the Specimen Holder. The cutting board also allows the user to neatly trim the petiole or stem for ease in viewing the arrival of the leaf or stem water at the trimmed surface (Fig. 9b).

3.9 Quick Connect Inlet Pressure Port

A Quick-Connect Pressure Supply Port, (Fig. 10), is located at the top right of the PPWS Console Panel. Use the 3074 Quick-Connect Hose (see below) to supply pressure from the compressed gas cylinder.

Fig. 9a/b Sample preparation board

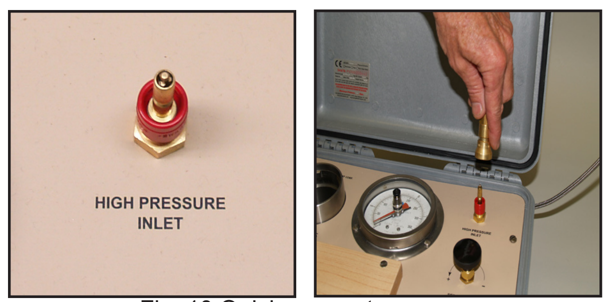

Fig. 10 Quick-connect pressure port

3.10 Use the Standard 22 cu.ft (622 liter) or Extended Capacity 33 cu.ft (934 liter) Cylinder

A Compressed Gas Cylinder, is required to pressurize the PPWS Console. Two sizes are available; the standard 3072V22 Compressed Gas Cylinder (22 cu.ft. capacity) or larger 3072V33 Compressed Gas Cylinder (33 cu.ft. capacity) (Fig. 11).

Fig. 11 Pressure cylinders

3.11 High Pressure braided stainless steel Quick Connect Pressure Supply Hose

The Quick-Connect Hose (3074), (Fig. 12), a high pressure stainless steel braided delivery hose with regulator and CGCA gas bottle fitting, is required to connect the Compressed Gas Cylinder to the PPWS Console.

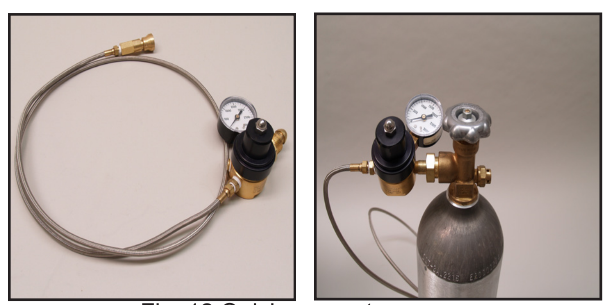

Fig. 12 Quick connect pressure supply hose

3.12 4.5” deep Stainless Steel Pressure Vessel

The stainless steel Pressure Vessel, (Fig. 13a), is 2-3/4 inches by 4.5 inches deep to conserve gas pressure per use, and will accept a great variety of leaf samples. The Vessel’s high pressure gas inlet / outlet is in the lower vessel wall (see Fig. 13b).The PPWS Console pressure vessel is designed to handle most commercial plant species where Plant Water Status is routinely monitored for irrigation scheduling. Other Plant Water Consoles manufactured by Soilmoisture Equipment Corp. are designed for research applications for the widest variety of plant leaf and stem sizes.

Fig. 13b Vessel high pressure gas inlet/outlet

Go to www.soilmoisture.com and search for models 3000 and 3005 Plant Water Consoles.

Fig. 13a Stainless steel pressure vesel

Safety

☞ *** * * Practice Safety First … Always! * * ***

These instructions are very important to carefully read and understand, because we are dealing with pressures up to 2200 psi (150 bar)

When making a measurement: **NEVER PLACE YOUR FACE OVER THE CENTER OF THE SPECIMEN HOLDER ASSEMBLY.** Always use a hand lens or magnifying glass to observe the expressed water at the cut petiole surface.

Always remind yourself that we are working with very high pressures, and that one should use this equipment with caution and to have a very clear understanding of the physical principals involved in the equipment and plant measurement.

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4. Using your New PPWS for the first time:

The Model 3115 is housed in a water and dust proof Pelican tm instrument case. The convenient handle and rugged design make it an excellent choice for field work.

Fig. 14Field plant water status

4.1 Select a convenient platform from which to make your measurements. You will need a hand lens (5x to 10x) or magnifying glass, a sharp knife o r razor blade, and the ability to easily view the top of the specimen holder assembly. A t a i l gate, field table, ATV rack, or convenient stump make excellent platforms. Move the N2 gas bottle (3072V22 or 3072V33) to a safe and convenient location nearby (see Fig. 14)

Fig. 15 a/b Turn the valve to OFF

4.2 Check the 3-Way Valve on the 3115 Control Panel. Assure that this valve is turned to **OFF** (see Fig. 15a-replace w/ ne EXHAUST). Also gently turn the Metering Valve clock-wise until it seats fully (see Fig. 15b); TO PREVENT DAMAGE, DO NOT OVER-TIGHTEN THE METERING VALVE

Fig. 16a Tightning with open ended wrench

4.3 Attach the Quick Connect stainless steel braided high pressure hose with exterior regulator to the Compressed Gas Cylinder and to the PPWS Console. Thread the CGA580 fitting into the supply bottle Valve and tighten clock-wise with a 1-1/8” open-ended wrench (see Fig16a). Attach the 3074 Quick Connect fitting to the PPWS Console (see Fig. 16b).

NOTE: When you attach the Quick Connect fitting to the High Pressure Inlet fitting on the 3115 Control Panel, you should hear a “click” as the Quick Connect mates with the High Pressure Inlet Fitting. Try to remove the connected hose to check for a secure connection before you pressurize the hose and the 3115 unit.

Fig. 16b Attaching quick connect fitting to the console

4.4 With the Quick Connect fitting attached to the console and the 3-way Valve turned to OFF, try to pressurize the hose/connection by opening the main valve on the gas bottle. If you hear hissing, re-tighten the CGA fitting. Once secure, read the 2” dial gauge on the remote regulator; this indicates the pressure in the supply tank.

4.5 Remove the Specimen Holder Assembly

Fig. 17 Removing specimen holder.

When the Specimen Holder (3015G4 or 3015G2) is removed the first time, it may require considerable force. Do not worry, this is normal. The O-ring used to make the pressure seal tends to “seize” to the metal surface if it is allowed to remain in the compressed position for a considerable time. To minimize this problem, apply a thin coat of light grease, such as stopcock grease or Vaseline, to the inside pressure vessel lip (the ½” (12.5mm) surface inside the pressure vessel just above the 4 locking cams … the surface where the Specimen Holder O-ring (M802X149) (see Fig. 17) seats. Then, after the specimen holder is removed for the first time, it will enter and close with ease.

Caution: the use of a light grease will tend to accumulate dust and other foreign materials. Be sure to clean these surfaces regularly and to re-grease as necessary to maintain the unit in good operating order.

Remove the Specimen Holder Assembly from the pressure vessel by placing both hands on the Specimen Holder and pushing down gently while turning the assembly counter-clockwise until you hear a soft click indicating the cam-lock seat is now open.

Fig. 18 Specimen holder placed on prep board

Lift the Specimen holder from the pressure vessel. Place the specimen holder in the convenient notch on the Preparation Board (see Fig. 18). In this example we have used the 3015G4 Specimen Holder.

The G4 Specimen Holder is a sub-assembly of the PPWS Console. There are several components:

a) The Sealing Knob with collet-type seat;
b) The Sealing Grommet --- may be accompanied by a Sealing Sleeve;
c) The Support Washer.

