

Implexx Sap Flow Sensor Gen2
Manual
ver. May 2023



Implexx Sense
Digital Environmental Sensing

WARNING!

Opening of the white enclosure will damage the sensor and void warranty. Under no circumstances should the white enclosure ever need to be opened or be opened.

WARNING!

Only ever start a measurement of the Sap Flow Sensor when the needles, or probes, are embedded inside a material such as the foam block or a tree. **NEVER** start a measurement when the needles are in air. This may cause damage to the heater element and void warranty.

WARNING!

The most frequent data collect interval is 10 minutes. An SDI-12 M! or C! command should never be sent to the sap flow sensor more frequently than 10-minute intervals.

WARNING!

Only a 12 VDC power should be applied to the Implexx Sap Flow Sensor Gen2. The application of a larger VDC power supply may damage the sensor and will void warranty.

WATCH THE YOUTUBE VIDEO!

There is a brief, 2-minute YouTube video demonstrating how the Implexx sap flow sensor should be installed. We strongly recommend you watch the video now:

<https://www.youtube.com/watch?v=QJXdQWPkfeE>

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Disclaimer and Warranty

Warranty is immediately void if the white enclosure is opened or if there is an attempt to open the white enclosure.

Seller warrants new equipment of its own manufacture against defective workmanship and materials for a period of one year from the date of receipt of equipment.

Note: We do not consider the results of ordinary wear and tear, neglect, misuse, or accident as defects.

The Seller's liability for defective parts shall in no event exceed the furnishing of replacement parts \freight on board the factory where originally manufactured. Material and equipment covered hereby which is not manufactured by Seller shall be covered only by the warranty of its manufacturer. Seller shall not be liable to Buyer for loss, damage or injuries to persons (including death), or to property or things of whatsoever kind (including, but not without limitation, loss of anticipated profits), occasioned by or arising out of the installation, operation, use, misuse, non-use, repair, or replacement of said material and equipment, or out of the use of any method or process for which the same may be employed. The use of this equipment constitutes Buyer's acceptance of the terms set forth in this warranty.

There are no understandings, representations, or warranties of any kind, express, implied, statutory or otherwise (including, but without limitation, the implied warranties of merchantability and fitness for a particular purpose), not expressly set forth herein.

Introduction

The Implexx Sap Flow Sensor Gen2 enables the latest advancements in the measurement of plant water use for researchers, growers, engineers and students. The Implexx Sap Flow Sensor Gen2 outputs 34 parameters including:

- Total stem or trunk sap flow
- Sap flux density
- Raw data for the calculation of heat velocity and sap flux density
- Sapwood, or stem, water content
- Sapwood, or stem, temperature
- Sapwood, or stem, thermal properties
- Electronic and sensor diagnostics.

Most users will only require total sap flow or sap flux density. But it is strongly recommended to always log and monitor the raw data required for the calculation of sap flow.

The Implexx Sap Flow Sensor Gen2 utilises the SDI-12 protocol for integration into data logging, IoT and telemetry systems. User must have an SDI-12 enabled device and it is assumed that users have some familiarity with the SDI-12 protocol. Implexx Sense can provide programs and programming advice for some models of data loggers or IoT device, if required.

This manual outlines the installation and wiring procedure for the Implexx Sap Flow Sensor Gen2. Maintenance and troubleshooting of common issues are also outlined in this manual. The published, scientific theory, on which the sensor measurements are based, are provided. Lastly, references and citations are provided.

Specifications

Feature	Specification
Sap Flow Measurements	
Measurement Range	-200 to >+1000 cm/hr heat velocity
Measurement Accuracy	< 3% or ± 0.1 cm/hr heat velocity
Measurement Resolution	0.001 cm/hr heat velocity
Measurement Points	2: outer and inner
Measurement Theory	Dual Method Approach, Heat Ratio (Slow Rates of Flow Method), Tmax
Stem (Sapwood) Water Content Measurements	
Measurement Range	0 to 100 % volumetric
Measurement Accuracy	$\pm 3\%$
Measurement Resolution	0.01
Measurement Points	2: downstream outer and inner
Stem (Sapwood) Temperature Measurements	
Measurement Range	-30 to +70 °C
Measurement Accuracy	± 0.015 °C
Measurement Resolution	0.001 °C
Measurement Points	4: down- and upstream outer and inner
Sensor Specifications	
Needle Dimensions	L: 30 mm; D: 1.6 mm
Response Time	200 milliseconds
Power Input	12 VDC
Power Consumption	Idle: 4mA; Measure: 270 mA
Sensor Output	SDI-12 (ver. 1.4)
Measurement Duration	120 seconds
Environmental Rating	IP68; -30 to +70 °C
Enclosure Materials	Acrylonitrile Styrene Acrylate
Needle Materials	Stainless Steel (304)
Cable Materials	Ozone, UV and weather-resistant according to EN 50396 and HD 605 S2
Warranty	1 year parts and labour



Sensor Design Overview

The Implexx Sap Flow Sensor consists of a white enclosure and 3 stainless steel probes set approximately 8 mm apart and in parallel.

The white enclosure houses the electronics of the sap flow sensor. Opening of the white enclosure will likely damage the electronics and void warranty.

The stainless steel probes are the temperature sensors and heater element. The top and bottom probes measure temperature whereas the central probe is the heater element.

The top probe is also referred to as the downstream temperature probe and the bottom probe the upstream temperature probe. Downstream and upstream refer to the direction of sap flow in the plant. Usually, sap in xylem flows from the roots, through the stem and towards the leaves in the canopy. This pathway of flowing sap is analogous to water running in a river from the mountains to the ocean. The mountains are upstream, and the ocean is downstream to the point of measurement. Similarly, the roots are upstream, and the canopy is downstream to the point of sap flow measurement. Therefore, the top and bottom temperature probes are commonly referred to as the downstream and upstream temperature probes.

There are two thermistors located within each temperature probe. A thermistor is a temperature sensor. The thermistors are located at 10 mm (outer) and 20 mm (inner) distance from the white enclosure. The thermistor located at 10 mm is known as the outer thermistor because, once installed into a plant, it is located towards the outside of the xylem whereas the inner thermistor is located towards the inside of the xylem.

The measurement zone of influence for each thermistor is approximately 5 mm radius. Therefore, the outer thermistor measures sap flow between 5 and 15 mm distance from the white enclosure. The inner thermistor measures sap flow between approximately 15 and 25 mm distance from the white enclosure.

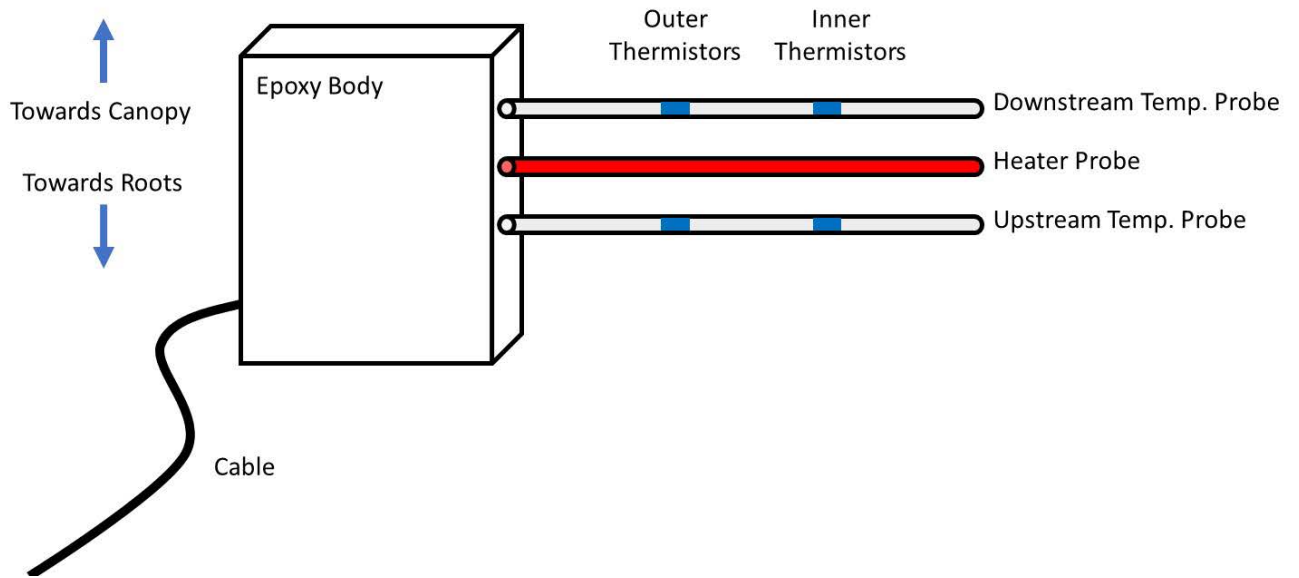


Figure 1. A schematic of the Implexx Sap Flow Sensor Gen2 indicating the outer and inner positions.

Outer and Inner Measurement Zones

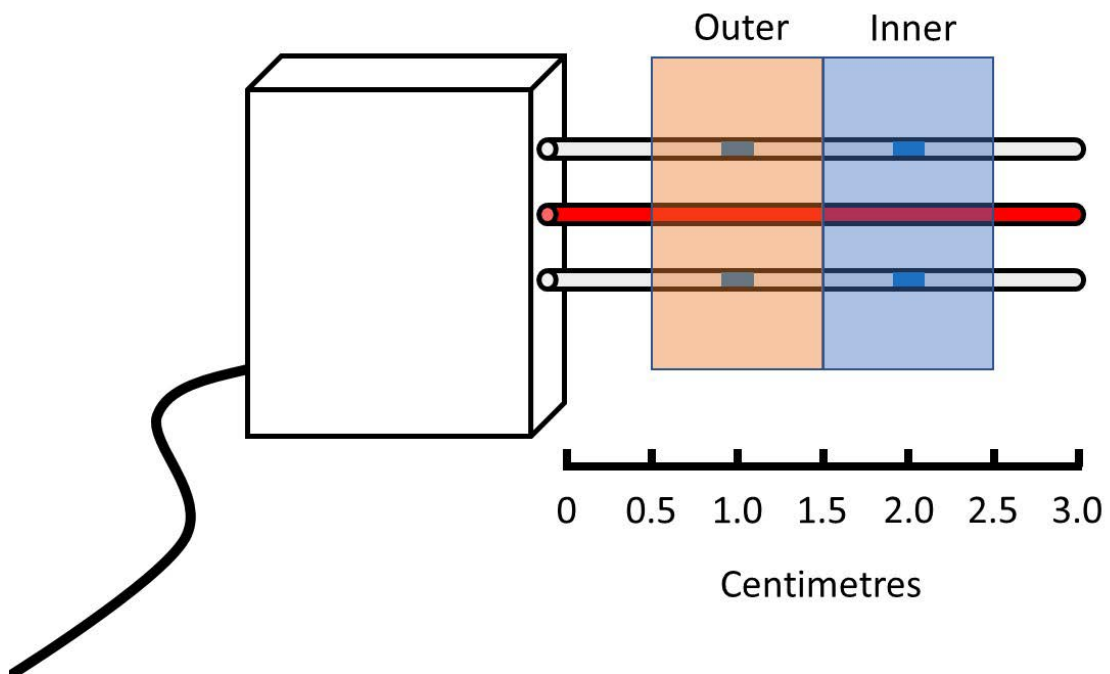


Figure 2. A schematic of the Implexx Sap Flow Sensor Gen2 indicating the outer and inner positions and their approximate measurement zone of influence within the stem.

Theory – Sap Flow Measurements

The Implexx Sap Flow Sensor Gen2 is based on the heat pulse family of measurements including dual method approach (DMA), heat ratio and Tmax. However, it is possible to extract raw temperature data from the sensor for alternative methods or for the user to build their own method. Implexx Sense strongly recommends the use of the dual method approach as this method measures the entire measurement range of sap flow in plants from reverse, to zero to extremely fast flow.

The dual method approach used in the Implexx Sap Flow Sensor Gen2 was developed by Forster (2020). It is recommended that all users thoroughly read and understand Forster (2020):

Forster, M.A., 2020. The importance of conduction versus convection in heat pulse sap flow methods. *Tree Physiol.* 40 (5), 683–694.

<https://doi.org/10.1093/treephys/tpaa009>

The Conduction/Convection Heat Transfer Equation

The two-dimensional conduction/convection heat transfer equations for xylem was outlined by Marshall (1958):

$$\Delta T_d = \frac{q}{4\pi kt} \exp \left[- \frac{(x - V_h t)^2}{4kt} \right] \quad \text{Eq. 1}$$

$$\Delta T_u = \frac{q}{4\pi kt} \exp \left[- \frac{(x + V_h t)^2}{4kt} \right] \quad \text{Eq. 2}$$

where ΔT is the change in temperature following a heat pulse in the downstream (*d*- subscript, Eq. 1) and upstream (*u*- subscript, Eq. 2) temperature needles in an axial direction from the heater needle, q is heat input (W m^{-1}), k is thermal diffusivity ($\text{m}^2 \text{s}^{-1}$), V_h is heat velocity (m s^{-1}), t is time since heat pulse emission (s), and x is the distance (m) between the heater and temperature needles.

