

WATER POTENTIAL SYSTEMS



W E S C O R

W E S C O R S C I E N T I F I C P R O D U C T S C A T A L O G

WESCOR[®]

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Water Potential and Thermocouple Psychrometry

Water potential is defined in terms of the energy status of water. Water potential is the energy required to remove water reversibly and isothermally from a standard reference state to the soil, plant, or atmospheric system under consideration. The reference state chosen is usually pure, free water at the same temperature as water in the system and at a pressure of one standard atmosphere.

Water moves from regions of high water potential to regions of lower water potential. The greater the difference in potential of each region, the greater will be the energy exchange in the transfer of the water. Growing plants respond to water according to the energy required to assimilate and move it through the plant.

Thermocouple psychrometers/hygrometers provide a means of measuring the total water potential. The measurement is based on the energy exchange and is an actual measurement of water potential. Other methods measure water content, electrical conductivity, or other conditions related to water potential. These other methods require a knowledge of the composition of the soil or other factors that affect the relationship between the measured parameter and the water potential, in order to obtain accurate results.

Water potential is related to relative humidity by the Kelvin equation:

$$\Psi = \frac{RT}{V_W} \ln e/e_0$$

WHERE:

Ψ is the water potential (Pa)

R is the universal gas constant
(8.3143 J mol⁻¹K⁻¹)

e/e_0 is the relative humidity expressed as a fraction

T is the absolute Temperature (K)

V_W is the molar volume of water
(1.8 X 10⁻⁵m³mol⁻¹)

In practice, soil psychrometers/hygrometers measure the relative humidity of a small sample of air that has been allowed to equilibrate with the soil (or other sample material) being analyzed for water potential.

Using Peltier-cooled psychrometers was first proposed by D. C. Spanner in 1951. Since then, thousands of papers have reported the use of this method of water potential measurement.

A comprehensive review of thermocouple psychrometry/hygrometry is available from Wescor. Request the publication "Thermocouple Psychrometers for Water Potential Measurement." Several additional publications of general interest are listed below:

1. Brown, R.W. and Van Haveren, B.P. (eds.) Psychrometry in Water Relations Research. Utah Agric. Res. Stat. and Utah State Univ., p. 328.
2. Spanner, D.C. The Peltier effect and its use in the measurement of suction pressure. J. Exp. Bot. 2:145-168, 1951.
3. Neuman, H.H. and Thurtell, G.W. A Peltier cooled thermocouple dewpoint hygrometer for in situ measurement of water potential. Psychrometry in Water Relations Research, (R.W. Brown and B.P. Van Haveren, eds.) Utah Agric. Exp. Stat. and Utah State Univ., pp. 103-112.
4. Campbell, E.C., Campbell G.S., and Barlow, W.K. A dewpoint hygrometer for water potential measurement. Agric., Meteorol. 12:113-121, 1973.
5. Brown, R.W. and Collins, J.M. A screen-caged thermocouple psychrometer and calibration chamber for measurements of plant and soil water potential. Agron. J. 72:851-854.1980.
6. Savage, M.J., Wiebe, H.H. and Cass, A. In situ field measurement of leaf water potential using thermocouple psychrometers. Plant Physiol. 73:609-613, 1983.
7. Savage, M. J., Wiebe, H.H. and Cass, A. Effect of cuticular abrasion on thermocouple psychrometric in situ measurement of leaf water potential. J. Exp. Bot. 35:36-42, 1984.
8. Campbell, G.S. and Campbell M.D. Evaluation of a thermocouple hygrometer for measuring leaf water potential in situ. Agron. J. 66:24-27, 1974.
9. Savage, M.J. and Cass, A. Measurement of water potential using in situ thermocouple hygrometers. Advances in Agronomy. 37:73-126.
10. Wiebe, H.H., et al. Measurement of plant and soil water status. Bulletin 484, Utah Agric. Exp. Stat. May 1971.