The G2 Specimen Holder is a sub-assembly of the PPWS Console. There are several components:

a) The Compression Ring;
b) The Sealing Plug;
c) The Support Washer.

Fig. 19 Inspection of the specimen holder assembly

4.6 Remove the Sealing Knob or the Compression Ring from the Specimen Holder assembly (see Fig. 19) and inspect the Sealing Sleeve, and/or Sealing Grommet, and the Support Washer for the G4 holder or Sealing Plug and Support Washer for the G2 holder. One must decide on the ‘tightest’ fit of grommet, sealing sleeve or sealing plug and sealing washer to match the plant specimen petiole, stem or blade-type leaf to assure safe operation of the PPWS Console. When purchased new, there were a complete set of sealing sleeves, sealing grommets and support washers for the G4 holder or sealing plugs and support washers for the G2 holder.

CAUTION: ***<u>Remember</u> that the specimen placed in the pressure vessel will be under high pressure. A loose sealing grommet or oversized sealing washer may allow the specimen to ‘explode’ from the Specimen Holder Assembly.***

For example: if you want to measure grape leaf petioles that have a diameter of 3.75 mm to 4.25 mm.

The appropriate selection of sealing sleeve grommet, and support washer are;

1 - 3018G4-003K1, sealing sleeve, ½” OD (12.7 mm) x 3/16” (4.76 mm) ID
1 – 3019G4-011K1, stem grommet, individual, saucer-type, ½” ID (12.7 mm)
1 – 3020G4-001K1, brass support washer, for stem grommets, ¼” diam. hole (6.35 mm)

Washer being placed on top, over the grommet and sleeve.

Please see Replacement and Repair Parts listed below (page 22).

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4.7 Make a leaf or stem water potential measurement:

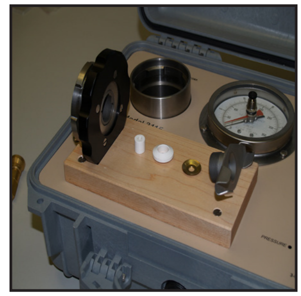

Fig. 20 Observe the pressure in supply tank

With the 3-way control valve turned to OFF, open the main valve on the pressure supply bottle. Observe the pressure in the supply tank by viewing the 2" gauge (0781P3000) attached to the regulator (see Fig. 20). Decide if you have enough gas pressure to conduct your measures without re-filling during a set of measurements. Experience with the particular species, level of water status deficit, and aspect/slope/location will be the determining factors. For all intents and purposes, one should refill the portable pressure supply tank when the test gauge reads 250 psi (appx. 17 bar) as this is a common value for mid-day leaf water potentials of low to moderate water stress.

NOTE: Plants under greater water deficit will have higher leaf or stem water potentials than non-stressed plants. Because gas pressure / volume relationships vary due to the level of water stress, then we expect to see the volume of gas used for a set of measurements to increase as the plant experiences greater water deficits. The model 3115 pressure vessel is 4.5" ht. X 2.5" diam., and is smaller than previous models. The smaller vessel will consume less gas volume per measurement than the standard 7' height vessel. This helps to conserve gas volume during each measurement. As an additional gas conservation technique, one can partially fill the pressure vessel with glass marbles to occupy a volume within the vessel. The marbles should not block the inflow or outflow of gas within the vessel.

Note: Before pressurizing the Pressure Vessel for the first time, ALWAYS verify that the Specimen Holder is turned completely clockwise (as defined above), then double-check by trying to remove the Specimen Holder by lifting it from the Pressure Vessel. The Locking Pin should seat against the internal cam-lock and the Specimen Holder cannot be removed from the Pressure Vessel. An additional safety feature is the safety relief piston, that prevents build-up of pressure in the chamber if the Specimen Holder is not 'cam-locked' into the pressure vessel.

CAUTION: If necessary, practice the routine of inserting, attaching, locking and checking the pressure hose and specimen holder assemblies until you are comfortable with these procedures; your safety depends on it.

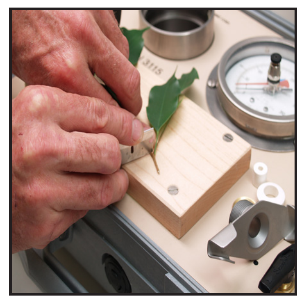

Fig. 21 Inspection of the specimen holder assembly

Example 1 using the G4 holder with sealing sleeve and grommet ---
Select and remove an appropriate leaf or stem sample. Please read: Theory of Plant Water Status Measurements, (Appendix 1, these instruction) to decide where and when to sample within the plant canopy. Leaves may be pulled from the plant or preferably cut with a knife or razor blade.

Place the leaf or stem specimen on the Sample Board and trim the petiole or stem with a razor blade before inserting the sample into the specimen holder (Fig. 21); it will be much easier to observe the pressure associated with the arrival of plant water in the petiole when making the measurement.

Insert the leaf specimen into the sealing sleeve, petiole or stem first (see Fig. 22a). Then insert the sleeve into the sealing grommet within the specimen holder (see Fig. 22b). The severed leaf will extend into the pressure vessel chamber while the petiole is positioned to be viewed outside the chamber with a hand lens. Gently tighten the Sealing Knob enough to hold the specimen in place, (Fig. 22c). Lower the severed leaf specimen into the pressure vessel, (Fig. 22d) and check for good alignment for viewing with a hand lens, (Fig. 22e).

Fig. 22a
inserting leaf specimen into sealing sleeve

Fig. 22b
Inserting sealing sleeve into sealing grommet

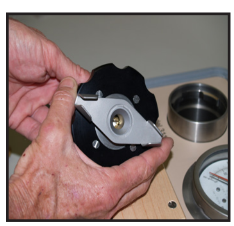

Fig. 22c
Gently tighten sealing knob

Fig. 22d
Lower the severed leaf specimen into the pressure vessel

Fig. 22e
Check for good alignment for viewing

4.8 Insert the Specimen Holder with leaf sample into the Pressure Vessel by matching the cam-locks of the specimen holder and the pressure vessel. Press to seat the Specimen Holder. A dull thud-ring sound should be heard as the specimen holder seats in the pressure vessel. Now turn the Specimen Holder clockwise 1/8 turn to lock it in place. A soft click should be heard as the Specimen Holder stop pin (roll pin MSL014-005) seats securely against the internal cam-lock, (Fig. 23).

Fig. 23 Specimen holder is turned clockwise to lock

4.9 Next, turn the 3-way control valve to PRESSURE (see Fig. 24). Observe the 41/2” diameter, ½ % accuracy Test Gauge, it indicates the pressure within the Pressure Vessel at all times.

Fig. 24 Turn control valve to pressure

Open the Metering Valve to control the rate at which pressure is built up in the Pressure Vessel. **The Metering Valve is usually adjusted so that the rate of pressure increase is in the range of 3-5 psi per second (Fig. 25).** The inflow rate should be slow enough to clearly see the end point and the equivalent leaf or stem water potential. If the inflow rate is too fast, it is possible to ‘over-run’ the end point. Experience with the particular plant species will help refine the pressure increase rate. Either use the grommet blank (to seal the pressure vessel) or adjust the inflow with a specimen in the pressure vessel.