The V_h and k parameters are the convective and conductive components, respectively, and k is further defined as:

$$k = \frac{K}{\rho c} \quad \text{Eq. 3}$$

where K ($\text{W m}^{-1} \text{K}^{-1}$) is thermal conductivity and ρ (kg m^{-3}) and c ($\text{J kg}^{-1} \text{K}^{-1}$) are the density and heat capacity, respectively, of the sap and wood matrix. The parameters K , ρ and c require further resolution, based on wood and sap properties, stem water content, and more, with detailed procedures and calculations provided in the next section of the manual (see section titled “Correction Factors for Sap Flow Measurements”).

Thermal Equilibrium and the Conduction/Convection Equation

Thermal equilibrium is defined as the equal change in the ratio of ΔT_d to ΔT_u for all V_h . Resolving equations 1 and 2, in combination with the equidistant, three-needle heat pulse probe design, shows that the ratio of ΔT_d to ΔT_u is equal for all V_h . This is thermal equilibrium: the relative change in downstream and upstream temperature needles, post-heat pulse, is in equilibrium for all values of V_h .

Thermal equilibrium is theoretically defined as (α is alpha and β is beta from the raw data outputs of the Implexx Sap Flow Sensor Gen2):

$$\alpha = \beta \quad \text{Eq. 4}$$

where

$$\alpha = \ln\left(\frac{\Delta T_d}{\Delta T_u}\right) \quad \text{Eq. 5}$$

In practice, pre-heat pulse temperature is an average temperature over some duration prior to the release of the heat pulse (usually 10 seconds). The post-heat pulse temperature is defined as the average temperature between 60 and 80 seconds following the heat pulse.

The right-hand side of the thermal equilibrium equation is defined as:

$$\beta = \ln\left(\frac{\Delta T_{d,max}}{\Delta T_{u,max}}\right) \quad \text{Eq. 6}$$



where $\Delta T_{d,max}$ and $\Delta T_{u,max}$ are the difference between maximum temperature post-heat pulse and the pre-heat pulse temperature in the downstream and upstream temperature needles, respectively. Note that these parameters can also be an output from the Implexx Sap Flow Sensor Gen2 (i.e., the M1! and M2! SDI-12 commands).

Thermal disequilibrium occurs when:

$$\alpha \neq \beta$$

Eq. 7

Thermal disequilibrium is significant because it means that the combined utilisation of equations 1 and 2 to resolve V_h is invalid. Either equation 1 or 2 can be used under conditions of thermal disequilibrium but not together. Under conditions of thermal disequilibrium, equation 1 would be used to resolve V_h because it is the heat transfer equation in the downstream direction (i.e. sap flowing from the roots to the canopy).

The Péclet Equation and the Péclet Number

The Péclet equation, also referred to as the Péclet number, is the ratio of conduction to convection. The Péclet equation is:

$$Pé = \frac{V_h x}{k}$$

Eq. 8

When the Péclet number equals one then conduction and convection are equal. Values less than or greater than a Péclet number of one indicates a conductive or convective dominated process, respectively. In the context of the Péclet equation, V_h is convection, k is conduction, and x is the characteristic length (i.e. the distance between the heater and temperature needles).

The Slow Rates of Flow (Heat Ratio) Equation

The Slow Rates of Flow Method, commonly referred to as the Heat Ratio Method (HRM), is a derived formula from combining equations 1 and 2 for characterising heat transfer in the downstream and upstream directions. The equation is:

$$V_h = \frac{\alpha k}{x} \quad \text{Eq. 9}$$

A modified version of equation 9 was introduced by Kluitenberg et al. (2007) to account for differences in heat pulse duration (t_0) and distance between downstream (x_d) and upstream (x_u) temperature needles from the heater needle:

$$V_h = \frac{2k\alpha}{x_d + x_u} + \frac{x_d - x_u}{t - \left(\frac{t_0}{2}\right)} \quad \text{Eq. 10}$$

As the HRM is a combination of equations 1 and 2, it is only valid under conditions of thermal equilibrium.

The Relationship Between Thermal Equilibrium, Péclet and HRM Equations

The Péclet and HRM equations are algebraic re-arrangements of the other. Furthermore, via the inclusion of α and β into the equations, the relationship between thermal equilibrium, the Péclet and HRM equations can be theoretically demonstrated. That is, equations 4, 5, 6, 8 and 9 are equivalent:

$$Pé = \frac{V_h x}{k} = \alpha = \beta \quad \text{Eq. 11}$$

Therefore, the HRM equation describes thermal equilibrium.

The Tmax Equation

The Tmax method only requires a two-needle configuration where the temperature needle is positioned downstream to the heater needle. The Tmax formula was outlined by Cohen et al. (1981) as:

$$V_h = \frac{\sqrt{x_d^2 - 4kt_m}}{t_m} \quad \text{Eq. 12}$$



where t_m is the time to maximum temperature rise following the heat pulse.

The Tmax formula (eq. 9) is highly dependent on an accurate measurement of x_d and heat pulse duration (t_0). Therefore, to account for slight variations in these parameters, Kluitenberg and Ham (2004) and Kluitenberg et al. (2007) proposed the following equation:

$$V_h = \sqrt{\frac{4k}{t_0} \ln\left(1 - \frac{t_0}{t_m}\right) + \frac{x_d^2}{t_m(t_m - t_0)}} \quad \text{Eq. 13}$$

As the Tmax is derived only from equation 1, and it requires just a downstream temperature needle, it can theoretically be used under conditions of thermal disequilibrium.

The Dual Method Approach (DMA)

The DMA is an algorithmic technique that utilises the optimal V_h derived from HRM at reverse/slow velocities and Tmax at faster velocities. Forster (2019, 2020) suggested using a critical threshold to switch between HRM and Tmax methods. A theoretical threshold/transition value is introduced based on equation 11. Values less than or equal to a Péclet number of one correspond to HRM whereas values greater than one correspond to Tmax. The algorithm for the theoretical DMA method, hereafter called DMA_{Péclet}, is:

If $\beta \leq 1$ Then $V_h = \text{HRM}$;

Else $V_h = \text{Tmax}$.

Wounding and Corrected Heat Velocity (V_c)

Following the correct determination of V_h , it is necessary to correct for sensor installation, as well as sap and wood properties, to calculate sap flux density. The next step after correctly calculating V_h is the calculation of heat velocity corrected for wounding, V_c . A wound correction factor is required due to the insertion of needles into xylem disrupting flow and the formation of tyloses. V_c (m s^{-1}) is calculated as:

$$V_c = aV_h + bV_h^2 + cV_h^3 \quad \text{Eq. 14}$$

where a , b , and c are co-efficients that are calculated via finite-difference numerical modelling and vary with wound width, probe size, and spacing.

Sap Flux Density (J)

The next step is to convert V_c to sap flux density (J). A common conversion of V_c to J ($\text{m}^3 \text{m}^{-2} \text{s}^{-1}$; or more commonly expressed as: $\text{cm}^3 \text{cm}^{-2} \text{hr}^{-1}$) is via (Barrett et al. 1995):

$$J = \frac{V_c \rho_d (c_d + m_c c_w)}{\rho_w c_w} \quad \text{Eq. 15}$$

where ρ_d is sapwood dry density (kg kg^{-1}), c_d and c_w are the specific heat capacity of the dry wood matrix ($1200 \text{ J kg}^{-1} \text{K}^{-1}$) and sap solution ($4182 \text{ J kg}^{-1} \text{K}^{-1}$), respectively. ρ_w is the density of sap (assumed to be the density of water, 1000 kg m^{-3}) and m_c is sapwood moisture content (kg kg^{-1} ; calculated as: $[w_f - w_d]/w_d$).

Total Sap Flow (Q)

Following the estimation of sap flux density (J), total sap flow can be calculated. Total sap flow (Q) is the sum of J for all measurement positions multiplied by sapwood area (A). For the Implexx Sap Flow Sensor Gen2, there are two measurement positions: outer and inner. Therefore, Q is the sum of J , multiplied by sapwood area, in the outer and inner positions:

$$Q_{outer} = J_{outer} A_{outer} \quad \text{Eq. 16a}$$

$$Q_{inner} = J_{inner} A_{inner} \quad \text{Eq. 16b}$$

$$Q_{total} = Q_{outer} + Q_{inner} \quad \text{Eq. 16c}$$

The Implexx Sap Flow Sensor Gen2 outputs Q_{total} .

The Implexx-SF Sap Flow Excel Workbook

There is a limited ability to input, or change, correction factors via SDI-12 commands in the Implexx Sap Flow Sensor Gen2. For a thorough investigation and research of correction factors, and to improve the overall accuracy of data, it is recommended to download the raw data (i.e., alpha, beta and Tmax data) and import these data to the Implexx-SF Sap Flow Excel Workbook. Detailed information, including manuals and guides, for the Excel Workbook can be found on the Implexx Sense website:

<https://www.implexx.io/sap-flow/implexx-sf-sap-flow-excel-workbook/>

Correction Factors for Sap Flow Measurements

Wound Diameter

Equipment Required:

- Callipers
- Dissecting blade
- Hand lens or dissecting microscope

Wounding is an inevitable consequence of drilling into the plant and inserting the sensor probes. For accurate sap flow data, it is critical that wounding is measured and corrected for in converting heat pulse velocity into sap flux density and sap flow.

The wound should be visually observable once the sensor probes have been carefully removed from the plant. You may need to scrape away, or remove, the bark with a dissecting blade to visually see the wound on the sapwood.

The wound is the hole where the sensor is inserted into the plant plus a ring, or donut, shape surrounding the hole. This is tyloses – or cell death to prevent infections from entering the plant.

Measure the wound diameter with a set of callipers. Measure the average of the three wounds from the three sensor probes.

Wound diameter value should range between 0.17 and 0.3 cm (centimetres).

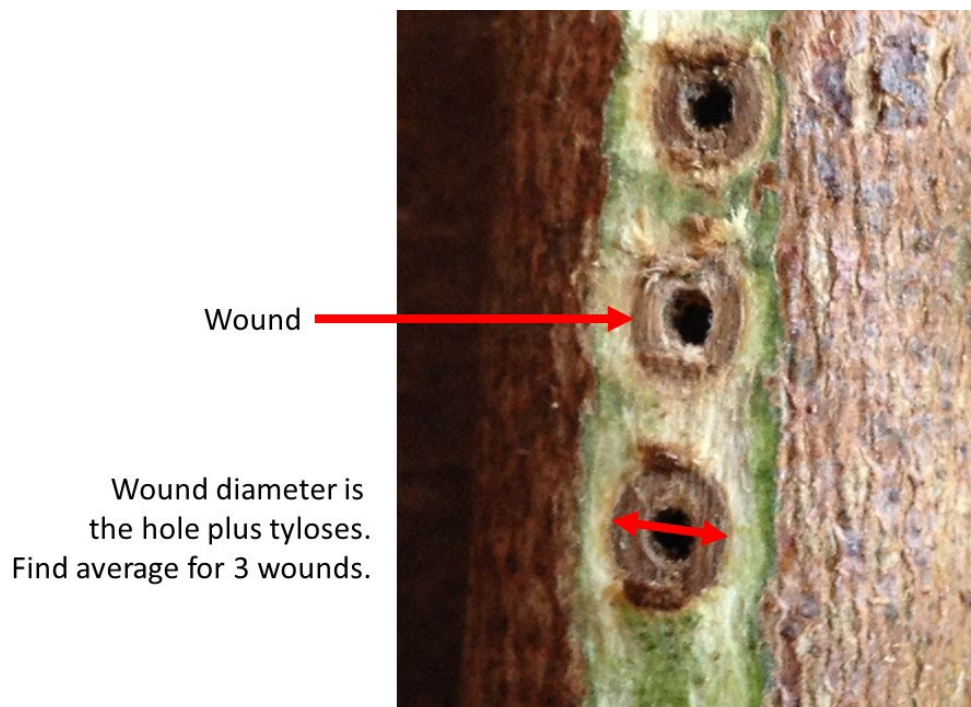


Figure 3. An example of a wound caused by probe/needle insertion into the xylem. The wound diameter is measured to the side of the drilled holes.

Sapwood Fresh Volume, Weight and Dry Weight

Equipment Required:

- Increment borer
- Secateurs
- Dissecting blade
- Callipers
- 3 or 4 decimal point weigh scale
- Drying oven

The sapwood fresh volume, weight and oven dry weight is measured to determine the wood bulk density and gravimetric moisture content of sapwood.

A sample of sapwood must be collected from your measured plant. For large trees, a sample can be collected using an increment borer. For small stems, a sample can be collected using secateurs and a dissecting blade.

It is important that only sapwood is sampled. Do not measure bark and/or heartwood.



Figure 4. An example of the plant tissues within a tree with bark towards the outside of the tree, then phloem, and xylem (sapwood and heartwood).



Figure 5. An increment borer is shown taking samples of sapwood within a tree.

Sapwood Fresh Weight

Immediately following the collection of the sapwood sample, it is important that the weight of the sample is measured.

Ideally, the sample should be weighed immediately. However, in the field this may not be possible. Therefore, wrap the sample in parafilm or other material to prevent desiccation. Place the sample in a zip lock bag and into an Esky or ice container. You need to ensure that moisture loss is minimised.

Sapwood Fresh Volume

Immediately following measuring sapwood fresh weight, it is important that the shape, or volume, is measured.