Psychrometric (Wet Bulb) Method

The technique of measuring water potential by determining the wet bulb depression temperature. A thermocouple is cooled below the dew point by means of the Peltier Effect, thereby collecting micro-droplets of condensed water upon the junction surface. The water is then allowed to evaporate, causing the temperature of the junction to be depressed below the ambient temperature, due to evaporative cooling. The wet bulb temperature depression persists until all the water has been evaporated; then the thermocouple returns to the ambient temperature.

Hygrometric (Dew Point) Method

The technique of measuring water potential by determining the dew point depression temperature. This method is made possible by a special electronic technique pioneered by Wescor. A thermocouple is cooled below the dew point as in the psychrometric method, but the temperature of the thermocouple is then controlled by the heat of condensation from the water condensing on its surface. This causes the thermocouple temperature to converge to the dew point, where it remains with a static amount of water. The dew point measurement is therefore continuous in nature, rather than transitory, as with the wet bulb depression measurement. Greater precision of measurement is possible, along with other advantages. For technical information regarding the dew point method, contact Wescor, Inc.

Thermocouple Cooling Coefficient Π_V

The Cooling Coefficient Π_V , of a given thermocouple transducer is defined as the emf in microvolts produced by the temperature differential that results from the passage of a specified nominally optimum cooling current through the junction.

Π_V is related to the Peltier Coefficient Π_{ab} which expresses the theoretical cooling capability of any junction composed of two dissimilar metals, a and b. The actual cooling capability of a thermocouple transducer is affected by a number of factors in addition to its theoretical cooling ability. These factors include geometric and metallurgical anomalies in the junction and lead wires, length of the lead wires, mounting structure and materials, mounting geometry, etc.

If the Π_V of a thermocouple hygrometer is known, then its maximum range is also known. In specifying Π_V , both the cooling current and the ambient temperature must also be specified. For Example:

$$\Pi_V (8 \text{ mA}, 25^\circ \text{ C}) = 66 \text{ microvolts}$$

We invite inquiries for further information or technical assistance in special applications.

PCT-55 / PST-55

SOIL HYGROMETER/PSYCHROMETER

For In Situ Water Potential Measurements



This proven transducer is used in research programs throughout the world. It may be employed in either wet bulb or dew point mode of operation.

Porous ceramic shields or ultrafine dutch weave stainless steel screen shields are available. The stainless steel screen has larger pore size and faster equilibration. The porous ceramic has thermal conductivity similar to most soils.

FEATURES

- Removable thermocouple shields (PCT-55) for easy cleaning
- Controlled junction size and chamber geometry for consistent performance
- Gold plated internal connections to resist corrosion
- High sensitivity
- Tested individually for cooling coefficient (Π_V), leaks, cleanliness, and sensitivity
- Individual psychrometric calibration curve provided with each unit
- *SUREFAST*[™] connector option available
- When used with the HP-115, PR-55, and PS-10, requires the *SUREFAST*[™] connector. The HR-33T can be used with or without the *SUREFAST*[™] connector

CORROSION PROTECTION

Protected with Corro-Guard[™]
The Corro-Guard process protects the psychrometric thermocouple from corrosion even in hostile soil environments.



*Psychrometer
Cut-away*

SPECIFICATIONS

PSYCHROMETER OUTPUT:	Typically 4.7 microvolts/MPa at 25° C.
HYGROMETER OUTPUT:	Typically 7.5 microvolts/MPa at 25° C.

TYPE DESIGNATION

Specify type PCT-55 (ceramic shield) or type PST-55 (ultrafine dutch weave stainless steel screen) and 1.5 or 3 meter lead length by dash number.

Example: PCT-55-15 (1.5 meters)* } Standard Lengths
PCT-55-30 (3.0 meters)* }

* Specify non-standard lengths in decimeters. Example: PST-55-100 (10 meters)

Specify *SUREFAST*[™] connector option by adding SF. Example: PCT-55-15 SF.