Fig. 25 Opening of metering valve

Listen for gas leakage around the petiole or stem. Tighten the Sealing Knob or Compression Ring until the gas leak stops. **If there is gas leakage from around the petiole use the** Sealing Knob (Fig. 26a) on the G4 Specimen Holder to gently increase the seal until the gas leakage ceases. The Sealing Knob actuates the collet-type closure that pressure seals the specimen and sealing sleeves during a run. Turning the Sealing Knob clockwise seals the specimen. Turning counter clockwise releases the seal. When in the middle of pressurizing the leaf or stem sample and gas begins to leak from the collet-type seal, then simply tighten the seal by turning the Sealing Knob clockwise or tighten the compression ring with the Allen Wrench for the G2 holder (Fig. 26b) until the hissing gas leak stops.

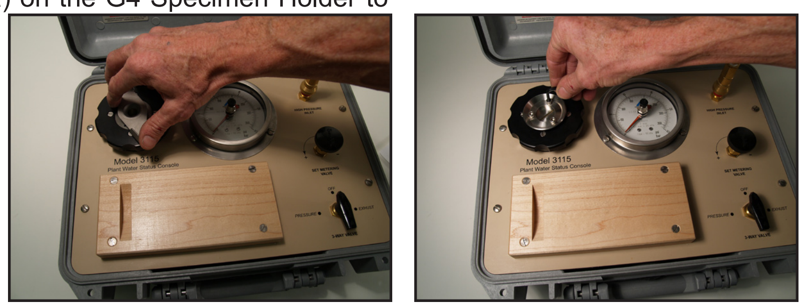

Fig. 26a/b Tighten sealing knob or compression ring

Note: It is important to not crush he vascular system when tightening the sealing grommet, sleeve or sealing plug. Tighten only enough to seal the specimen.

Use a Hand Lens to view the cut petiole or stem surface (Fig. 27). It is very important to clearly see the water approach the cut petiole surface and it therefore becomes important to establish an inflow rate compatible with the plant species and level of water stress. The only satisfactory approach has been to sample the water stress in the plant by test sampling appropriate tissues from similar species, similar stress and landscape position.


Fig. 27 Using a hand lense to view the cutteing

Pressurizing too fast can result in 'over pressure' errors and can cause the phloem sap to froth and occlude the xylem surface before the arrival of the xylem water. Turn the Metering Valve clockwise to decrease the rate of flow. During routine tests, the Metering Valve can be left at one fixed position to give uniform pressure build up on all samples.

4.10 Use a hand lens (10x) or magnifying glass at 'arm's length' (see Fig. 27) with your face away from the center of the specimen holder, and observe the generally crystalline white surface of the cut petiole (some petioles take on a sugary appearance in hues of green). Continue to observe while the pressure in the chamber increases to push leaf water to the cut surface. The liquid water front can be seen to approach the cut surface as the crystalline white xylem and pyrenchma appear to turn grey or white in color.

The following photo sequence, (Fig. 28aa to Fig. 28ee), show a severed stem of an Acer spp. as pressure increases in the pressure vessel.

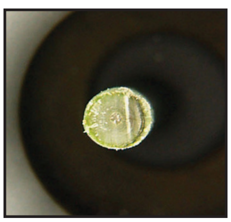
Fig. 28aa

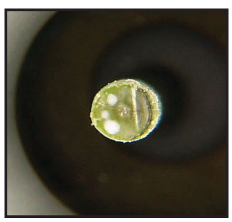
Fig. 28bb

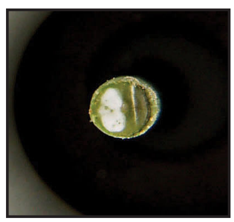
Fig. 28cc

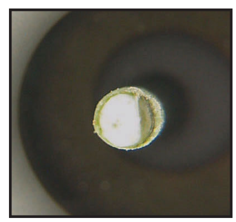
Fig. 28dd

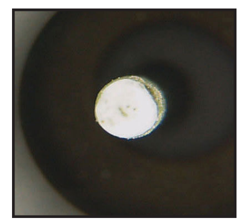
Fig. 28ee

4.11 The proper end-point measurement is obtained when liquid water arrives at the cut surface (Fig. 28bb) = 17.2 bar, as the result of the pressurizing the specimen in the pressure vessel.
Just prior to the arrival of the xylem fluids at the surface of the cut petiole, the generally lighter green sugary appearance in Fig28aa-3115 began to darken indicating the end-point. (Figs.28cc through Fig. 28ee) show the cut stem with excess xylem water continuing to exude at the cut surface, over-running the end-point. As the picture sequence was taken in 1 second intervals, we can observe that our lack of vigilance can result in over-run errors; with an additional 3 seconds of pressurizing the chamber in the present example, we over-ran the end point by 0.7 bar (10.2 psi).

We have therefore outfitted the test gauge on Model 3115P40G2 or 3115P40G4 with a Floating Pointer Needle (red) (Fig. 29) that is pushed by the main needle to the maximum pressure noted and remains fixed after the pressure in the vessel has been halted by turning the 3-way Control Valve to OFF or exhausted by turning the 3-way control knob to EXHAUST. With this gauge, one can concentrate on observing the correct end-point without having to view the gauge simultaneously.

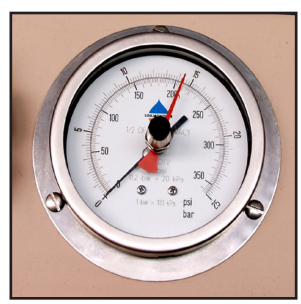
Fig. 29 Floating pointer needle

4.12 Special Note: our determination of the end-point, when liquid water is forced to the cut petiole or stem surface, is the <u>essence</u> of our estimation of plant water stress. Careful vigilance and attendance to proper methods result in repeatable data. While some users of this type of tool claim accuracy, when they have pulled the leaf sample from the plant, inserted the sample in the pressure vessel without trimming the petiole with a razor blade, and observed the end-point without a magnifying glass, their accuracy is highly doubtful. Careful attendance to detail and procedure will assure accuracy and success using the Portable Plant Water Status Console.

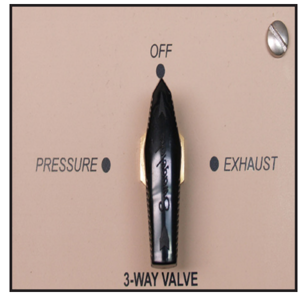

Fig. 30 Turn 3-way valve to OFF

4.13 Turn the 3-way valve to OFF (Fig. 30) when the wetting front reaches the cut surface, and record the maximum gauge value indicated by the floating needle.

When complete, this needle must be manually returned to zero for the next measurement (see Fig. 31a and Fig. 31b).

Next, **turn the 3-way valve to EXHAUST (Fig. 32)** to depressurize the vessel.



Fig. 31a/b Return the floating needle manually

4.14 Finally, remove the used leaf or stem specimen and discard it.

NOTE: it is best to complete a set of measurements as rapidly as possible, as the climate factors controlling water deficit often vary. For routine irrigation scheduling, two periods of the day (pre-dawn and mid-day) that relate specifically to minimum and maximum water stress have been identified. In practice, the pre-dawn measurement is more accurate for predicting plant water stress because leaf stomata have been closed since the previous sunset, and water in the plant has had the opportunity to equilibrate with available soil water content. In practice, however, few desire to work in the orchard or vineyard before dawn and therefore new techniques have been developed to estimate plant water stress. Please read

Sometimes it is not possible to obtain a complete measurement set with the small supply bottle (3072V22, 22 cuft), and therefore a larger supply bottle should be used (3072V33, 33 cuft), or use a standard gas supply bottle with 304 cuft of compressed gas.