With a sample from an increment borer, you can carefully cut the ends of the sapwood core to create a cylindrical shape. With a set of callipers, measure the height and diameter of the cylinder and calculate volume.

With a sample from a small stem or wood section, it may be possible to cut the sample into a cube, cuboid or cylinder to measure the volume.

Often, the shape will be irregular. For these samples, the volume can be determined following Archimedes' principle.

Sapwood Oven Dry Weight

Place the sample in a drying oven at a temperature of 70 °C to remove all moisture from the sample. Depending on the moisture content of the sample, it may take several hours or a couple of days to remove all moisture.

Every few hours, remove the sample from the drying oven and re-weigh. Once the weight is no longer decreasing, then all moisture has been dried from the sample. This is the oven dry weight.

Stem Diameter, Bark Depth and Sapwood Depth

Equipment Required:

- Diameter tape
- Callipers
- Increment borer

It is critical to measure the size of the plant to convert sap flux density into volumetric, or whole-plant, sap flow.

Measure the diameter of the plant where the sap flow sensor was installed with either a diameter tape for large trees or callipers for small stems.

Measure the bark depth, or radius, of your plant.

Measure the sapwood radius, or depth, at the location where the sap flow sensor was installed. Ideally, a cut stem is the most accurate approach to measure sapwood radius. For small stems a pair of secateurs can cut the stem. For large trees a chainsaw, operated by a qualified technician, may be required. Only operate a chainsaw under appropriate supervision and training.

Where it is not possible to cut a large tree, an increment borer can be used to measure sapwood radius. With the increment borer, sample to at least halfway into the tree. Remove the core and measure the sapwood length.

Note that sapwood depth may be irregular around the circumference of the tree. You may need to measure at several circumferential locations to better understand the distribution of sapwood.

Uniform sapwood depth



Irregular, or non-uniform, sapwood depth

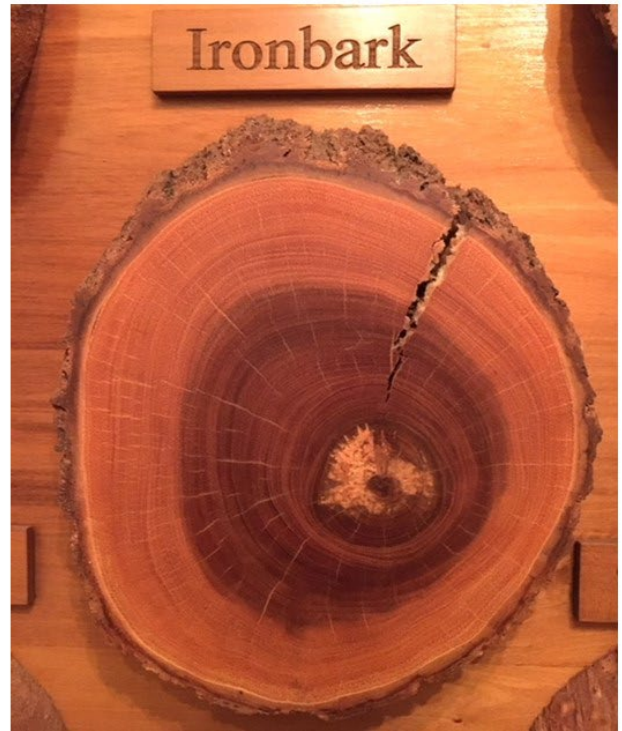


Figure 6. Examples of the circumferential distribution of sapwood in two *Eucalyptus* spp. (tallowwood and ironbark) from New South Wales, Australia. The tallowwood on the right shows a relatively uniform distribution of sapwood. In contrast, the ironbark on the left is irregular.

Theory – Stem Water Content Measurements

What is stem water content?

Stem water content refers to the amount of water inside stems, trunks, branches, twigs, etc, of plants. Stem water content is also referred to as sapwood water content, moisture content, sapwood gravimetric water content, or sapwood volumetric water content.

Stem water content may be differentiated into sapwood, heartwood water content, or a combination of sapwood and heartwood water content. Therefore, it is more precise to differentiate stem water content into sapwood or heartwood water content. The bark may also be measured as part of stem water content.

Figure 7 is an anatomical diagram of the stem showing the bark, phloem, xylem, sapwood and heartwood and the locations where water content may be estimated.



Figure 7. The anatomy of a representative dicotyledon woody stem. Typically, stem water content is measured in the sapwood and is therefore also referred to as sapwood water content. However, water content in the bark and heartwood can also be measured.

Why is stem water content important?

Stem water content is a measure of the hydration levels in stem tissues. Hydration, or the amount of water, is critical for a large range of plant physiological processes including transpiration, photosynthesis, reproduction, growth, organ development, cell structure and function, osmotic relations, and more.

Stem water content is also important for several parameters of interest to hydrologists such as storage (capacitance) and the abilities of plants to respond to soil moisture deficits, droughts and extreme weather events.

How is stem water content measured?

Stem water content is measured destructively or estimated with sensor technology.

Destructive measurements are the most accurate method to determine stem water content. But, as the name implies, it also means wounding, damaging, or harvesting the plant.

In trees, a sample is collected via a stem borer. The wet weight of the sample is quickly measured on a weigh scale. The sample is then oven dried to remove all moisture and the sample is reweighed to find the dry weight. The water content of the sample can then be calculated.

Sensor technology is an in-situ, continuous and non-destructive estimate of stem water content. Sensing technology is not a direct measurements of water content rather it is an estimate based on physical principles. This may include capacitance sensors measuring the dielectric permittivity of stems; or thermal sensors measuring the thermal properties of stems via thermal conduction. The dielectric permittivity or thermal properties of the stem are then converted to water content through a series of equations.

The Implexx Sap Flow Sensor (Figure 8) estimates stem water content via thermal properties and thermal conduction.

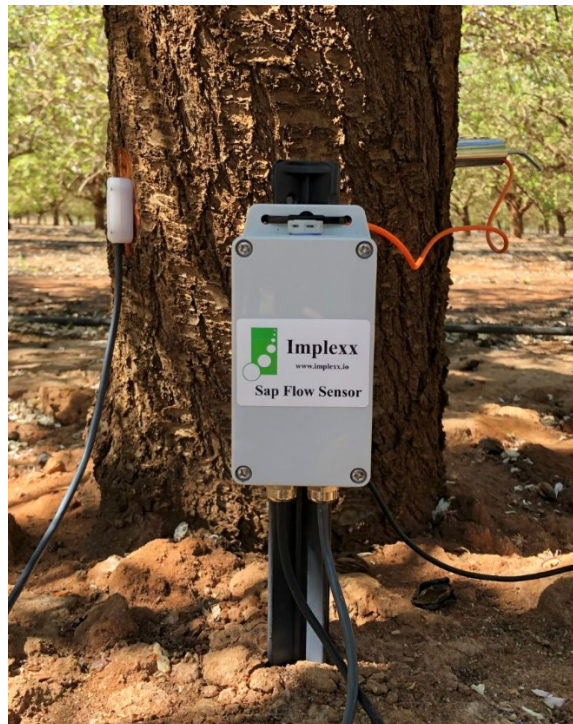


Figure 8. The Implexx Sap Flow Sensor provides in-situ, non-destructive and continuous estimates of stem water content as well as sap flow and stem temperature.

How are water content and thermal conduction related?

Thermal conduction is the movement of heat in a sample via diffusion. The sample can be anything from plant material (i.e., stem or sapwood) to soil to rocks to water to fabric to metals and more.

Thermal conduction is dependent on several parameters including the amount of heat input into the sample, maximum change in temperature, and properties of the sample including its density, its specific heat capacity, the specific heat capacity of water (or sap within plants), and, most importantly for stem water content, the water content of the sample.

How is stem water content calculated from thermal properties?

The equation for volumetric stem water content (θ , %) is:

$$\theta = \frac{\rho c - \rho_d c_d}{\rho_w c_w} \quad \text{Eq. 17}$$

where ρc (kJ m^{-3}) is volumetric heat capacity of the stem, ρ_d (kg m^{-3}) is dry wood density, c_d is heat capacity of dry wood ($1.2 \text{ kJ kg}^{-1} \text{ K}^{-1}$), ρ_w is the density of sap (1000 kg m^{-3}), and c_w is the heat capacity of sap ($4.182 \text{ kJ kg}^{-1} \text{ K}^{-1}$).

From equation 17, c_d , ρ_w and c_w are fixed parameters. Therefore, these parameters are assumed to be the same for all plants (although, strictly, these values vary slightly between species and with temperature and the careful, thorough researcher will check their own values).

The ρ_d parameter (denoted as DDW in the Implexx Sap Flow Sensor) is both a fixed and variable parameter. That is, ρ_d varies between species, varieties, individuals, and location within the plant (e.g., at the base of the trunk versus the branches). However, once wood has formed within plants ρ_d is then a fixed value at a specific location. That is, the density of wood does not change once it is formed. Therefore, ρ_d must be measured once at a location as close as possible to the sensor's installation site.

The parameter ρc is a variable in equation 17. Therefore, an accurate measurement of ρc is required to estimate stem water content. The parameter ρc is further defined as:

$$\rho c = \frac{(q/1000)}{e\pi x^2 \Delta T_m} \quad \text{Eq. 18}$$

where q is the heat pulse energy (J m^{-1}), x is the distance (m) between the heater and temperature probes, and ΔT_m (K) is the maximum temperature following the heat pulse minus the pre heat pulse temperature.

The x parameter is usually assumed to be a fixed value although it can vary depending on the installation (see probe misalignment issues and application note). Additionally, x may vary over time as the plant grows, develops wounds, and undergoes other changes. Therefore, x should be carefully observed.

The q parameter is dependent on electronics and the application of a heat pulse. As q is electronically dependent it is assumed to be a fixed parameter, but it can vary with temperature and other properties. The Implexx Sap Flow Sensor measures q for every heat pulse and the value is included in the stem water content calculation.

The ΔT_m parameter is the variable directly correlated with stem water content. The correlation between ΔT_m and stem water content is negative where wet stems with high moisture content have relatively small ΔT_m values and dry stems with low moisture content have relatively large ΔT_m values.

How accurate is the Implexx Sap Flow Sensor in estimating stem water content?

The Implexx Sap Flow Sensor accurately estimates stem water content. Figure 9 shows the correlation between volumetric stem water content measured from an Implexx Sap Flow Sensor and actual volumetric stem water content measuring with a drying oven. The samples were measured from 4 different species. Analysis found that the accuracy is approximately 3%.

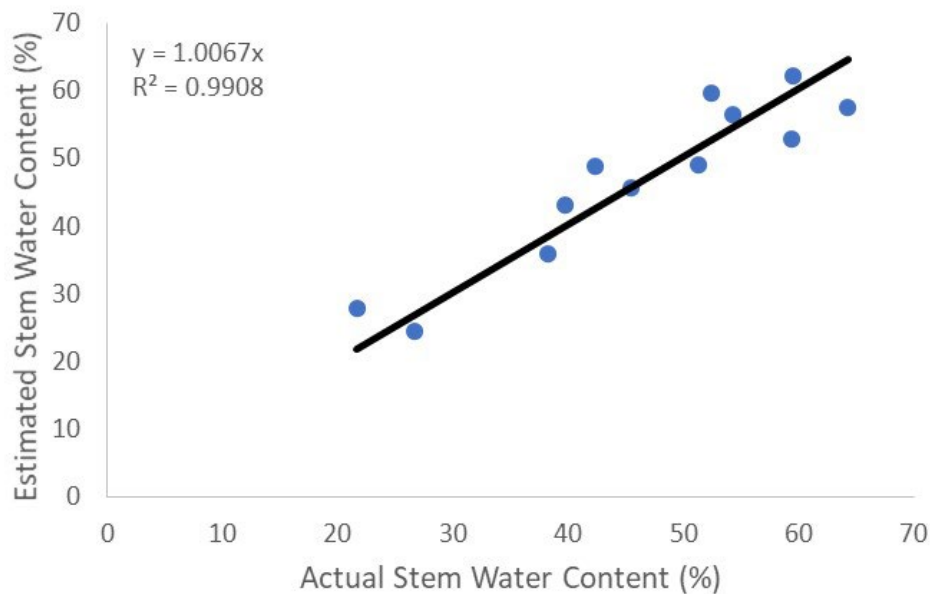


Figure 9. A comparison of actual stem water content, measured via destructive sampling technique, and estimated stem water content via the Implexx Sap Flow Sensor.

Radial measurements of stem water content

The Implexx Sap Flow Sensor can estimate stem water content at multiple depths into the stem. Known as “radial profiling”, measurements are undertaken towards the outside (“outer”) and inside (“inner”) portions of the stem (Figure 10). The 30 mm length needles of the Implexx Sap Flow Sensor have a temperature sensor (thermistor) at 10 mm (outer) and 20 mm (inner) depth. Therefore, these two measurement locations can be used to resolve stem water content at different locations within the stem’s anatomy.