C-52

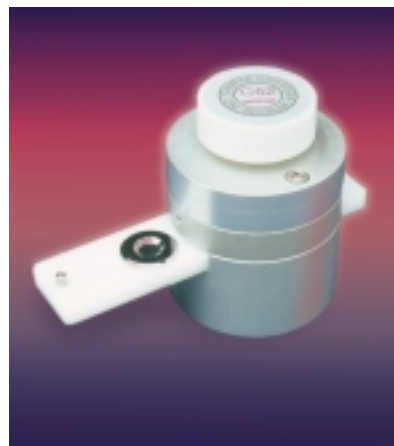
Sample Chamber

The Sample Chamber measures water potential of small samples in the laboratory or in the field without requiring a constant temperature bath. A precision thermocouple transducer in an internal chamber functions either as a psychrometer (wet bulb depression method), or as a hygrometer (dew point depression method) depending upon the type of readout equipment employed. Researchers have reported exceptional ease and accuracy using this chamber, resulting in more and better data from field and/or laboratory research.

The instrument is precision machined and expertly assembled to assure accuracy and precise operation. Each unit is individually performance tested before leaving the factory.

An all-metal thermocouple mount provides direct thermal contact between the thermocouple and the upper heat sink. This and the solid aluminum housing give more rapid temperature equilibration and reduced zero offset error.

A copper-constantan temperature sensor allows accurate chamber temperature measurements to be made for correction of psychrometric readings or for Π_V temperature correction when large temperature changes are encountered.



NOTE

When used with the HP-115, PR-55, or the PS-10, the SUREFAST™ connector is required.

APPLICATIONS

- Measuring total water potential of soil or plant tissue
- Measuring relative vapor pressure of organic solvent solutions (alcohol, acetone, carbon tetrachloride, toluene, benzine, etc.)
- Multiple C-52 chambers can be connected to the CR-7 Datalogger to function as an automated multichannel osmometer
- As an osmometer, can do rapid, accurate sampling without freezing (10 microliter samples)

SPECIFICATIONS

DIMENSIONS:	Approximately 57 mm diameter x 75 mm height
WEIGHT:	Approximately 0.45 kg
LEAD LENGTH:	1.5 m
SAMPLE HOLDERS:	6 holders furnished (2 of each size): 9.5 mm diameter x 4.5 mm deep for soil or other large samples 7 mm diameter x 2.5 mm deep for leaves 7 mm diameter x 1.25 mm deep for saturated filter paper discs
RANGE:	-0.05 MPa to -8 MPa nominally, with capability to -300 MPa using special techniques
CALIBRATION:	By standard solutions
PROCESS TIME:	30 seconds up to several minutes, depending upon time required for sample to reach vapor equilibration
PRECISION:	0.01 MPa ± 2%

SUREFAST™ connector option available (specify C-52-SF)

L-51 and L-51A

Leaf Hygrometer/Psychrometer



The L-51 Leaf Hygrometer is designed for in situ measurement of leaf water potential, using either the wet bulb or dew point method of data readout. L-51A has a special chamber configuration for use with grass. The all-metal thermocouple mounting system is similar to that used in the C-52 Sample Chamber. Given isothermal conditions, this configuration provides rapid equilibration and excellent precision.

A copper-constantan temperature sensor allows accurate ambient temperature measurements to be made for correction of psychrometric readings or for Π_V temperature correction when encountering large temperature changes. In use, the section of leaf to be tested is swabbed clean, then inserted in the lateral slot in the body of the sensor. Gentle pressure is applied to capture the leaf between the mount and the measuring chamber. A small amount of petroleum jelly or a beeswax-lanolin mixture is used to effect a vapor seal.

A nylon mounting bracket is included with the sensor to provide thermal isolation from metal support structures.