Also NOTE: Review Appendix 1 below. When making plant water status measurements it is important to understand that there exist inherent tensional gradients in the plant from the roots to the leaves. These gradients are further compounded by daily climate (temperature / humidity), soil water content, and tissue shading … to name a few. Leaf or stem tissues are usually selected for uniformity in canopy position and tissue age when estimates of plant water stress are used for irrigation scheduling

4.14 Remember:

The Three-Way Pressure Control Valve directs the flow of gas into or out of the Pressure Vessel and seals the gas within the Pressure Vessel.

When the Three-Way Pressure Control Valve is in the "OFF" position, high pressure gas is sealed within the Pressure Vessel and no gas can enter or leave.

When the Three-Way Pressure Control Valve is in the "PRESSURIZE" position, high pressure supply air from the Pressure Regulator flows through the Metering Valve, through the Control Valve and then into the Pressure Vessel.

When the Three-Way Pressure Control Valve is in the "EXHAUST" position, the high pressure gas from the supply tank is shut-off and the pressure within the Pressure Vessel exhausts immediately to the atmosphere.

Located underneath the panel (not shown), a Safety Relief Valve has been incorporated into the system to prevent damage from any excess buildup of pressure. The Relief Valve is set at the factory so that pressure will be released when it exceeds the maximum operating range of the console.

5. General Maintenance

Fig. 33 Source tank pressure gauge

5.1 Refill the Compressed Gas Source Tank

The Source Tank Pressure Gauge (2" white face) screwed into one of the ports of the Regulator on the (3074) Quick Connect Pressure Supply Hose indicates the pressure within the Compressed Gas Tank and is used as a guide to indicate when the Cylinder needs refilling (Fig. 33). When this gauge reads 200 to 250 psi (13.6 to 17.0 bar), then for all intents and purposes the tank should be refilled as the pressure is minimal for most low to moderate plant water stress measurements. To refill the compressed gas cylinder, the following procedure is used:

1) Close the Metering Valve (Fig. 34a), by turning clockwise. REMEMBER … DO NOT OVER TIGHTEN.

2) Turn the 3- Way Control Valve to "OFF" position (Fig. 34b).

3) Close the Compressed Gas Cylinder Valve on the 3072V22 or 3072V33 gas cylinders; turn the valve clockwise (Fig. 3c).

4) Turn the 3 – way Control Valve to Exhaust (Fig. 34d) to release any remaining pressure in the vessel, valves, and supply hose.

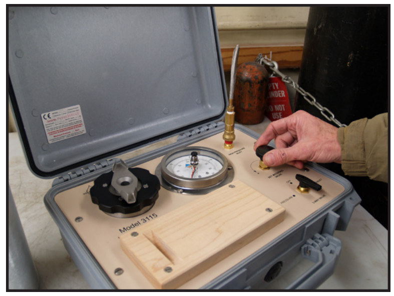

Fig. 34a Close metering valve

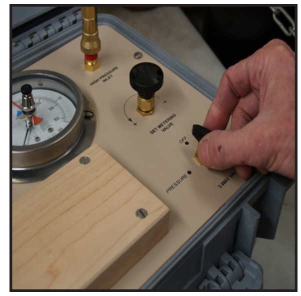

Fig. 34b Turn 3-way control valve to OFF

5) Use a 1-1/8" open end wrench to disconnect the CGA580 fitting from the Compressed gas cylinder (see Fig. 34e). Sometimes there may be pressure remaining in the hose, so use the 1-1/8" wrench to only loosen the fitting (do not remove at this time). You will hear hissing at the fitting if there is still pressure in the system. If the hissing continues, the valve on the Compressed Gas Cylinder may still be open. ALWAYS DOUBLE CHECK YOUR PROCEDURES. When the hissing stops, it will be safe to completely remove the 3074 supply hose and regulator assembly from the compressed gas cylinder.

Fig. 34c Close compessed gas cylinder

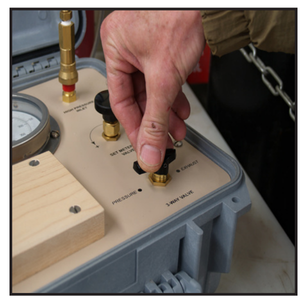

Fig. 34 d Turn 3-way control valve to EXHAUST

Either take the empty compressed gas cylinder to a qualified compressed gas supplier, or refill the bottle yourself. The gas most commonly used for Plant Water Status measurements is N_2 although some use atmospheric gas.

If you intend to refill your own compressed gas cylinders, please take the time to review these procedures and be very familiar with the hazards involved;

*** * * Practice Safety First … Always! * * ***

<u>These instructions are very important to carefully read and understand, because we are dealing with pressures up to 2200 psi (151 bar)</u>

Always remind yourself that we are working with very high pressures, and that one should use this equipment with caution and to have a very clear understanding of the physical principals involved in the equipment and the plant measurement.
WORKING WITH HIGH PRESSURE COMPRESSED GAS IS DANGEROUS … BE VERY CAREFUL.

Fig. 34e Disconnect the fitting

5.2 Refill the Compressed Gas Bottle yourself

A large compressed gas supply bottle (304 cuft, 8.6 M^3) can be obtained from a qualified gas supply dealer. They are also qualified to refill your High Pressure Bottle (Fig. 35).

Fig. 35 Large compressed gas supply bottle

However, if you intend to refill your smaller more portable Pressure Supply Bottle (3072V22 or 3072V33) yourself, you will need the 0777L60 Valved Filler Hose (order this item separately) (see Fig. 36)

This refill system has a high pressure CGA580 fittings on either end of the hose. The stainless braided filler hose includes a valve to control the flow of gas from the large bottle to the smaller portable field bottle used with the 3115, and a dial gauge to view the supplied pressure to the smaller bottle.

Fig. 36 Valved filler hose

Look at the 0777L60 Valved Filler Hose; it has CGA580 fittings on both ends of the hose. It is very important that the gas flows through the valve from the large source tank to the small tank.

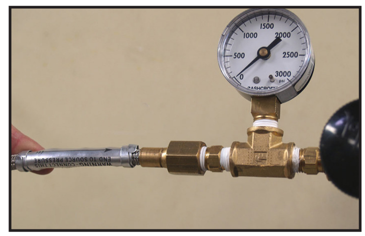

Fig. 37a Connect vave filler hose to large bottle

Take special note of the metal warning tag attached to the hose near the pressure gauge and valve. It reads: **WARNING: CONNECT THIS END TO SOURCE PRESSURE** (Fig. 37a) and has a **large arrow pointing to the gauge and meter side of the hose.**

When received there was also a RED TAG with the warning:

NEVER FILL GAS CYLINDER TO GREATER THAN RATED PRESSURE.

DO NOT EXCEED 2000 PSI FOR THE ALUMINUM BODY 3072V22 OR 3072V33 GAS CYLINDER.

Fig. 37b Connect remaining fitting to small gas bottle

Assemble the Valved Filler Hose (gauge and valve side) to the large bottle first. Use the 1-1/8” open end wrench to tighten the fitting at the supply bottle (Fig. 37b).

Next connect the remaining CGA580 fitting to the PPWS small compressed gas bottle (3072V22 or 3072V33) that needs refilling. Tighten this fitting with the 1-1/8” open end wrench (Fig. 37c).

Fig. 37c Tighten this fitting with 1 1/8" wrench

5.3 Check for Leaks:

Large bottles of compressed gas are typically received with up to 2200 psi compressed nitrogen gas. With the CGA580 fittings tightened at both ends and the small bottle compressed gas valve closed and the Filler Hose valve closed, open the compressed gas valve on the main bottle first; listen for leaks. If the CGA580 fitting on the main bottle is leaking, use the 1 1/8” open end wrench to tighten the fitting until it stops leaking.