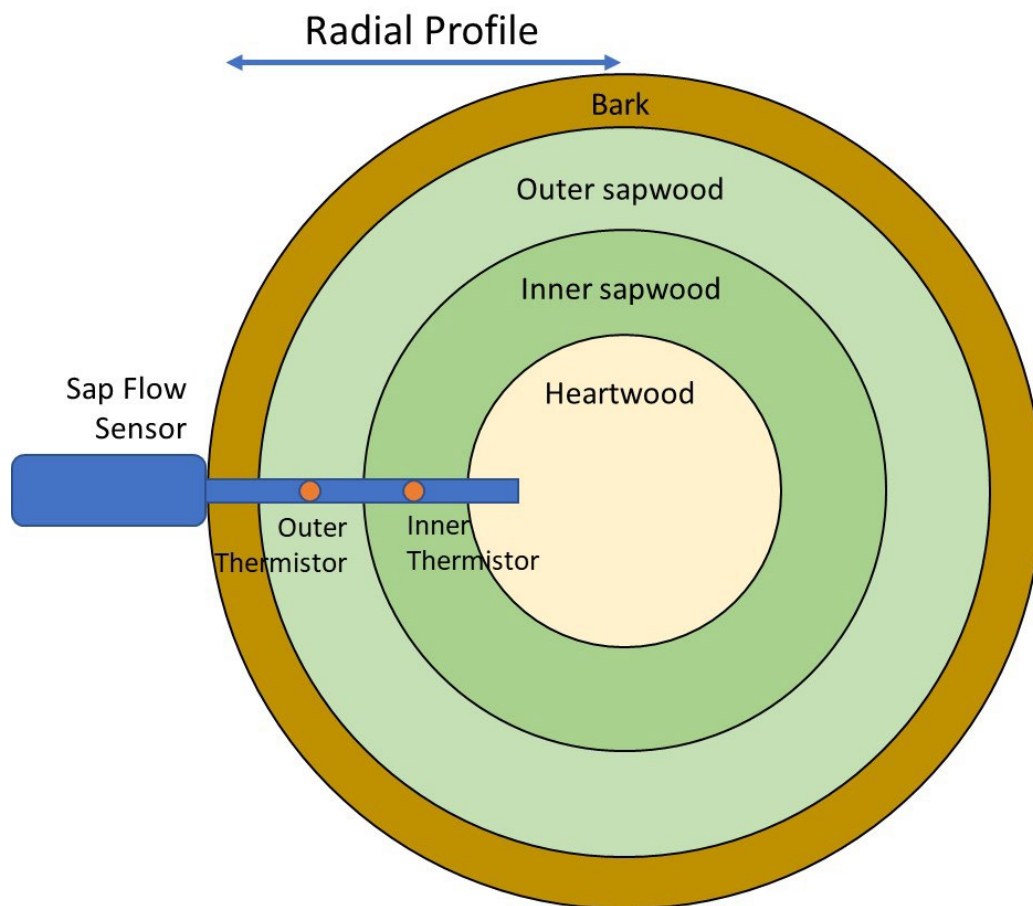


Figure 10. The radial profile of a stem is that portion from the outside of the bark to the middle of the heartwood. The radial profile may also be extended across the diameter of the stem. The Implexx Sap Flow Sensor measures at 2 locations along the radial profile: outer (towards the outside of the stem) and inner (towards the inside of the stem).



Understanding the dynamics of water content across the radial profile will provide invaluable insights to plant adaptation and physiology. For example, in some plants the inner portion of the stem, or even the bark, may be a zone of water storage (capacitance) that is important during time of soil moisture deficit. The importance of such storage, and its dynamics, can only be known if it is measured.

The high spatial resolution of the Implexx Sap Flow Sensor is a distinct advantage over other sensing technology that measure stem water content. For example, soil water content sensors that are installed inside trees, such as capacitance probes, or time domain reflectometry (TDR) probes, integrate water content measurements over the entire length of the probe. This length may be 50 mm or longer and can cross different stem tissue such as bark, sapwood and heartwood. These probes have a poor spatial resolution and misinterpretation of data may occur (Figure 11).

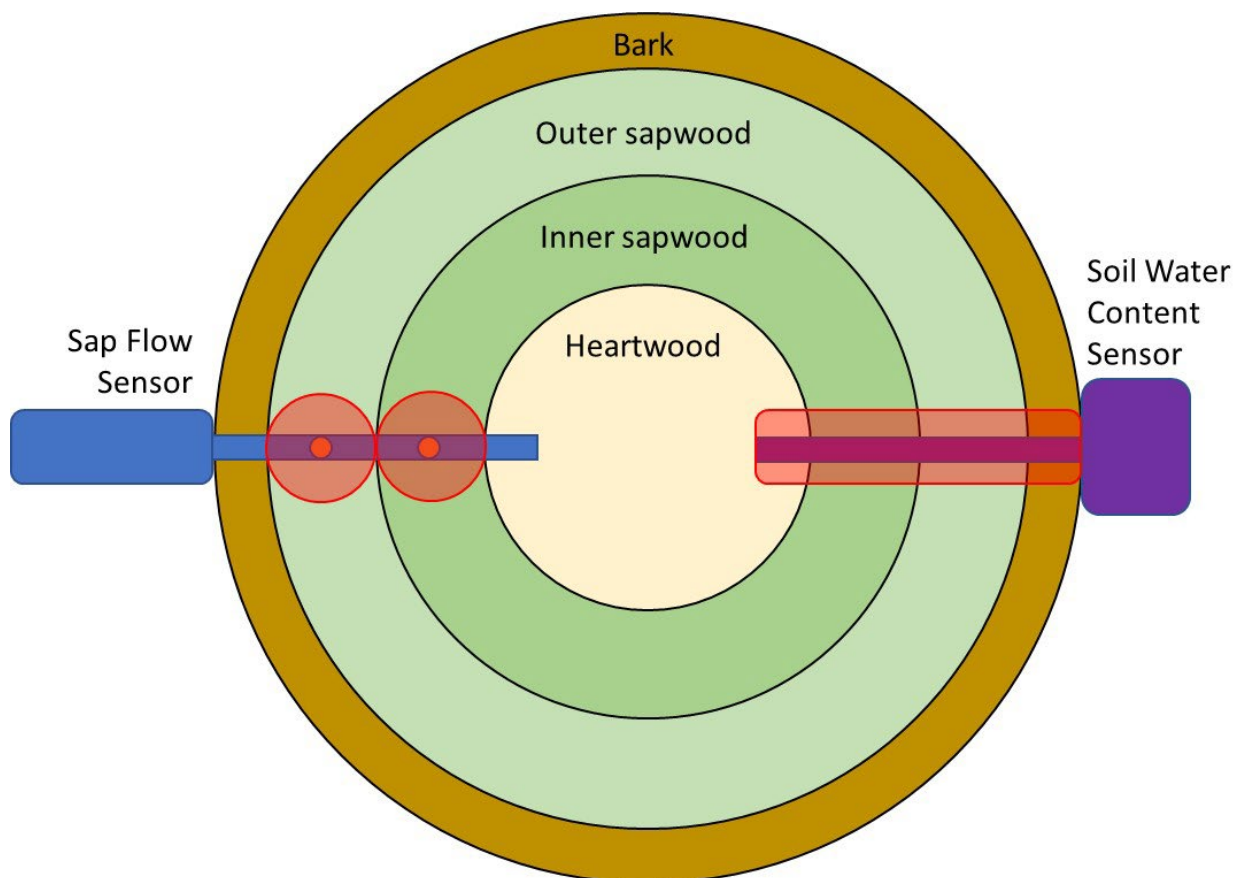


Figure 11. The spatial resolution of the Implexx Sap Flow Sensor, based on thermal properties, versus a soil water content sensor based on either capacitance or TDR. The zone of influence, or spatial resolution, is highlighted in red.

Stem water content under high sap flow conditions

The estimation of stem water content via the theory of thermal conduction assumes that there is zero thermal convection. That is, the sap, or fluid, inside the stem, during a measurement cycle, is assumed to be static or non-moving. This assumption is found in equation 17 where there is no parameter for velocity or convection.

Therefore, stem water content estimated via thermal properties is most accurate under zero, or very slow, sap flow conditions. Such conditions occur during the night, typically in the pre-dawn period approximately 1 to 2 hours prior to sunrise. It is recommended that stem water content is measured at this time.

Under high sap flow conditions, the estimation of stem water content via a thermal sensor will be drier than actual stem water content. This result is found from equation 18 where ΔT_m is influenced by sap flow. Under high flow conditions, ΔT_m is relatively larger due to heat convection. An increase in ΔT_m causes ρc to decrease (because ΔT_m is the denominator, or a parameter below the line, in equation 18). A decrease in ρc in equation 17 will lead to a smaller stem water content value.

One possible approach to estimate stem water content under high sap flow conditions is to install the probes perpendicular to the direction of sap flow (i.e., the yellow circles in Figure 12). Although, caution with this approach should be taken as this method has not been extensively researched or tested. Also, it is not possible to estimate sap flow with this style of installation.

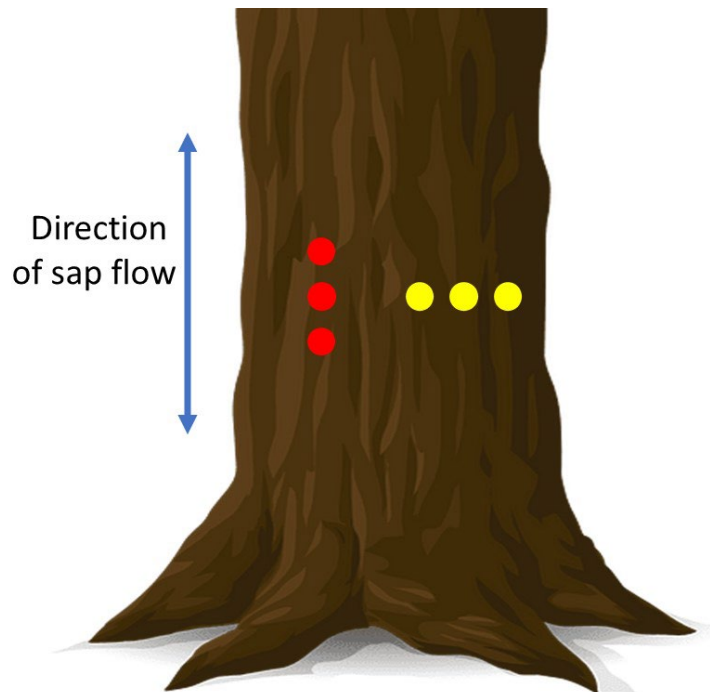


Figure 12. Under high sap flow, stem water content may be estimated by installing the sensor perpendicular to the assumed direction of sap flow. The red circles represent a typical sap flow sensor installation where the sensor is installed parallel to the direction of flow. The yellow circles represent a sensor installation perpendicular to the direction of sap flow. Caution should be exercised with this approach as it has not been extensively tested or investigated.

Negative stem water content?

The observable range of values for stem water content is between 0 % (completely dry) and 100 % (pure water). Typically, values range between 10 % and 80 % as some moisture is always retained in the stem and the stem cannot be pure water.

However, the Implexx Sap Flow Sensor may output a negative stem water content or a value greater than 100 %.

The sensor is not faulty. Rather, the parameters from equations 17 and 18 have not been configured correctly. A correct configuration will remove negative or erroneous values.

The two most important parameters from equations 17 and 18 that must be configured correctly are dry sapwood density (ρ_d), also known as dry density of sapwood (DDW), and the distance (x) between the heater and temperature probes. The importance of ρ_d to stem water content is shown in equation 17. Similarly, x is important in equation 18. The parameters ρ_d and x are explained in detail in the section above, “How is stem water content calculated from thermal properties?”.

Further information, and how to measure ρ_d and x , are provided in the application notes “How to measure sapwood density” and “Correction for probe misalignment” on the Implexx Sense website.

Installation

Step 1: Select an installation site

- (a) - Choose a representative or study tree of interest.
- (b) - If you are installing a single sensor on the tree, install the sensor on the north face (if you are in the Southern hemisphere) or south face (if you are in the northern hemisphere).
- (c) - If you are installing two sensors, install one on the north and south face; if you are installing four sensors, install one on the north, south, east and west face, and so on.
- (d) - To measure whole tree water use, install the sensor beneath lowest branch. That is, install the sensor beneath all the leaves so you are measuring the entire canopy. Avoid any obvious scars, decay, wounding, damage, etc.
- (e) - It's not always critical but try and install the sensor above the root stock.
- (f) - The golden rule is to be consistent. For all your installation sites on different trees, install the sensor in a similar location.

Step 2: Measure tree and wood parameters

- (a) - Measure trunk diameter (TDD), in centimetres, where the sensor will be installed.
- (b) - Measure bark depth (BDD), in centimetres, close by to where the sensor will be installed.

Step 3: Measure dry density of wood (DDW) also known as sapwood density

- (a) - DDW is a critical parameter for the calibration co-efficient. You can either measure it directly on your tree with a stem borer or contact Implexx Sense for more information.
- (b) - DDW should be measured as grams per centimetre cubed (g/cm^3). Values range between 0.100 and 1.200 g/cm^3 with typical values ranging between 0.400 and 0.800 g/cm^3 .

IMPORTANT TIP!

The second set of steps is to configure your sap flow sensor for your installation site. You will need to know trunk diameter (TDD), bark depth (BDD) and dry density of wood (DDW). You will also need to have some knowledge or experience with configuring SDI-12 communication style sensors. Implexx Sense can provide a device where you can talk directly to the sap flow sensor via SDI-12 communication.