SPECIFICATIONS

SIZE:	19 mm x 25 mm x 46 mm (exclusive of leads)
WEIGHT:	Approximately 100 grams
LEAD LENGTH:	1.5 meters
RANGE:	-0.05 MPa to -7 MPa nominally
SLOT WIDTH:	2 mm
CHAMBER DIMENSIONS:	
(MODEL L-51).....	3 mm diameter x 2 mm deep
(MODEL L-51A).....	3 mm by 2 mm x 2 mm deep

Used with the HR-33T and PR-55 of the HP-115. When used with the HP-115, PR-55 or the PS-10 *SUREFAST*TM connector is required. (Can be used with HR-33T with or without *SUREFAST*TM connector.)

*SUREFAST*TM connector option available (specify L-51-SF or L-51A-SF).

C-30

Sample Chamber

The sample chamber is made from modified stainless steel tube fittings and a PST-55-15 thermocouple psychrometer/hygrometer. The sample chamber is large enough to accommodate an entire small leaf (about 1 inch square) or a significant portion of larger leaves. The stainless steel fittings and O-rings provide a positive seal. The entire chamber can be immersed in liquid nitrogen to freeze and break down cellular structure, allowing the measurement of the osmotic potential of leaves or leaf discs. The chamber can be immersed in a waterbath although it is satisfactory to use an insulated box to maintain isothermal conditions.

The C-30 Sample Chamber is designed to be used with the HR-33T Dewpoint Microvoltmeter, the Wescor/Campbell CR-7 Datalogger, the PR-55 Psychrometer Microvoltmeter or the HP-115 Water Potential Data System.



SPECIFICATIONS

CONSTRUCTION:	Modified stainless steel tube fittings
TRANSDUCER:	PST-55-15 thermocouple psychrometer/hygrometer
CHAMBER:	
INTERIOR DIMENSIONS:	12 mm dia x 23 mm deep
WEIGHT:	110 grams

SUREFAST[™] connector option available (specify C-30-SF)

When used with the HP-115, PR-55, or the PS-10, a *SUREFAST*[™] is required. The HR-33T can be used with or without the *SUREFAST*[™] connector.

PS-10

Psychrometer Switchbox

Successful switching of thermocouple hygrometer/psychrometer transducers requires that thermally induced error signals be minimized through proper switch design and careful selection of components and materials. The PS-10 Switchbox has been engineered to meet these criteria. It allows 10 hygrometers/psychrometers to be connected to a single readout device such as the HR-33T. Connections to the PS-10 Switchbox are made with *SUREFAST*[™] Connectors.



SPECIFICATIONS

SELECTOR:	10 position rotary switch
INPUTS/OUTPUT	<i>SUREFAST</i> [™] bulkhead receptacles
SIZE:	15.5 cm x 12.5 cm x 8.5 cm
WEIGHT:	0.4 kg

LP-27

Markhart Leaf Press



This leaf press was designed at the University of Minnesota. The liquid sample is extracted directly to a filter paper disc. The disc can then be inserted into a Wescor Vapor Pressure Osmometer or a C-52 Sample Chamber for determination of the osmotic potential.

Using this press simplifies the liquid extraction process and reduces errors due to concentration of the sample by evaporation.

FEATURES

- Easy to use
- Direct collection of sample for osmotic determination
- Reduces errors due to evaporation

SPECIFICATIONS

MATERIALS:	Stainless steel plunger and screen, aluminum body
DIMENSIONS:	5.5 cm dia x 11 cm
WEIGHT:	0.42 kg

HR-33T

Dew Point Microvoltmeter

For Water Potential Measurement by Dew Point or Wet Bulb Methods

The HR-33T Dew Point Microvoltmeter is a self-contained electronic system designed specifically for measuring water potential with thermocouple transducers. It contains sophisticated sensing and control circuitry that automatically maintains the temperature of the thermocouple junction at the dew point temperature when operating in the dew point mode. The HR-33T can be used in either dew point or wet bulb mode so that the advantages of each can be utilized. When combined with the C-52 Sample Chamber, the HR-33T becomes a complete portable laboratory for sample measurements.