Next, open the valve on the filler hose and listen for leaks at the portable bottle CGA580 fitting; the CGA580 valve on the smaller bottle should be closed. If the fitting is leaking, then tighten as above. At this point the hose has been pressurized and the gauge will show how much pressure is in the main bottle (Fig. 38a).

Next, close the filler hose valve and open the Compressed Gas Cylinder Valve on the small supply tank … **just a small amount. We want to refill this bottle slowly** to avoid excessive heat build-up due to rapid compression of the gas in the small bottle. By transferring the gas slowly we avoid this potentially hazardous action (Fig. 38b).

Next, open the filler hose valve slowly and allow the pressurized N_2 gas in the main bottle to flow to the small bottle. Watch the pressure gauge. The pressure shown is the pressure in the small tank (Fig. 38c).

Remember: DO NOT EXCEED 2000 PSI IN THE SMALL TANK.

Once the portable bottle has been filled, shut off the Filler Hose Valve first. This will terminate the transfer of gas (Fig. 38d).

Next, shut off the Compressed Gas Supply Valve at the small bottle first (Fig. 38e), and then close the valve on the main bottle. At this point there will still be high pressure in the stainless steel braided supply hose.

Use the 1-1/8" open ended wrench to '**crack-open**' either CGA580 connection at either the main supply tank or small bottle. Just 'crack-open' the CGA580 fitting to release the pressure in the hose (Fig. 38f). When the hissing stops, it will be safe to remove the fitting completely.

Re-connect the 3074 Quick Connect Pressure Supply Hose hose to the small pressure supply bottle by inserting the CGA580 fitting and tightening with the 1-1/8" open ended wrench (Fig. 38g). Check for leaks and re-tighten if necessary. Reconnect the Quick Connect Hose fitting to the 3115 and make sure to open the main valve on the 3072V22 or 3072V33 (Fig. 38h).

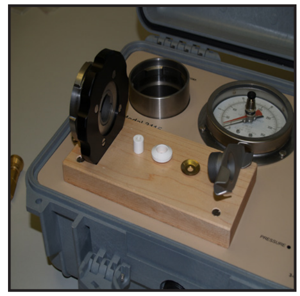

Fig. 38a Gauge showing pressure in main bottle

Fig. 38b Open valve just a little

Fig. 38d Shut off filler hose valve

Fig. 38c Open filler hose slowly; pressure shown is pressure in small tank

Fig. 38e Shut off supply vaslve of small bottle

Fig. 38f Crack-open fitting

Fig. 38g Re-connect quick connect pressure supply hose to small bottle

Fig. 38h Re-connect to the 3115

5.4 Cleaning Maintenance

Occasionally you should thoroughly clean and check your 3115 PPWS unit for damage and normal wear.

Field work is always a dusty and dirty environment. Your tools can suffer most from dust and grit wearing the metal at all points where two surfaces move against each other. The model 3115 PPWS Console is enclosed in an air/water tight Pelican Case™. This case dramatically reduces most of the dust/dirt collecting on the instrument during transport, however it can not prevent dust/dirt accumulation when the tool is in use. Periodically use high pressure air to blow dust off the exterior case and interior instrument.

Occasionally, the specimen holder may need thorough cleaning because vacuum grease or other lubricant has been used on the moving parts. The parts are constructed of stainless steel and can be washed and/or brushed in a mild soapy water solution, then rinsed in Deionized water, and thoroughly dried with a soft towel.

Routine care for your instrument will provide you with long uninterrupted service.
For maintenance purposes or to check out the PPWS Console, and/or to acquaint yourself with its operation, you can substitute a round dowel pin for the leaf sample in order to seal the Specimen Holder. Or use the supplied blank sealing sleeve and blank support washer to pressurize and test the 3115 pressure vessel and gauge.

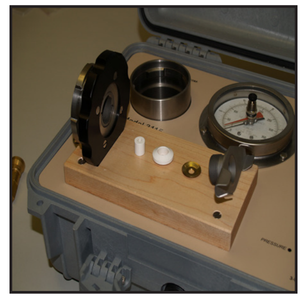

Fig. 39 Remove/replace sealing sleeve or sealing grommet

5.5 Remove / Replace the Sealing Sleeve or Sealing Grommet:

Remove Specimen Holder from Pressure Vessel, as described earlier, and place it in the notch on the Sample Preparation Board. Remove the Sealing Knob, the support washer, the sealing sleeve or sealing grommet (see Fig. 39).

The sealing sleeve or sealing grommet (or the sealing plug in the 3015G2 holder) receive the most routine use, as the leaf or stem specimens are inserted and removed from the pressure vessel. Some petioles and stems are smooth (causing little wear each use), and some are rough (causing more wear each use). It is always wise to keep a set of spare grommets and sleeves.

A failing grommet or sealing sleeve will be characterized by not being able to 'seal' the petiole or stem in the specimen holder assembly accompanied by gas leaking. To seal, simply tightening the 'Sealing Knob' (or the compression ring on the 3015G2 holder), when the specimen is under pressure. If tightening the Sealing Knob does not stop the pressure leak, then replace the grommet, sealing sleeve or sealing plug, or check to see that you have the 'best fit' sealing sleeve, grommet or sealing plug.

Fig. 39a Remove the gauge face cover glass

5.6 Re-Set the Needle Pointer on the 4.5" dial gauge:

Re-adjust the needle pointer to ZERO in the event that the needle has been 'jarred' and needs to be re-set.

Remove the gauge face cover glass by turning the stainless steel housing counterclockwise (Fig. 39a). There is a rubber 'o-ring' beneath the glass cover plate and it may be initially difficult to remove for the first time.

Take extra care to not damage the 'floating needle' that is loosely mounted to the face plate. The hanging needle float pin hangs deeper than the attached cover plate and housing assembly and can be easily damaged if the face cover is placed right-side-up on a table top or work bench. Turn the face cover assembly upside down (ie. with the floating needle up) before setting it on the work bench. (Fig. 39b)

Fig. 39b face cover assembly upside down

Use a small bladed screwdriver to adjust the main needle to the 'zero' position (Fig. 39c). The needle is mounted with a small ratcheting gear that may be re-adjusted as needed. Replace the cover face plate assembly and tighten by twisting the housing clockwise.

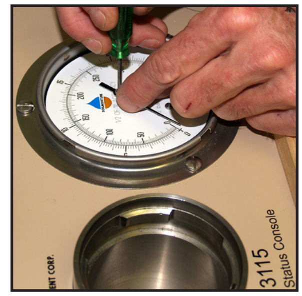

Fig. 39c Adjust the main needle with small screwdriver

5.7 Repair/up-grade the Specimen Holder Assembly:
At times it may be necessary to replace O-rings or up-grade (effective Oct 2006) the Safety Relief Piston assembly in either the G2 or G4 Specimen Holder. Use the special kit Z3015K1 that includes the following items (see Fig. 40a and Fig. 40b):

Fig. 40a Special kit

Fig. 40b Special kit

To repair or replace these items, please follow these simple instructions.

For the 3015G2 or 3015G4 Specimen Holder –
Remove the Specimen Holder from the pressure vessel and place on the work bench.

For the G2 holder, use the allen wrench to remove the 3 hex cap screws from the compression ring (Fig. 41a). For the G4 holder, remove the sealing knob sleeves and grommets.