Step 4: Configure SDI-12 settings in the sap flow sensor

- (a) - Consult the sap flow sensor integrator's guide for complete details on the SDI-12 settings available in the sap flow sensor.
- (b) - Use the following SDI-12 commands to perform these basic configuration functions:
- (c) - ?! ENTER – returns the sensor's SDI-12 address. The default address is 0.
- (d) - 0XTDD! ENTER – returns trunk diameter value for sensor address 0. Default value is 10.0 cm.
- (e) - 0XTDD=24.3! ENTER – changes the trunk diameter to 24.3 cm. Instead of 24.3, insert the value for your trunk diameter which you measured in Step 2(a).
- (f) – 0XBDD! ENTER – returns bark depth value for sensor address 0. Default value is 0.5 cm.
- (g) – 0XBDD=0.2! ENTER - changes the bark depth to 0.2 cm. Instead of 0.2, insert the value for your bark depth which you measured in Step 2(b).
- (h) – 0XDDW! ENTER – returns dry density of wood for sensor address 0. Default value is 0.400 g/cm³.
- (i) – 0XDDW=0.558! ENTER – changes the dry density of wood to 0.558 g/cm³. Instead of 0.558, insert the value for your dry density of wood measured in Step 3.
- (j) – You may have more than one SDI-12 sensor connected to your bus or data acquisition unit. SDI-12 sensors can never have the same address. Therefore, you will need to change the address of at least one SDI-12 sensor. To change an address, use the following command: 0A1! ENTER. This command will change sensor address 0 to address 1.
- (k) – your sap flow sensor is now configured and ready to install into the tree.

Step 5: To remove or not remove bark?

See diagrams on page 6 and 7 for detailed information.

- (a) – Ideally, you should minimise the impact or damage on the tree when installing a sap flow sensor.
- (b) – Bark should only ever be removed if it is thicker than 0.5 cm depth. In Step 2(b), if you measured bark depth (BDD) as greater than 0.5 cm, then you will need to remove some bark. If the BDD value is less than 0.5 cm, then do not remove bark.
- (c) – If bark depth (BDD) is greater than 0.5 cm, carefully remove bark, with a dissecting blade or chisel, so that BDD equals 0.5 cm.

Step 6: Apply thermal grease to the needles or probes

- (a) – Before you start drilling, it's always a good idea to apply thermal grease to the sap flow sensor needles.

Step 7: Drilling into the tree

- (a) – Strap or cable tie the drill guide to the tree. Ensure the 3-holes on the drill guide are aligned with the direction of sap flow.
- (b) – Insert the drill bit into the chuck of the drill. You only need to insert the drill bit 2 or 3 mm into the chuck.
- (c) – Start drilling into the tree.
- (d) – Minimise your impact on the tree by drilling in short, sharp steps. You should only drill a few millimetres at a time and frequently cleaning the flute of the drill bit.
- (e) – Golden rule – short, sharp and clean cuts!
- (f) – Only remove the drill guide after you have completed drilling all 3 holes. If the drill guide is removed before this, you will need to start again.

Step 8: Inserting the sap flow sensor into the tree

- (a) – Remove the drill guide (only after all 3 holes have been completely drilled through).
- (b) – As quickly as possible, insert the 3 needles of the sap flow sensor into the drilled holes.
- (c) – The needles should slide into the holes firmly but with no resistance.
- (d) – Occasionally, the needles do not insert entirely into the holes. You may need to carefully remove the needles and re-drill the holes to a deeper depth. Always be careful with this step.
- (e) – Always position the outer thermistor at 0.5 cm depth beneath the bark or into the sapwood. See diagrams on pages 6 and 7 for further information.

WARNING!

The sap flow sensor must always be installed so the outer thermistor is at 0.5 cm depth into the sapwood. If the bark depth (BDD) is less than 0.5 cm, this will mean a small portion of the sap flow needles will not be inside the tree. This is not a problem. Simply insulate the exposed portion of the needles with foam and aluminium foil.

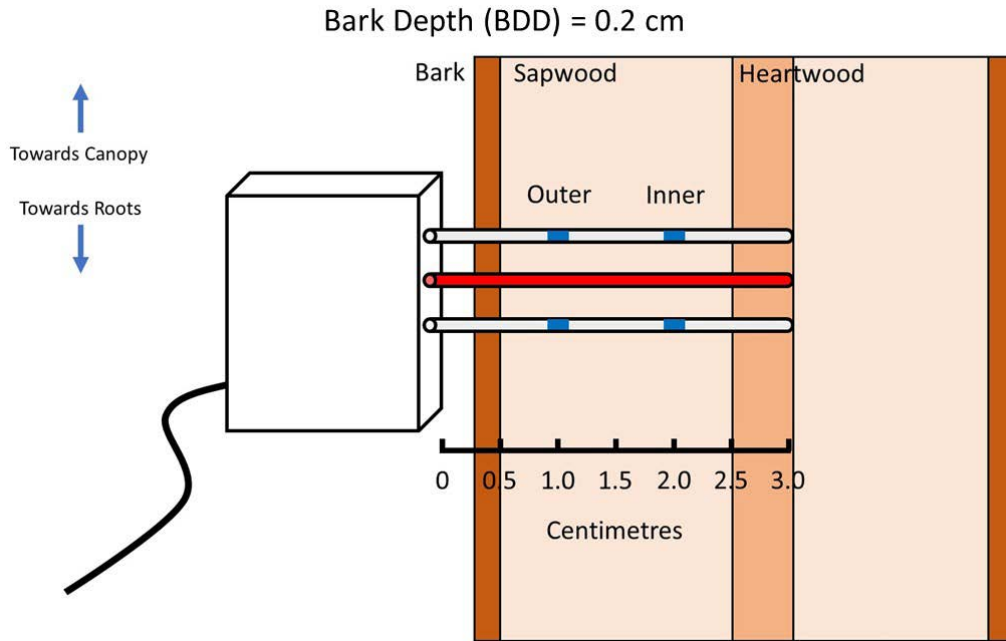


Figure 13. Thinner bark: a portion of the probes will be outside of the tree. Insulate this with foam/aluminium.

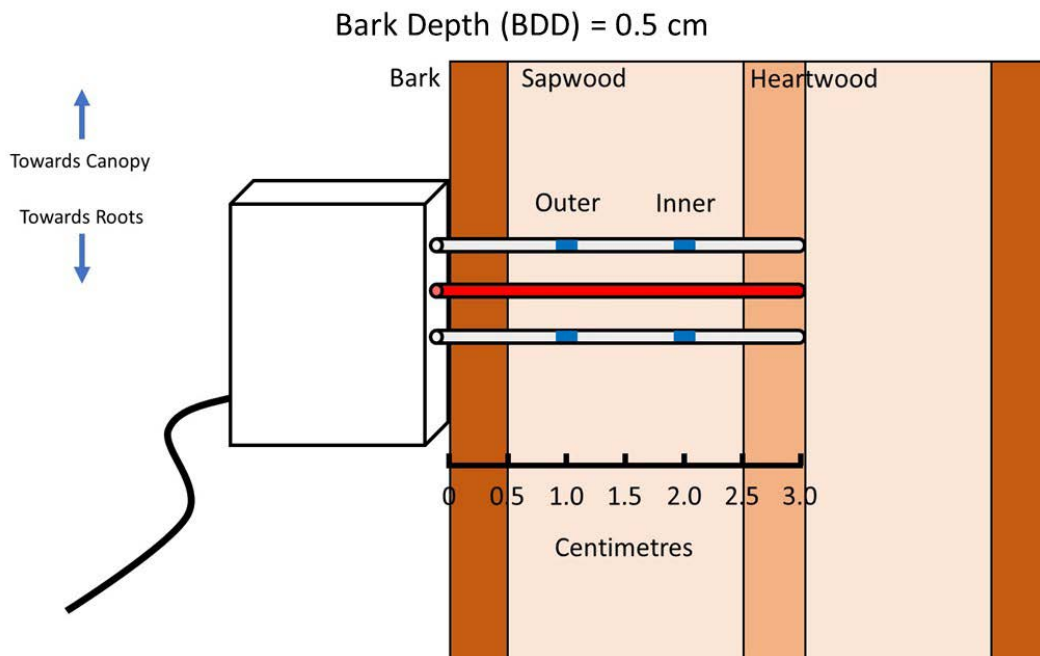


Figure 14. Do not remove any bark when thickness is approximately 0.5cm.

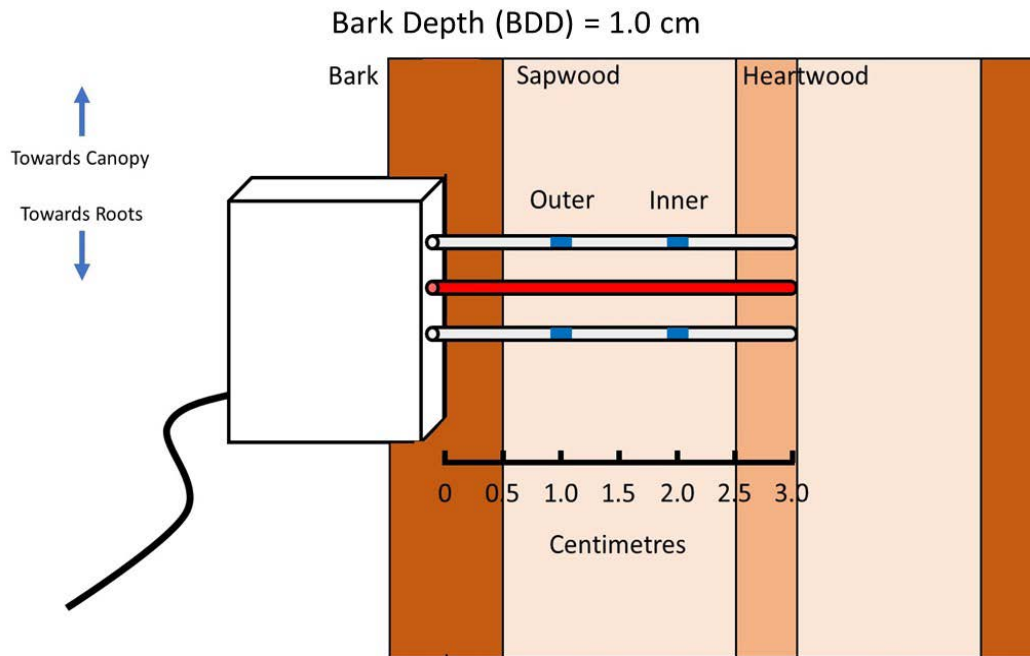


Figure 15. Thicker bark: carefully remove a portion of the bark with a dissecting blade or chisel until bark depth is approximately 0.5 cm.

Step 9: Insulate Sensor Installation with Aluminium Foil

- Wrap a generous amount of foil around the sensor and stem. This reflects direct sunlight and external heat to avoid any errors associated with thermal gradients.
- BUT do not cable tie the sensor directly against the stem. The stem grows outwards, and the cable tie pushes inwards. Therefore, fixing the sensor directly against the stem with a cable tie will crush and destroy the sensor. Fix the cable tie above and below the sensor.





Figure 16. A sensor with insulation. DO NOT CABLE TIE THE SENSOR DIRECTLY AGAINST THE TREE!

Step 10: Connect the sap flow sensor cable to the data unit

- (a) – The sap flow sensor has a 3-core (wire) cable that must be connected to a data acquisition unit, data logger or data transmission unit. Wiring: Red – 12 VDC power; Black – ground; White – data. Or: Brown – 12VDC power; Green – ground; White – data.

Step 11: Tidy up the installation site

- (a) – Carefully mount the sap flow sensor digital interface box to the tree or stake. Ensure there is no tension on the cables or wire. Always place cable inside conduit.

Step 12: Start collecting data

- (a) – Ensure your data unit is properly programmed, connected to enough power (e.g. solar panels and batteries).

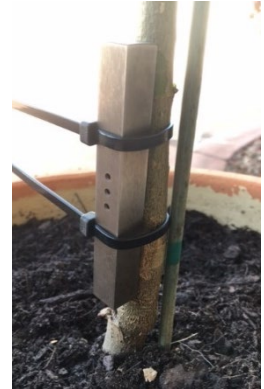
WARNING!

The most frequent data collect interval is 10 minutes. An SDI-12 M! command should never be sent to the sap flow sensor more frequently than 10-minute intervals.

Small Stem Installation

The Drill Guide

- Ensure holes are aligned with direction of xylem flow.
- Cable ties are ideal to fix the DG1 to a small stem.
- It is **critical** that the drill guide **never** moves during installation and drilling of holes. If the drill guides move, reinstall and start again.
- If a drill bit breaks during installation, remove and start again.



Correct Positioning of Thermistors

- For small stems, it is recommended to use one set of thermistors such as the outer thermistors.
- Prior to installation, measure the diameter of the stem and know exactly where the thermistors will be installed.
- It is recommended to install the thermistors at 5mm depth below the bark.
- Use a guide, or stopper (for example, the red insulation material in the photo to the right), to assist in correct placement of the thermistors in the plant.



Insulate Sensors

- If the stainless steel probes are exposed, or are located outside of plant tissue, then this will lead to errors in measurements due to external heat/temperature gradients.
- Insulate the sap flow sensors with a foam such as housing insulation material.
- Wrap a layer of aluminium foil around the insulation material but be careful not to cable tie the sensor against the stem. **DO NOT CABLE TIE THE SENSOR DIRECTLY AGAINST THE TREE!** Place the cable tie above and/or below the sensor.