FEATURES

- Functions in either hygrometric (automatic dew point depression) or psychrometric (wet bulb depression) mode
- Low noise, low drift, chopper-stabilized microvoltmeter
- Integral precision panel meter with mirrored scale
- Available with alkaline battery (HR-33T) or rechargeable nickel cadmium battery (HR-33T-R)
- Recorder output
- Convenient sensor connection
- Optional power supply modules available
- Rugged formed aluminum carrying case
- Optional power supply modules available:
 - Model 5106: 115 VAC 50 to 60 Hz
 - Model 5109: 220/240 VAC 50 to 60 Hz
 - Model 5112: Nickel cadmium rechargeable (specify 115 VAC or 220/240 VAC)

SPECIFICATIONS

RANGES:	10, 30, 100, and 300 microvolts full scale
ACCURACY:	± 1% of full scale (recorder output) ± 2% of full scale (panel meter)
ZERO DRIFT:	Less than 0.5 microvolts per 24 hours, less than 0.1 microvolts per °C
NOISE:	0.1 microvolts peak-to-peak
INPUT IMPEDANCE:	1 Megohm
MAXIMUM SOURCE IMPEDANCE:	100 ohm (higher impedances will degrade accuracy)
RISE TIME:	2 seconds
ZERO SUPPRESSION:	± 75 microvolts
REFERENCE JUNCTION:	Copper-constantan (± 0.5° C from 0° C to 40° C)
RECORDER OUTPUT:	10 volts full scale (10 mA)
CONNECTORS:	Binding posts and SUREFAST™ receptacle
BATTERY OPERATING TIME:	Alkaline Battery: 10 hours Nickel Cadmium: 10 hours per charge
DIMENSIONS:	23.5 cm x 30.5 cm x 13.3 cm
WEIGHT:	3.3 kg with batteries

SUREFAST™ connector retrofit kits are available for previously purchased instruments.

Vapro[®]

Vapor Pressure Osmometer
Model 5520



Wescor's Vapro Vapor Pressure Osmometer operates on the dew point depression principle using a thermocouple hygrometer over a sample in a closed chamber. This method brings unprecedented simplicity, ease of use, and economy to the measurement of osmolality.

Unlike the cryogenic method, The Vapro osmometer handles samples of elevated viscosity and complex physical form. This provides biology researchers with data not previously obtainable, particularly in invertebrate physiology.

The noninvasive aspect of vapor pressure osmometry makes measuring osmolality feasible on the fluids associated with thin slices of plant and animal tissue. The instrument is also valuable for investigating biological and other fluid phenomena.

Small sample size capability allows you to reliably assay samples as small as 2 μL using special procedures. This is an important feature considering the high cost of certain samples.

The Vapro osmometer adds convenience to its other capabilities with a host of features to help you get more done with less fuss. The instrument is truly simple to operate, and its internal diagnostics alert you to the need for sensor cleaning. All functions of the instrument can be selected from a simple menu.

FEATURES

- Functions are selected from a simple and logical menu
- Superb accuracy, unsurpassed by any other method
- Trouble-free operation with few moving parts and no mechanical adjustments or breakdowns
- Easy push button calibration
- Low initial cost and no expensive proprietary supplies
- Built in self-diagnostics alert you to instrument malfunction or procedural error
- Average Mode displays the average and standard deviation of several samples
- Clean Test gives a precise indication of thermocouple cleanliness (uses a 100 mmol/kg standard)
- Process Hold feature allows for equilibration of leaf discs or other samples that have long equilibration times