Use a blade-type screwdriver to remove the 4 8-32 x 5/16 flat head screws from the closing ring (Z3015G4-003) (Fig. 41b).

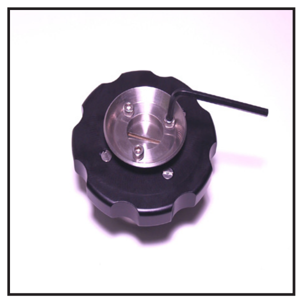

Fig. 41a Remove the hex cap screws

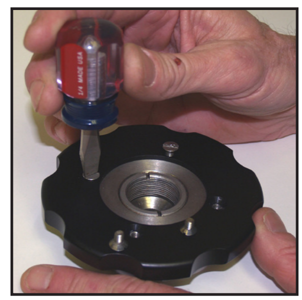

Fig. 41b Remove the flat head screws

Use the Teasing Needle (MML049) to remove the large O-ring (M802X149) from the specimen holder housing (3015G2-100) and replace it with a new O-ring (Fig. 41c).

Up-grade the Safety Relief Piston assembly (effective Oct. 2006). Use the special collar removal tool (3015K1-001) to remove the old style retaining collar (Z3015G1-005) (Fig. 41d),

Fig. 41c Remove the large O-ring

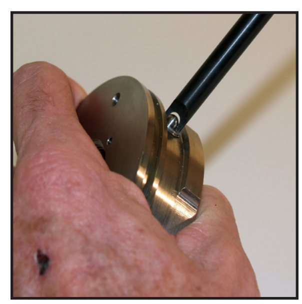

Fig. 41d Remove old style retaining

the nylon washer, the piston with o-ring (Z3015G4-004) and stainless steel spring (MSM002-002) from the G2 or G4 specimen holder. Fig. 41e, shows the old Piston Relief Assembly vs the new assembly; particularly note that the nylon washer and old retaining collar with internal O-ring have been removed and changed respectfully.

Remove and replace the Piston.Use the teasing needle to add the #3 O-ring (Fig. 42), discard the old Retaining Collar (3015G1-005), piston (3015G1-004) with interior O-ring (M802X007) and the Nylon Washer (MYL027).

Fig. 41e Old vs new piston relief assembly

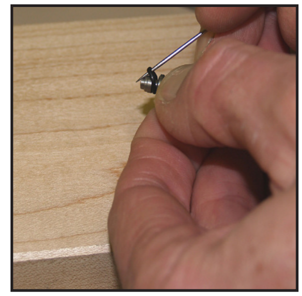

Fig. 42 Use the teasing needle to add the O-ring

Replace in order; the spring (Fig. 43a), the piston with new o-ring (Fig. 43b), and the new retaining collar (Fig. 43c).

Replace the Closing Ring and the 4 8-32 x 5/16 flat head screws.

Replace the closing ring or sealing knob.

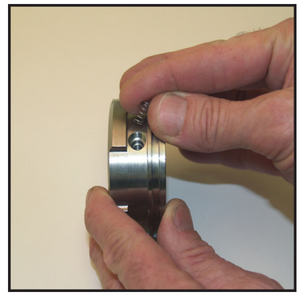

Fig. 43a Replace the spring

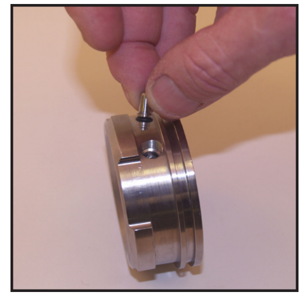

Fig. 43b Piston with new O-ring

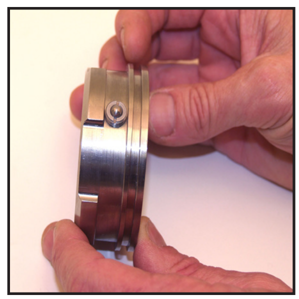

Fig. 43c New retaing collar

5.8 Repair/replace the helicoil insert in the G4 Specimen Holder

Occasionally the threaded seat for the sealing knob becomes worn from use. Replace the helicoil insert with a new insert (3015G4-002).

The specimen holder housing must be heated to soften the glue used to lock the helicoil in place, in the specimen holder housing. (Fig. 44a) shows the insert being threaded into the specimen holder housing. Use lock-tight thread cement when seating the new insert.

Fig. 44a Insert in threaded into the housing

Fig. 44b Insert seated in housing

SOILMOISTURE EQUIPMENT CORP.
P.O. Box 30025, Santa Barbara, CA 93105 U.S.A.
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Email: sales@soilmoisture.com - Website: http://www.soilmoisture.com

6. Replacement & Accessory Parts for the 3115

0761G12	0.75#/0.34kg	Valve, ball, 3-way, 6000 psi/413.8MPa
0761G13	0.62#/0.28kg	Metering Flow Control Valve
0777L60	2.43#/1.10kg	Valved Filler Hose, 60in/1.52m, ss braided hose, 3005 and 3115 models
0781P1500	0.25#/0.01kg	Regulated Pressure Gauge,1500psi/103.5MPa, 1.5in/3.8cm,white
0781P3000	0.25#/0.01kg	Source Tank Pressure Gauge, 3000psi/206.9MPa, 1.5in/3.8cm,white
0783P0600	1.20#/0.54kg	Dual Scale (psi/bar), 0to600psi/0to40bar, 4.5in/11.4cm, floating needle, white
0783P0350	1.20#/0.54kg	Dual Scale (psi/bar), 0to350psi/0to25bar, 4.5in/11.4cm, floating needle, white
3015G2	1.96#/0.86kg	G2 Specimen Holder, for blade type leaves up to 1in/2.5cm wide
3015G2-001CR	1.72#/0.78kg	G2 Housing, specimen holder
3015G2-002	0.18#/0.80kg	G2 Compression ring, specimen holder, G2 only
3015G4	2.00 #/0.91kg	G4 Specimen Holder, for stems and leaves up to ½in/1.3cm diam
3015G4-001CR	1.81#/0.82kg	G4 Housing, specimen holder
3015G4-002	0.06#/0.03kg	G4 Insert (helicoil), replacement, specimen holder
Z3015G4-003	0.20#/0.09kg	G4 Closing Ring, specimen holder
Z3015G1-004	0.11#/0.05kg	Piston, safety relief action, all specimen holders
Z3015G1-005	0.11#/0.05kg	Retaining Collar, for piston, all specimen holders
Z3015G4-100	0.20#/0.09kg	G4 Sealing Knob, specimen holder, G4 only
3071L60	1.15#/0.52kg	Quick Connect Hose, regulated, 60in/1.52m, ss braided hose only
3072V22	9.83#/4.46kg	Compressed Gas Cylinder, 22 cuft/623.0 l
3072V33	15.0#/6.80kg	Compressed Gas Cylinder, 33 cuft/934.6 l
M802X149	0.01#/4.5g	Buna N O-ring Seal, for G2/G4 specimen holders
M802X003	<0.05#/22.7g	O-ring Seal, Piston safety relief, for G2/G4 specimen holders
MSM002-002	<0.05#/22.7g	Spring, Piston safety relief, for G2/G4 specimen holders
MSL014-005	<0.05#/22.7g	Roll Pin, stop, for G2/G4 specimen holders, 3/32in x 5/16in
Q0832CAQ05	<0.05#/22.7g	Screws (4), flathead, 8-32x5/16", G4 specimen holders
Q1024CAF10	<0.05#/22.7g	Screws (3), socket head, 10-24 x 5/16", stainless steel
MSL032	<0.05#/22.7g	5/32" , hex , Allen Wrench, G2 Specimen Holder
Z3015K1	<0.05#/22.7g	Up-grade kit, Safety Relief Piston