Wiring

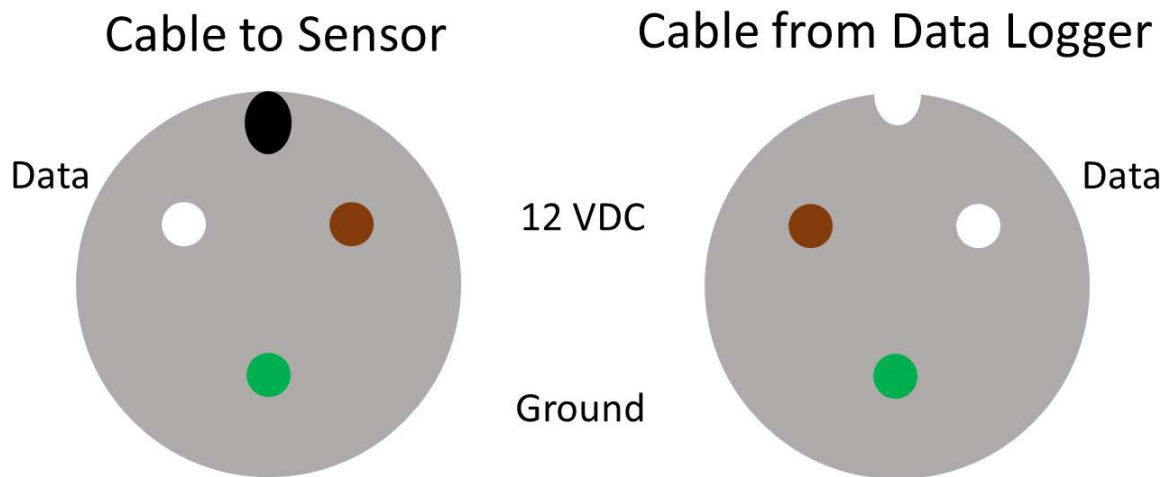
Wiring Sensor to a Data Logger, Implexx Sensor Hub, or other device:

Green -> Ground

White -> Data

Brown -> Power (12 VDC)

Cable Connector Wiring:



SDI-12 Commands

Implexx Sense assumes the user has some familiarity with the SDI-12 protocol and commands. For an introduction to SDI-12, visit the SDI-12 Support Group website:

<https://sdi-12.org/>

The following table summarises the available SDI-12 commands in the Implexx Sap Flow Sensor Gen2. For further details on integrating the sap flow sensor with your SDI-12 enabled device, download the Implexx Sap Flow Sensor Gen2 Integrator's Guide from the Implexx Sense website:

<https://www.implexx.io/manuals-and-guides/>

SDI-12 Command	Parameter	Units	Description
M! or C!	SapFlowTotal	L/hr	Total sap flow (Eq. 16c).
Main Outputs	SFD_Outer	cm ³ /cm ² /hr	Sap flux density in the outer measurement position (Eq. 15).
	SFD_Inner	cm ³ /cm ² /hr	Sap flux density in the inner measurement position (Eq. 15).
	Alpha_Outer	dimensionless	The ratio of temperature in the downstream over the upstream outer position after the heat pulse (Eq. 5).
	Alpha_Inner	dimensionless	The ratio of temperature in the downstream over the upstream inner position after the heat pulse (Eq. 5).
	Beta_Outer	dimensionless	The ratio of maximum temperature rise after the heat pulse in the downstream over the upstream outer position after the heat pulse (Eq. 6).
	Beta_Inner	dimensionless	The ratio of maximum temperature rise after the heat pulse in the downstream over the upstream inner position after the heat pulse (Eq. 6).
	Tmax_Outer	seconds	The time to maximum temperature rise after the heat pulse in the outer, downstream position.
	Tmax_Inner	seconds	The time to maximum temperature rise after the heat pulse in the inner, downstream position.



M1! or C1!	TdsPreOuter	°C	The average temperature prior to the heat pulse in the outer, downstream position.
Outer Temperature	dTmaxDsOuter	°C	The maximum temperature after the heat pulse in the outer, downstream position.
	TdsPostOuter	°C	The average temperature 60 to 80 seconds after the heat pulse in the outer, downstream position.
	TusPreOuter	°C	The average temperature prior to the heat pulse in the outer, upstream position.
	dTmaxUsOuter	°C	The maximum temperature after the heat pulse in the outer, upstream position.
	TusPostOuter	°C	The average temperature 60 to 80 seconds after the heat pulse in the outer, upstream position.
M2! or C2!	TdsPreInner	°C	The average temperature prior to the heat pulse in the inner, downstream position.
Inner Temperature	dTmaxDsInner	°C	The maximum temperature after the heat pulse in the inner, downstream position.
	TdsPostInner	°C	The average temperature 60 to 80 seconds after the heat pulse in the inner, downstream position.
	TusPreInner	°C	The average temperature prior to the heat pulse in the inner, upstream position.
	dTmaxUsInner	°C	The maximum temperature after the heat pulse in the inner, upstream position.
	TusPostInner	°C	The average temperature 60 to 80 seconds after the heat pulse in the inner, upstream position.
M3! or C3!	SWC_Outer	%	Stem (sapwood) water content in the outer, downstream position (Eq. 17).
Stem Water Content	SWC_Inner	%	Stem (sapwood) water content in the inner, downstream position (Eq. 17).
	VolHeatCapOuter	kJ/m ³	Volumetric heat capacity in the outer position (Eq. 17 and 18)
	VolHeatCapInner	kJ/m ³	Volumetric heat capacity in the inner position (Eq. 17 and 18).
	PulseEnergy	J/m	The amount of energy per heat pulse (q in Eq. 18).



	PulseTime	seconds	The length in time of the heat pulse.
M4! or C4!	AvgVolts	volts	Average volts during the heating period (diagnostic purposes only).
Sensor Diagnostics	AvgCurrent	milliamp	Average current during the heating period (diagnostic purposes only).
	MaxVolts	volts	Maximum volts during the heating period (diagnostic purposes only).
	MinVolts	volts	Minimum volts during the heating period (diagnostic purposes only).
	Diagnostic Flag	dimensionless	See Integrator's Guide for detailed information on sensor diagnostics.
M5! or C5!	tMaxTusOuter	seconds	The time to maximum temperature rise after the heat pulse in the outer, upstream position.
Upstream Tmax	tMaxTusInner	seconds	The time to maximum temperature rise after the heat pulse in the inner, upstream position.
M6! or C6!	TdsRawOuter	°C	Current temperature in the outer, downstream position
Raw Temperature	TusRawOuter	°C	Current temperature in the outer, upstream position.
	TdsRawInner	°C	Current temperature in the inner, downstream position.
	TusRawInner	°C	Current temperature in the inner, downstream position.
X Commands:			
TDD	Trunk Diameter	cm	The diameter of the trunk or stem at site of sensor installation. Default value: 10 cm.
BDD	Bark Depth	cm	Bark thickness at site of sensor installation. Default value: 0.5 cm.
SDD	Sapwood Depth	cm	Sapwood depth at site of sensor installation. Default value: 2.5 cm.
DDW	Density of Dry Wood	g/cm ³	Gravimetric, or specific, wood density. Default value: 0.7 g/cm ³ (ρ_d in Eq. 15 and 17).
TDF	Thermal Diffusivity	cm ² /s	Sapwood thermal diffusivity (Eq. 3). Default value: 0.0025 cm ² /s.
BMD	Baseline temperature measurement duration	seconds	The duration to find the average temperature prior to the heat pulse. Default value: 10 seconds.
HTD	Heat Pulse Duration	seconds	The duration of the heat pulse. NOTE: altering the duration may damage the heater element and the plant. It is not recommended to change this parameter. Default value: 3 seconds.



PMS	Post-heat temperature measurement start	seconds	The amount of time after the heat pulse to commence post-heat pulse temperature measurements. Default value: 60 seconds.
PMD	Post-heat temperature measurement duration	seconds	The duration to find the average temperature after the heat pulse. Default value: 20 seconds.
TMD	Maximum temperature measurement duration	seconds	The amount of time after the heat pulse to find T _{max} . Default value: 120 seconds.
PRS	Probe spacing	cm	The distance between the heater and downstream or upstream temperature needle. Default value: 0.8 cm.
PRL	Probe length	cm	The length of the needles. Default value: 3.0 cm.
CDW	Specific heat capacity of dry wood	J/kg/K	Sapwood heat capacity (Eq. 15 and 17). Default value: 1200.



Programming

The Implexx Sap Flow Sensor Gen2 is an SDI-12 enabled device and will connect to any data logger that supports the SDI-12 protocol. Implexx Sense assumes the user has some familiarity with the SDI-12 protocol and the basics of data logger programming. Implexx Sense strongly recommends contacting the manufacturer of your data logger for further assistance with programs.

Below are example data logger programs for a Campbell Scientific CR300 data logger via the CRBasic programming language.

The first example program is for the operation of 2 Implexx Sap Flow Sensors.

The second example program is for the operation of 16 Implexx Sap Flow Sensors.

Further information is available on the Implexx Sense website:

<https://www.implexx.io/manuals-and-guides/>

A Program to Operate 2 Implexx Sap Flow Sensors on a CR300 Data Logger.

```
' Program Name: Program to operate 2 x Implexx Sap Flow Sensor on a CR300 data logger.
'
' (C) Copyright 2022. This program, and associated information, is copyright to, and property
' of Edaphic Scientific Pty Ltd. This program is not to be copied or disseminated to any
' person, under any format, with out the written permission of Edaphic Scientific Pty Ltd.
'
' Date: 24/05/2022
' Program author: Implexx Sense
```

```
ConstTable (Station_Settings,0)
Const MEAST_INTERVAL_MIN = 15
EndConstTable
```

```
'Declare Public Variables
```

Public PTemp, Batt_volt

'===== SAP FLOW VARIABLES =====

'C! Command - Main variables

Public SapFlow_a(9)

Alias SapFlow_a(1)=TotalSapFlow_a : Units TotalSapFlow_a=L/hr

Alias SapFlow_a(2)=Vh_Outer_a : Units Vh_Outer_a=cm/hr

Alias SapFlow_a(3)=Vh_Inner_a : Units Vh_Inner_a=cm/hr

Alias SapFlow_a(4)=Alpha_Outer_a

Alias SapFlow_a(5)=Alpha_Inner_a

Alias SapFlow_a(6)=Beta_Outer_a

Alias SapFlow_a(7)=Beta_Inner_a

Alias SapFlow_a(8)=Tmax_Outer_a : Units Tmax_Outer_a=secs

Alias SapFlow_a(9)=Tmax_Inner_a : Units Tmax_Inner_a=secs

Public SapFlow_b(9)

Alias SapFlow_b(1)=TotalSapFlow_b : Units TotalSapFlow_b=L/hr

Alias SapFlow_b(2)=Vh_Outer_b : Units Vh_Outer_b=cm/hr

Alias SapFlow_b(3)=Vh_Inner_b : Units Vh_Inner_b=cm/hr

Alias SapFlow_b(4)=Alpha_Outer_b

Alias SapFlow_b(5)=Alpha_Inner_b

Alias SapFlow_b(6)=Beta_Outer_b

Alias SapFlow_b(7)=Beta_Inner_b

Alias SapFlow_b(8)=Tmax_Outer_b : Units Tmax_Outer_b=secs

Alias SapFlow_b(9)=Tmax_Inner_b : Units Tmax_Inner_b=secs

Dim d_SapFlow(9) 'This variable is required for correct timing of M! or C! command measurements

'===== STEM TEMPERATURE VARIABLES =====

'C1! Command - Outer thermistor measurements

'C2! Command - Inner thermistor measurements

Public Stem_Temp_Outer_a(6)

Public Stem_Temp_Inner_a(6)

Alias Stem_Temp_Outer_a(1) = Pre_Temp_Down_Outer_a : Units
Pre_Temp_Down_Outer_a=deg_C

Alias Stem_Temp_Outer_a(2) = Max_Temp_Down_Outer_a : Units
Max_Temp_Down_Outer_a=deg_C

Alias Stem_Temp_Outer_a(3) = Post_Temp_Down_Outer_a : Units
Post_Temp_Down_Outer_a=deg_C

Alias Stem_Temp_Outer_a(4) = Pre_Temp_Upper_Outer_a : Units
Pre_Temp_Upper_Outer_a=deg_C

Alias Stem_Temp_Outer_a(5) = Max_Temp_Upper_Outer_a : Units
Max_Temp_Upper_Outer_a=deg_C

Alias Stem_Temp_Outer_a(6) = Post_Temp_Upper_Outer_a : Units
Post_Temp_Upper_Outer_a=deg_C

Alias Stem_Temp_Inner_a(1) = Pre_Temp_Down_Inner_a : Units Pre_Temp_Down_Inner_a=deg_C

Alias Stem_Temp_Inner_a(2) = Max_Temp_Down_Inner_a : Units
Max_Temp_Down_Inner_a=deg_C

Alias Stem_Temp_Inner_a(3) = Post_Temp_Down_Inner_a : Units
Post_Temp_Down_Inner_a=deg_C

Alias Stem_Temp_Inner_a(4) = Pre_Temp_Upper_Inner_a : Units Pre_Temp_Upper_Inner_a=deg_C