SPECIFICATIONS

SAMPLE VOLUME	10 μL nominal (larger samples or samples as small as 2 μL can be measured reliably with special procedures)
MEASUREMENT RANGE	Typically 0 to 3200* mmol/kg @ 25° C ambient
MEASUREMENT TIME	75 seconds
RESOLUTION	1 mmol/kg
REPEATABILITY	Standard deviation = ± 2 mmol/kg
LINEARITY	2% of reading from 100 to 2000 mmol/kg
READOUT	10 x 6.8 cm LCD
OPERATING TEMPERATURE	15 to 37° C ambient (instrument should be at stable temperature before calibrating)
CALIBRATION	Automatic using Opti-mole™ osmolality standards (non-battery memory backup system)
SERIAL OUTPUT	RS-232 (ASCII format)
ELECTRICAL	
LINE VOLTAGE	100 to 120 V or 220 to 240 V nominal, 50 to 60 Hz (set at factory, user selectable with fuse change)
POWER	Less than 5 watts
FUSES	1/8 amp time-delay type for 100/120 volts (2 required) 1/16 amp time-delay type for 220/240 volts (2 required)
SIZE	
HEIGHT	17 cm (6.6")
WIDTH	29 cm (11.5")
DEPTH	34 cm (13.5")
WEIGHT	3.6 kg (8 lbs)

*Upper limit of measurement range is between 3300 and 3800 mmol/kg depending on individual thermocouple characteristics and operating temperature

Wescor/Campbell

Water Potential System

W E S C O R
S C I E N T I F I C
P R O D U C T S

The Wescor/Campbell Water Potential System consists of a Campbell CR7 datalogger with psychrometer modules and any of Wescor's water potential sensors. When used with Wescor C- 52 Sample chambers it becomes an automated multi-channel osmometer.

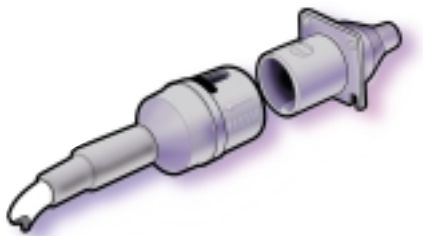
The system can operate with up to 140 individual sensors. It provides control and cooling for each sensor and stores the data for downloading to the computer.

The CR7 is a versatile datalogger with very high sensitivity and precision. In addition to water potential measurement, almost any kind of environmental sensors can be used.



SPECIFICATIONS

FULL SCALE RANGE:	$\pm 1.5 \text{ mV to } \pm 1.5 \text{ V}$
RESOLUTION:	50 nV
ACCURACY:	$\pm 0.02 \%$ Full Scale Range
MAXIMUM SAMPLE RATE:	2.9 ms/channel
ANALOG INPUTS:	140 maximum
SIZE:	ENC-7F: 50 cm x 33 cm x 25 cm ENC-7L: 43 cm x 30 cm x 15 cm
WEIGHT:	18 kg
POWER REQUIREMENTS:	
VOLTAGE:	9.6 to 15 volts DC
INTERNAL BATTERIES:	Sealed, rechargeable 2.5 Ahr/charge
AC SOURCE:	Selectable 120 or 240 VAC maintains full charge on internal batteries
CURRENT DRAIN:	6 mA quiescent 16 mA processing 100 mA during analog measurements



Cable connectors are available on all Wescor thermocouple hygrometer/psychrometer transducers. These connectors are standard on the PS-10 Switchbox, the PR-55, the HP-115 and current production HR-33T's.

SUREFAST™ Connectors are rugged and durable with high quality thermoplastic bodies. they are corrosion-resistant and feature gold-plated contact surfaces for low electrical and thermal noise. Positive polarization assures correct connection in seconds.

SUREFAST™ Connectors exhibit less thermal error than binding posts.

ORDERING INFORMATION

To specify *SUREFAST™* Connector option for transducers, add "SF" to the model number. For example : PST-55-30 SF, or L-51A SF.

To specify *SUREFAST™* Connectors for instruments, order the appropriate catalog number from the following:

- FS-256 *SUREFAST™* Connector retrofit kit (factory installation) for HR-33 and HR-33T Microvoltmeters.
- RK-002 *SUREFAST™* Connector retrofit kit (customer installation), for HR-33T Microvoltmeters with last four digits of serial number between 1606 and 1769.
- RP-050 *SUREFAST™* Cable connectors (for customer installation).
- RP-051 *SUREFAST™* Bulkhead connectors (for customer installation).
- RP-169 *SUREFAST™* Bulkhead adaptor cable.