Sealing Plugs, Sleeves, Grommets, and Support Washers

3017G2-005	0.02#/9.1g	G2 Sealing Plug, .094in/2.39cm wide, slot
3017G2-006	0.02#/9.1g	G2 Sealing Plug, .05in/0.13cm wide, slot
3018G4K1	0.04#/18.1g	G4 Stem Sleeve Sealing Kit, all sleeves and washers
3018G4K2	0.05#/22.7g	G4 Complete Sleeve Kit, 1 each of all sleeves
3018G4-000K1	0.05#/22.7g	G4 Sealing Sleeve, 5 PACK, 1/2in/1.27cm diam, blank
3018G4-001K1	0.05#/22.7g	G4 Sealing Sleeve, 5 PACK, 1/2in/1.27cm diam, 1/16in/0.159cm diam hole

3018G4-002K1	0.05#/22.7g	G4 Sealing Sleeve, 5 PACK, 1/2in/1.27cm diam, 1/8in/0.318cm diam hole
3018G4-003K1	0.05#/22.7g	G4 Sealing Sleeve, 5 PACK, 1/2in/1.27cm diam, 3/16in/0.478cm diam hole
3018G4-004K1	0.05#/22.7g	G4 Sealing Sleeve, 5 PACK, 1/2in/1.27cm diam, 1/4in/0.635cm diam hole
3018G4-005K1	0.05#/22.7g	G4 Sealing Sleeve Compression Holder, 5 PACK, 1/2in/1.27cm, saucer-type
3019G4-001K1	0.05#/22.7g	G4 Stem Grommet, 5 PACK, 1/16in/0.159cm diam hole
3019G4-002K1	0.05#/22.7g	G4 Stem Grommet, 5 PACK, 3/32in/0.24cm diam. hole
3019G4-003K1	0.05#/22.7g	G4 Stem Grommet, 5 PACK, 1/8in/0.318cm diam hole
3019G4-004K1	0.05#/22.7g	G4 Stem Grommet, 5 PACK, 3/16in/0.478cm diam hole
3019G4-005K1	0.05#/22.7g	G4 Leaf Grommet, 5 PACK, 1/16in/0.159cm wide X 1/4in/0.635cm ellipse
3019G4-006K1	0.05#/22.7g	G4 Leaf Grommet, 5 PACK, 1/8in/0.318cm wide X 1/2in/1.27cm ellipse
3019G4-007K1	0.05#/22.7g	G4 Leaf Grommet, 5 PACK, 1/8in/0.318cm wide X 1/2in/1.27cm arc
3019G4-008K1	0.05#/22.7g	G4 Leaf Grommet, 5 PACK, .05in/0.13cm wide X 1/2in/1.27cm slot
3019G4-009K1	0.05#/22.7g	G4 Stem Grommet, 5 PACK, blank
3019G4-010K1	0.05#/22.7g	G4 Stem Grommet, 5 PACK, 3/8in/0.95cm diam hole
3019G4-011K1	0.05#/22.7g	G4 Stem Grommet, 5 PACK, 1/2in/1.27cm diam hole
3019K1	0.04#/18.1g	G4 Stem Grommet Kit, 1 each all stem grommets and support washers
3019K2	0.04#/18.1g	G4 Leaf Grommet Kit, 1 each all leaf grommets and support washers
3019K3	0.25#/113.3g	G4 Complete Sleeve/Grommet Kit, all sleeves, grommets and washers
3020G4K1	0.02#/9.1g	G4 Brass Support Washer Kit, all washers for round holes
3020G4K2	0.10#/45.3g	G4 Brass Support Washer Kit, all washers for arcs and elipses
3020G4-001K1	0.05#/22.7g	G4 Brass Support Washer, 1/4” diam. hole, 5 PACK
3020G4-002K1	0.05#/22.7g	G4 Brass Support Washer, 1/16” wide X 1/2” slot, 5 PACK
3020G4-003K1	0.05#/22.7g	G4 Brass Support Washer, 1/8” wide X 1/2” slot, 5 PACK
3020G4-004K1	0.05#/22.7g	G4 Brass Support Washer, 3/8” diam. hole, 5 PACK
3020G4-005K1	0.05#/22.7g	G4 Brass Support Washer, 1/2” diam. hole, 5 PACK
3020G4-006K1	0.05#/22.7g	G4 Brass Support Washer, 9/64” diam. hole, 5 PACK
3021G2-000K1	0.05#/22.6g	G2 Brass Support Washer, blank, 5 PACK
3021G2-001K1	0.05#/22.6g	G2 Brass Support Washer, 1/16in/0.158cm slot, 5 PACK

Other Useful Accessories, to be supplied by Soilmoisture Equipment

Razor Blades

Magnifying Lens (either 5x or 10x)

Foil Lined Zippered Bag

1 1/8” Open End wrench

7. Appendix 1

Theory of Operating and Measuring Plant Water Potential

Water in the Earth environment can be in one of three phases: vapor, liquid or solid. Within the terrestrial plant systems, water somewhat freely moves within the soil, plant, and atmosphere in a continuum. As 98+% of the water in the terrestrial systems pass through the plant, it is important to characterize how water is controlled and how it is used by plant processes.

It can be shown that every living (biological) system on Earth is accompanied by a transfer of energy. Thus energy and it's attendant units are used to express how water does work in terrestrial systems. It is the chemical potential of pure water at standard temperature and pressure, that defines the reference for water potential in plants. And it is the free energy per unit quantity (mol) of a compound that defines its chemical potential. The chemical potential of any substance is expressed in joules/kg or joules/mol. And thus the chemical potential of water is expressed in units of pressure using the equilvalent expression:

1 bar = 0.1 MPa = 10^6 dynes / cm $^{-2}$ = 0.9869 atmosphere = 10^2 Joules / kg^{-1} = 14.5 PSI

Water potential can be expressed as follows:

$$W_p = (qw - qw^*) / V_w$$

Where;

W_p = water potential,

qw = chemical potential of the system studied

qw^* = chemical potential of pure water at atmospheric pressure and same temperature as the system studied

V_w = partial molar volume of water (ie. 18 cm^3 / ml)

The water potential in soils is most always negative and held under tension. The more negative this value the lower the water potential.

Water Potential in the Soil-Plant-Atmosphere Continuum

Atmosphere	---	< -30.0 MPa
Boundary Layer	---	< -10.0 MPa
Stomata	---	~ -2.0 MPa
Substomatal Cavity	---	~ - 1.0 to - 2.0 MPa
Leaf mesophyll	---	~ - 1.2 MPa
Xylem	---	~ -0.7 MPa
Root Surface	---	~ -0.3 MPa
Soil	---	~ 0 to -0.15 MPa

In the soil – plant – atmosphere continuum, total water potential is the sum of its main components:

Wp = p + m + s + g

p = pressure potential. Equal to the hydrostatic pressure. Usually carries a positive sign in water delivery systems. In soils and plants the sign is usually negative and indicates that water is held under tension.

m = the matrix potential is the result of adhesive and cohesive forces in the soil-water system between the liquid water phase and the solid mineral surface. This value is negative.

s = the solute (osmotic) potential, the affinity for salts to adsorb water. This value is negative.

g = the gravitational potential carries a negative value. Significant in soil-water systems, but not in plant-water systems.