Alias Stem_Temp_Inner_a(5) = Max_Temp_Upper_Inner_a : Units
Max_Temp_Upper_Inner_a=deg_C

Alias Stem_Temp_Inner_a(6) = Post_Temp_Upper_Inner_a : Units
Post_Temp_Upper_Inner_a=deg_C

Public Stem_Temp_Outer_b(6)

Public Stem_Temp_Inner_b(6)

Alias Stem_Temp_Outer_b(1) = Pre_Temp_Down_Outer_b : Units
Pre_Temp_Down_Outer_b=deg_C

Alias Stem_Temp_Outer_b(2) = Max_Temp_Down_Outer_b : Units
Max_Temp_Down_Outer_b=deg_C

Alias Stem_Temp_Outer_b(3) = Post_Temp_Down_Outer_b : Units
Post_Temp_Down_Outer_b=deg_C



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Alias Stem_Temp_Outer_b(4) = Pre_Temp_Upper_Outer_b : Units
Pre_Temp_Upper_Outer_b=deg_C

Alias Stem_Temp_Outer_b(5) = Max_Temp_Upper_Outer_b : Units
Max_Temp_Upper_Outer_b=deg_C

Alias Stem_Temp_Outer_b(6) = Post_Temp_Upper_Outer_b : Units
Post_Temp_Upper_Outer_b=deg_C

Alias Stem_Temp_Inner_b(1) = Pre_Temp_Down_Inner_b : Units Pre_Temp_Down_Inner_b=deg_C

Alias Stem_Temp_Inner_b(2) = Max_Temp_Down_Inner_b : Units
Max_Temp_Down_Inner_b=deg_C

Alias Stem_Temp_Inner_b(3) = Post_Temp_Down_Inner_b : Units
Post_Temp_Down_Inner_b=deg_C

Alias Stem_Temp_Inner_b(4) = Pre_Temp_Upper_Inner_b : Units
Pre_Temp_Upper_Inner_b=deg_C

Alias Stem_Temp_Inner_b(5) = Max_Temp_Upper_Inner_b : Units
Max_Temp_Upper_Inner_b=deg_C

Alias Stem_Temp_Inner_b(6) = Post_Temp_Upper_Inner_b : Units
Post_Temp_Upper_Inner_b=deg_C

'===== STEM WATER CONTENT VARIABLE =====

'C3! Command

Public Stem_Water_a(6)

Alias Stem_Water_a(1) = SWC_Outer_a : Units SWC_Outer_a=%

Alias Stem_Water_a(2) = SWC_Inner_a : Units SWC_Inner_a=%

Alias Stem_Water_a(3) = Heat_Capacity_Outer_a : Units Heat_Capacity_Outer_a=kJ/m³

Alias Stem_Water_a(4) = Heat_Capacity_Inner_a : Units Heat_Capacity_Inner_a=kJ/m³

Alias Stem_Water_a(5) = Pulse_Energy_a : Units Pulse_Energy_a=J/m

Alias Stem_Water_a(6) = Pulse_Duration_a : Units Pulse_Duration_a=sec

Public Stem_Water_b(6)

Alias Stem_Water_b(1) = SWC_Outer_b : Units SWC_Outer_b=%

Alias Stem_Water_b(2) = SWC_Inner_b : Units SWC_Inner_b=%

Alias Stem_Water_b(3) = Heat_Capacity_Outer_b : Units Heat_Capacity_Outer_b=kJ/m³



Alias Stem_Water_b(4) = Heat_Capacity_Inner_b : Units Heat_Capacity_Inner_b=kJ/m³

Alias Stem_Water_b(5) = Pulse_Energy_b : Units Pulse_Energy_b=J/m

Alias Stem_Water_b(6) = Pulse_Duration_b : Units Pulse_Duration_b=sec

'===== NEEDLE DISTANCE VARIABLES =====

'C5! Command - Time to maximum temperature in the upstream needle (outer and inner)

Public uTmax_a(2)

Alias uTmax_a(1) = uTmax_Outer_a : Units uTmax_Outer_a=sec

Alias uTmax_a(2) = uTmax_Inner_a : Units uTmax_Inner_a=sec

Public uTmax_b(2)

Alias uTmax_b(1) = uTmax_Outer_b : Units uTmax_Outer_b=sec

Alias uTmax_b(2) = uTmax_Inner_b : Units uTmax_Inner_b=sec

'===== DATA TABLES =====

DataTable (Sap_Flow_Data,1,-1)

DataInterval (0,MEAST_INTERVAL_MIN,Min,10)

Sample (9,SapFlow_a()),IEEE4)

Sample (9,SapFlow_b()),IEEE4)

EndTable

DataTable (Stem_Temp_Data,1,-1)

DataInterval (0,MEAST_INTERVAL_MIN,Min,10)

Sample (6,Stem_Temp_Outer_a()),IEEE4)

Sample (6,Stem_Temp_Inner_a()),IEEE4)

Sample (6,Stem_Temp_Outer_b()),IEEE4)

Sample (6,Stem_Temp_Inner_b()),IEEE4)



EndTable

DataTable (Stem_Water_Data,1,-1)

DataInterval (0,MEAST_INTERVAL_MIN,Min,10)

Sample (6,Stem_Water_a()),IEEE4)

Sample (6,Stem_Water_b()),IEEE4)

EndTable

DataTable (Diagnostic_Data,1,-1)

DataInterval (0,MEAST_INTERVAL_MIN,Min,10)

Sample (1,Batt_volt()),FP2)

Sample (1,PTemp()),FP2)

Sample (1,Tmax_Outer_a()),IEEE4)

Sample (1,Tmax_Inner_a()),IEEE4)

Sample (2,uTmax_a()),IEEE4)

Sample (1,Tmax_Outer_b()),IEEE4)

Sample (1,Tmax_Inner_b()),IEEE4)

Sample (2,uTmax_b()),IEEE4)

EndTable

'===== MAIN PROGRAM =====

BeginProg

Scan (MEAST_INTERVAL_MIN,Min,0,0)

PanelTemp (PTemp,60)

Battery (Batt_volt)

'Send command to start measurement

SDI12Recorder (d_SapFlow(),C1,"a","C!",1.0,0,-1,0)

SDI12Recorder (d_SapFlow(),C1,"b","C!",1.0,0,-1,0)



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'Retrieve the data from the C! command

Delay (0,140,Sec)

SDI12Recorder (SapFlow_a(1),C1,"a","D0!",1.0,0,-1,1)

SDI12Recorder (SapFlow_a(6),C1,"a","D1!",1.0,0,-1,1)

SDI12Recorder (SapFlow_b(1),C1,"b","D0!",1.0,0,-1,1)

SDI12Recorder (SapFlow_b(6),C1,"b","D1!",1.0,0,-1,1)

'Retrieve the data from the C1! C2! C3! C4! and C5! commands

SDI12Recorder (Stem_Temp_Outer_a(),C1,"a","C1!",1.0,0,-1,1)

SDI12Recorder (Stem_Temp_Inner_a(),C1,"a","C2!",1.0,0,-1,1)

SDI12Recorder (Stem_Water_a(),C1,"a","C3!",1.0,0,-1,1)

SDI12Recorder (uTmax_a(),C1,"a","C5!",1.0,0,-1,1)

SDI12Recorder (Stem_Temp_Outer_b(),C1,"b","C1!",1.0,0,-1,1)

SDI12Recorder (Stem_Temp_Inner_b(),C1,"b","C2!",1.0,0,-1,1)

SDI12Recorder (Stem_Water_b(),C1,"b","C3!",1.0,0,-1,1)

SDI12Recorder (uTmax_b(),C1,"b","C5!",1.0,0,-1,1)

'Call Output Tables

CallTable Sap_Flow_Data

CallTable Stem_Temp_Data

CallTable Stem_Water_Data

CallTable Diagnostic_Data

NextScan

EndProg

A Program to Operate 16 Implexx Sap Flow Sensors on a CR300 Data Logger.

' Program Name: Program to operate 16 x Implexx Sap Flow Sensor on a CR300 data logger.

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,

' Date: 05/06/2022

' Program author: Implexx Sense

ConstTable (Station_Settings,0)

Const MEAST_INTERVAL_MIN = 15

EndConstTable

'Declare Public Variables

Public PTemp, Batt_volt

'===== SAP FLOW VARIABLES =====

'SAP FLOW ADDRESS a...h on C1

'SAP FLOW ADDRESS A...H on C2

'C! Command - Main variables

Public SapFlow_a(9)

Alias SapFlow_a(1)=TotalSapFlow_a : Units TotalSapFlow_a=L/hr

Alias SapFlow_a(2)=Vh_Outer_a : Units Vh_Outer_a=cm/hr

Alias SapFlow_a(3)=Vh_Inner_a : Units Vh_Inner_a=cm/hr

Alias SapFlow_a(4)=Alpha_Outer_a

Alias SapFlow_a(5)=Alpha_Inner_a

Alias SapFlow_a(6)=Beta_Outer_a

Alias SapFlow_a(7)=Beta_Inner_a

Alias SapFlow_a(8)=Tmax_Outer_a : Units Tmax_Outer_a=secs

Alias SapFlow_a(9)=Tmax_Inner_a : Units Tmax_Inner_a=secs

Public SapFlow_b(9)

Alias SapFlow_b(1)=TotalSapFlow_b : Units TotalSapFlow_b=L/hr

Alias SapFlow_b(2)=Vh_Outer_b : Units Vh_Outer_b=cm/hr

Alias SapFlow_b(3)=Vh_Inner_b : Units Vh_Inner_b=cm/hr

Alias SapFlow_b(4)=Alpha_Outer_b

Alias SapFlow_b(5)=Alpha_Inner_b

Alias SapFlow_b(6)=Beta_Outer_b

Alias SapFlow_b(7)=Beta_Inner_b

Alias SapFlow_b(8)=Tmax_Outer_b : Units Tmax_Outer_b=secs

Alias SapFlow_b(9)=Tmax_Inner_b : Units Tmax_Inner_b=secs

Public SapFlow_c(9)

Alias SapFlow_c(1)=TotalSapFlow_c : Units TotalSapFlow_c=L/hr

Alias SapFlow_c(2)=Vh_Outer_c : Units Vh_Outer_c=cm/hr

Alias SapFlow_c(3)=Vh_Inner_c : Units Vh_Inner_c=cm/hr

Alias SapFlow_c(4)=Alpha_Outer_c

Alias SapFlow_c(5)=Alpha_Inner_c

Alias SapFlow_c(6)=Beta_Outer_c

Alias SapFlow_c(7)=Beta_Inner_c

Alias SapFlow_c(8)=Tmax_Outer_c : Units Tmax_Outer_c=secs

Alias SapFlow_c(9)=Tmax_Inner_c : Units Tmax_Inner_c=secs

Public SapFlow_d(9)

Alias SapFlow_d(1)=TotalSapFlow_d : Units TotalSapFlow_d=L/hr



Alias SapFlow_d(2)=Vh_Outer_d : Units Vh_Outer_d=cm/hr

Alias SapFlow_d(3)=Vh_Inner_d : Units Vh_Inner_d=cm/hr

Alias SapFlow_d(4)=Alpha_Outer_d

Alias SapFlow_d(5)=Alpha_Inner_d

Alias SapFlow_d(6)=Beta_Outer_d

Alias SapFlow_d(7)=Beta_Inner_d

Alias SapFlow_d(8)=Tmax_Outer_d : Units Tmax_Outer_d=secs

Alias SapFlow_d(9)=Tmax_Inner_d : Units Tmax_Inner_d=secs

Public SapFlow_e(9)

Alias SapFlow_e(1)=TotalSapFlow_e : Units TotalSapFlow_e=L/hr

Alias SapFlow_e(2)=Vh_Outer_e : Units Vh_Outer_e=cm/hr

Alias SapFlow_e(3)=Vh_Inner_e : Units Vh_Inner_e=cm/hr

Alias SapFlow_e(4)=Alpha_Outer_e

Alias SapFlow_e(5)=Alpha_Inner_e

Alias SapFlow_e(6)=Beta_Outer_e

Alias SapFlow_e(7)=Beta_Inner_e

Alias SapFlow_e(8)=Tmax_Outer_e : Units Tmax_Outer_e=secs

Alias SapFlow_e(9)=Tmax_Inner_e : Units Tmax_Inner_e=secs

Public SapFlow_f(9)

Alias SapFlow_f(1)=TotalSapFlow_f : Units TotalSapFlow_f=L/hr

Alias SapFlow_f(2)=Vh_Outer_f : Units Vh_Outer_f=cm/hr

Alias SapFlow_f(3)=Vh_Inner_f : Units Vh_Inner_f=cm/hr

Alias SapFlow_f(4)=Alpha_Outer_f

Alias SapFlow_f(5)=Alpha_Inner_f

Alias SapFlow_f(6)=Beta_Outer_f

Alias SapFlow_f(7)=Beta_Inner_f

Alias SapFlow_f(8)=Tmax_Outer_f : Units Tmax_Outer_f=secs

Alias SapFlow_f(9)=Tmax_Inner_f : Units Tmax_Inner_f=secs

Public SapFlow_g(9)