Plants – Soil – Atmosphere; a dynamic system

Water moves in the soil by bulk flow (positive gravity head), by soil water tension gradients (negative head), and by vapor transport. To enter the plant roots, water (liquid) must first pass the semi-permeable membrane of the cell wall. In particular, water moves into the non-suberized region behind the active growing root tip. Solute loading causes the osmotic potential of the xylem to decrease, thus causing a gradient in water potential from the soil solution to the xylem and water moves into the root.

The water concentration gradient across the root means that water which has entered the root hair cell continues to move across the cortex to the endodermis by osmosis. The route taken by much of the water is through the cellulose cell walls, the rest of the water either passes through the cytoplasm of the cells or via the cell vacuoles.

Once it reaches the endoderm cells, the water is forced to move through the cytoplasm. This is because the radial and transverse cell walls of the young endodermis are impregnated with an impervious material. This is known as the Casperian strip, its presence means the route through the cell walls is blocked.

The gradient of water concentration that exists across the cortex creates a pushing force called "root pressure", i.e. a pressure that "pushes" the water across. Root pressure can be demonstrated by cutting a stem at soil level, after a time, droplets of water can be seen exuding from the cut surface. In some plants the process occurs naturally as "guttation", when droplets of water are forced through special pores (hydathodes) on the leaf edges. It is likely that the process of root pressure requires energy, as metabolic poisons halt the process.

While root pressure might account for some of the upward movement of water in small herbaceous plants, it is insufficient to overcome the force of gravity and move water up tall plants. To determine what else is involved in ensuring water gets to the sites of photosynthesis, let us look at the plant's water transporting tissue, the xylem.

Once inside the plant, water moves by cohesive forces, that hold one water molecule to another, and pulls the transpiration stream by potential gradient as water evaporates from the stomatal cavity through the boundary layer to the ambient atmosphere above the leaf. A series of specialized, non-living, cell structures called tracheids and wood vessels allow the water column to be pulled to the leaf surface. Collectively, these cells are called the xylem These cells are particularly important for large trees that move water to a 100 m height.

The living cell structures that surround the xylem, are collectively called the phloem. These also conduct water, although in minor amounts. The principal activity of the phloem is to conduct manufactured sugars as sap …(a watery solution of sugars, salts, and minerals that circulates through the vascular system of a plant) from the leaves to other parts of the plant.

Water is depleted from plant tissues by evapotranspiration. The rate of evapotranspiration is controlled by the vapor pressure deficit between the saturated stomatal cavity and ambient vapor pressure of the air surrounding the leaf. Vapor pressure in air (ambient VP) is based on air temperature, relative humidity and barometric pressure in the local atmosphere. Vapor pressure deficit (VPD) is calculated as VPD = saturated vapor pressure (at leaf temperature) – ambient vapor pressure of the surrounding air (calculated at air temperature).

Soil water potential, root health and day length are additional factors that control plant water uptake. Since both vapor pressure deficit and day length are variable, one could obtain a different xylem water potential measurement each hour of the day. In fact one does obtain a daily diurnal deficit for xylem water potential when xylem water is monitored on an hourly schedule, through out a given day.

Besides the dynamic properties of water to move by potential gradient, plants are exposed to other environmental variables like temperature, aspect, slope, or seasonal day length, plant age and stage of physiologic development.

So, where do you sample in a plant canopy to adequately characterize the behavior of that plant when exposed to environmental stresses?

Plant canopy architecture and root structure vary between species, stage of growth, geographic position, soil type and environmental niche. Annual plants tend to have soft tissues compared to perennial bushes and trees that have hardened (suberized tissues). Young leaves tend to grow most on the outer portions of the canopy, and tend to shade the older inner leaves. Perennial trees like conifers tend to maintain leaves for 3 to 4 years. Deciduous trees, on the other hand, keep their leaves for only that season.

Plant canopy growth is generally controlled by plant hormones (auxins) that control apical dominance, thus new leaves tend to grow from apical positions at the outer edge of the canopy, unless animal or other mechanical pruning alters the hormonal balance and lower leaf primordia begin to grow. Thus one tends to identify where to monitor within the plant canopy to characterize plant water potential.

While, young leaves tend to have more problems with phloem sap mixing with xylem water, the most important leaf factor to consider is the rate of water loss from the leaf at the time of sampling. During the daytime, fully exposed, outer canopy leaves on the south-facing canopy, will loose water faster than other leaves on the same plant. A faster rate of water loss causes more negative potentials. The leaf position within the canopy tends to have a more negative xylem water potential the further the leaf is away from the roots. For this reason, the recommended leaf position on trees is from the lower interior canopy, near

the main trunk or scaffold branches
Irrigation Scheduling using Plant Based Water Potentials:

The practical application of plant water status is to guide when to irrigate to obtain a crop of highest quality and yield. Irrigation practices have found that for certain woody crops like almonds, prunes, walnuts and wine grape one can apply irrigation in deficit at certain times in the production cycle, rather than fully meeting the daily water requirement, to produce a crop of exceptional quality. Also deficit irrigation has reduced hull-split in Almond and thus reduced subsequent fungal damage in the canopy of the tree. Almond producers have also used plant water status as a guide to avoid cambium damage during mechanical shaking. For grape vines, intentional mild irrigation deficit during the 6 to 8 week ripening phase, as monitored by mid-day water potentials using the Pressure Chamber, have produced wines of exceptional quality.

Stem water potential eliminates errors for irrigation scheduling:

While leaf water potential may be influenced by the daily climate, the time of day, the age of tissue, these problems may be eliminated by measuring the stem water potential directly or measuring a very close approximation by covering the leaf for a period of at least 10 minutes, in a zippered foil lined plastic bag. The covering procedure stops the transpiration process and halts water loss from the leaf. The water potential in the leaf then equilibrates with the water potential in the stem and the subsequent measurement on the leaf is reported as stem water potential. The leaf should be covered for at least 2 hours prior to measurement.

When monitoring fully irrigated trees or vine crops, a baseline of expected pre-dawn or mid-day stem water potentials can be established and deviations from the baseline can be characterized for local daily climatic conditions such as air temperature and relative humidity. A baseline for a given crop at a given site can be established for a mature stand because a maximum leaf area tends to have developed, and is repeated year after year. Deviations from the baseline can be indications of plant health problems like root disease.

As the stem water potential measurement is an integrated value from the whole plant (unlike a soil moisture measurement which is localized), the type of irrigation can influence the measurement. For example, a uniformly ‘flood irrigated’ tree can reach it’s non-stress baseline, while a micro-sprinkler irrigated tree may experience saturated and non-saturated conditions in the root zone and never approach the established baseline because the entire plant root zone is partially wetted and fully integrated. Or when alternate set deficit irrigation strategies have been applied, (where alternating basins are flooded) the result is a controlled plant water stress that enhances crop quality or yield.

Because of the variability in the water potential measurement, two periods of the day have been most frequently reported; the maximum leaf water potential (when the leaf is most fully saturated with water) occurs just before dawn; before the stomates open and the plant has had the longest period of time to equilibrate with soil water potential. These measures are labeled pre-dawn xylem water potential or pre-dawn stem water potential. The measure of stem water potential at this time is the same as leaf xylem water potential, in fact techniques have been developed to perform the similar measurement at any time of day when a leaf sample can be enclosed in a light tight, zippered plastic bag.

At mid-day a leaf would have been exposed to the maximum environmental stresses for the given day. Mid-day maximum plant water stress values are reported for leaves measured from 1:00 to 3:00.

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