Alias SapFlow_g(1)=TotalSapFlow_g : Units TotalSapFlow_g=L/hr

Alias SapFlow_g(2)=Vh_Outer_g : Units Vh_Outer_g=cm/hr

Alias SapFlow_g(3)=Vh_Inner_g : Units Vh_Inner_g=cm/hr

Alias SapFlow_g(4)=Alpha_Outer_g

Alias SapFlow_g(5)=Alpha_Inner_g

Alias SapFlow_g(6)=Beta_Outer_g

Alias SapFlow_g(7)=Beta_Inner_g

Alias SapFlow_g(8)=Tmax_Outer_g : Units Tmax_Outer_g=secs

Alias SapFlow_g(9)=Tmax_Inner_g : Units Tmax_Inner_g=secs

Public SapFlow_h(9)

Alias SapFlow_h(1)=TotalSapFlow_h : Units TotalSapFlow_h=L/hr

Alias SapFlow_h(2)=Vh_Outer_h : Units Vh_Outer_h=cm/hr

Alias SapFlow_h(3)=Vh_Inner_h : Units Vh_Inner_h=cm/hr

Alias SapFlow_h(4)=Alpha_Outer_h

Alias SapFlow_h(5)=Alpha_Inner_h

Alias SapFlow_h(6)=Beta_Outer_h

Alias SapFlow_h(7)=Beta_Inner_h

Alias SapFlow_h(8)=Tmax_Outer_h : Units Tmax_Outer_h=secs

Alias SapFlow_h(9)=Tmax_Inner_h : Units Tmax_Inner_h=secs

Public SapFlow__A(9)

Alias SapFlow__A(1)=TotalSapFlow__A : Units TotalSapFlow__A=L/hr

Alias SapFlow__A(2)=Vh_Outer__A : Units Vh_Outer__A=cm/hr

Alias SapFlow__A(3)=Vh_Inner__A : Units Vh_Inner__A=cm/hr

Alias SapFlow__A(4)=Alpha_Outer__A

Alias SapFlow__A(5)=Alpha_Inner__A

Alias SapFlow__A(6)=Beta_Outer__A



Alias SapFlow__A(7)=Beta_Inner__A

Alias SapFlow__A(8)=Tmax_Outer__A : Units Tmax_Outer__A=secs

Alias SapFlow__A(9)=Tmax_Inner__A : Units Tmax_Inner__A=secs

Public SapFlow__B(9)

Alias SapFlow__B(1)=TotalSapFlow__B : Units TotalSapFlow__B=L/hr

Alias SapFlow__B(2)=Vh_Outer__B : Units Vh_Outer__B=cm/hr

Alias SapFlow__B(3)=Vh_Inner__B : Units Vh_Inner__B=cm/hr

Alias SapFlow__B(4)=Alpha_Outer__B

Alias SapFlow__B(5)=Alpha_Inner__B

Alias SapFlow__B(6)=Beta_Outer__B

Alias SapFlow__B(7)=Beta_Inner__B

Alias SapFlow__B(8)=Tmax_Outer__B : Units Tmax_Outer__B=secs

Alias SapFlow__B(9)=Tmax_Inner__B : Units Tmax_Inner__B=secs

Public SapFlow__C(9)

Alias SapFlow__C(1)=TotalSapFlow__C : Units TotalSapFlow__C=L/hr

Alias SapFlow__C(2)=Vh_Outer__C : Units Vh_Outer__C=cm/hr

Alias SapFlow__C(3)=Vh_Inner__C : Units Vh_Inner__C=cm/hr

Alias SapFlow__C(4)=Alpha_Outer__C

Alias SapFlow__C(5)=Alpha_Inner__C

Alias SapFlow__C(6)=Beta_Outer__C

Alias SapFlow__C(7)=Beta_Inner__C

Alias SapFlow__C(8)=Tmax_Outer__C : Units Tmax_Outer__C=secs

Alias SapFlow__C(9)=Tmax_Inner__C : Units Tmax_Inner__C=secs

Public SapFlow__D(9)

Alias SapFlow__D(1)=TotalSapFlow__D : Units TotalSapFlow__D=L/hr

Alias SapFlow__D(2)=Vh_Outer__D : Units Vh_Outer__D=cm/hr

Alias SapFlow__D(3)=Vh_Inner__D : Units Vh_Inner__D=cm/hr



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Alias SapFlow__D(4)=Alpha_Outer__D

Alias SapFlow__D(5)=Alpha_Inner__D

Alias SapFlow__D(6)=Beta_Outer__D

Alias SapFlow__D(7)=Beta_Inner__D

Alias SapFlow__D(8)=Tmax_Outer__D : Units Tmax_Outer__D=secs

Alias SapFlow__D(9)=Tmax_Inner__D : Units Tmax_Inner__D=secs

Public SapFlow__E(9)

Alias SapFlow__E(1)=TotalSapFlow__E : Units TotalSapFlow__E=L/hr

Alias SapFlow__E(2)=Vh_Outer__E : Units Vh_Outer__E=cm/hr

Alias SapFlow__E(3)=Vh_Inner__E : Units Vh_Inner__E=cm/hr

Alias SapFlow__E(4)=Alpha_Outer__E

Alias SapFlow__E(5)=Alpha_Inner__E

Alias SapFlow__E(6)=Beta_Outer__E

Alias SapFlow__E(7)=Beta_Inner__E

Alias SapFlow__E(8)=Tmax_Outer__E : Units Tmax_Outer__E=secs

Alias SapFlow__E(9)=Tmax_Inner__E : Units Tmax_Inner__E=secs

Public SapFlow__F(9)

Alias SapFlow__F(1)=TotalSapFlow__F : Units TotalSapFlow__F=L/hr

Alias SapFlow__F(2)=Vh_Outer__F : Units Vh_Outer__F=cm/hr

Alias SapFlow__F(3)=Vh_Inner__F : Units Vh_Inner__F=cm/hr

Alias SapFlow__F(4)=Alpha_Outer__F

Alias SapFlow__F(5)=Alpha_Inner__F

Alias SapFlow__F(6)=Beta_Outer__F

Alias SapFlow__F(7)=Beta_Inner__F

Alias SapFlow__F(8)=Tmax_Outer__F : Units Tmax_Outer__F=secs

Alias SapFlow__F(9)=Tmax_Inner__F : Units Tmax_Inner__F=secs

Public SapFlow__G(9)

Alias SapFlow__G(1)=TotalSapFlow__G : Units TotalSapFlow__G=L/hr

Alias SapFlow__G(2)=Vh_Outer__G : Units Vh_Outer__G=cm/hr

Alias SapFlow__G(3)=Vh_Inner__G : Units Vh_Inner__G=cm/hr

Alias SapFlow__G(4)=Alpha_Outer__G

Alias SapFlow__G(5)=Alpha_Inner__G

Alias SapFlow__G(6)=Beta_Outer__G

Alias SapFlow__G(7)=Beta_Inner__G

Alias SapFlow__G(8)=Tmax_Outer__G : Units Tmax_Outer__G=secs

Alias SapFlow__G(9)=Tmax_Inner__G : Units Tmax_Inner__G=secs

Public SapFlow__H(9)

Alias SapFlow__H(1)=TotalSapFlow__H : Units TotalSapFlow__H=L/hr

Alias SapFlow__H(2)=Vh_Outer__H : Units Vh_Outer__H=cm/hr

Alias SapFlow__H(3)=Vh_Inner__H : Units Vh_Inner__H=cm/hr

Alias SapFlow__H(4)=Alpha_Outer__H

Alias SapFlow__H(5)=Alpha_Inner__H

Alias SapFlow__H(6)=Beta_Outer__H

Alias SapFlow__H(7)=Beta_Inner__H

Alias SapFlow__H(8)=Tmax_Outer__H : Units Tmax_Outer__H=secs

Alias SapFlow__H(9)=Tmax_Inner__H : Units Tmax_Inner__H=secs

Dim d_SapFlow(9) 'This variable is required for correct timing of M! or C! command measurements

Dim D__SapFlow(9) 'This variable is required for correct timing of M! or C! command measurements

'===== STEM TEMPERATURE VARIABLES =====

'C1! Command - Outer thermistor measurements

'C2! Command - Inner thermistor measurements

Public Stem_Temp_Outer_a(6)



'Public Stem_Temp_Inner_a(6)

'Alias Stem_Temp_Outer_a(1) = Pre_Temp_Down_Outer_a : Units
Pre_Temp_Down_Outer_a=deg_C

'Alias Stem_Temp_Outer_a(2) = Max_Temp_Down_Outer_a : Units
Max_Temp_Down_Outer_a=deg_C

'Alias Stem_Temp_Outer_a(3) = Post_Temp_Down_Outer_a : Units
Post_Temp_Down_Outer_a=deg_C

'Alias Stem_Temp_Outer_a(4) = Pre_Temp_Upper_Outer_a : Units
Pre_Temp_Upper_Outer_a=deg_C

'Alias Stem_Temp_Outer_a(5) = Max_Temp_Upper_Outer_a : Units
Max_Temp_Upper_Outer_a=deg_C

'Alias Stem_Temp_Outer_a(6) = Post_Temp_Upper_Outer_a : Units
Post_Temp_Upper_Outer_a=deg_C

'Alias Stem_Temp_Inner_a(1) = Pre_Temp_Down_Inner_a : Units Pre_Temp_Down_Inner_a=deg_C

'Alias Stem_Temp_Inner_a(2) = Max_Temp_Down_Inner_a : Units
Max_Temp_Down_Inner_a=deg_C

'Alias Stem_Temp_Inner_a(3) = Post_Temp_Down_Inner_a : Units
Post_Temp_Down_Inner_a=deg_C

'Alias Stem_Temp_Inner_a(4) = Pre_Temp_Upper_Inner_a : Units
Pre_Temp_Upper_Inner_a=deg_C

'Alias Stem_Temp_Inner_a(5) = Max_Temp_Upper_Inner_a : Units
Max_Temp_Upper_Inner_a=deg_C

'Alias Stem_Temp_Inner_a(6) = Post_Temp_Upper_Inner_a : Units
Post_Temp_Upper_Inner_a=deg_C

Public Stem_Temp_Outer_b(6)

'Public Stem_Temp_Inner_b(6)

'Alias Stem_Temp_Outer_b(1) = Pre_Temp_Down_Outer_b : Units
Pre_Temp_Down_Outer_b=deg_C

'Alias Stem_Temp_Outer_b(2) = Max_Temp_Down_Outer_b : Units
Max_Temp_Down_Outer_b=deg_C

'Alias Stem_Temp_Outer_b(3) = Post_Temp_Down_Outer_b : Units
Post_Temp_Down_Outer_b=deg_C

'Alias Stem_Temp_Outer_b(4) = Pre_Temp_Upper_Outer_b : Units
Pre_Temp_Upper_Outer_b=deg_C



'Alias Stem_Temp_Outer_b(5) = Max_Temp_Upper_Outer_b : Units
Max_Temp_Upper_Outer_b=deg_C

'Alias Stem_Temp_Outer_b(6) = Post_Temp_Upper_Outer_b : Units
Post_Temp_Upper_Outer_b=deg_C

'Alias Stem_Temp_Inner_b(1) = Pre_Temp_Down_Inner_b : Units Pre_Temp_Down_Inner_b=deg_C

'Alias Stem_Temp_Inner_b(2) = Max_Temp_Down_Inner_b : Units
Max_Temp_Down_Inner_b=deg_C

'Alias Stem_Temp_Inner_b(3) = Post_Temp_Down_Inner_b : Units
Post_Temp_Down_Inner_b=deg_C

'Alias Stem_Temp_Inner_b(4) = Pre_Temp_Upper_Inner_b : Units
Pre_Temp_Upper_Inner_b=deg_C

'Alias Stem_Temp_Inner_b(5) = Max_Temp_Upper_Inner_b : Units
Max_Temp_Upper_Inner_b=deg_C

'Alias Stem_Temp_Inner_b(6) = Post_Temp_Upper_Inner_b : Units
Post_Temp_Upper_Inner_b=deg_C

Public Stem_Temp_Outer_c(6)

'Public Stem_Temp_Inner_c(6)

'Alias Stem_Temp_Outer_c(1) = Pre_Temp_Down_Outer_c : Units
Pre_Temp_Down_Outer_c=deg_C

'Alias Stem_Temp_Outer_c(2) = Max_Temp_Down_Outer_c : Units
Max_Temp_Down_Outer_c=deg_C

'Alias Stem_Temp_Outer_c(3) = Post_Temp_Down_Outer_c : Units
Post_Temp_Down_Outer_c=deg_C

'Alias Stem_Temp_Outer_c(4) = Pre_Temp_Upper_Outer_c : Units
Pre_Temp_Upper_Outer_c=deg_C

'Alias Stem_Temp_Outer_c(5) = Max_Temp_Upper_Outer_c : Units
Max_Temp_Upper_Outer_c=deg_C

'Alias Stem_Temp_Outer_c(6) = Post_Temp_Upper_Outer_c : Units
Post_Temp_Upper_Outer_c=deg_C

'Alias Stem_Temp_Inner_c(1) = Pre_Temp_Down_Inner_c : Units Pre_Temp_Down_Inner_c=deg_C

'Alias Stem_Temp_Inner_c(2) = Max_Temp_Down_Inner_c : Units
Max_Temp_Down_Inner_c=deg_C

'Alias Stem_Temp_Inner_c(3) = Post_Temp_Down_Inner_c : Units
Post_Temp_Down_Inner_c=deg_C



'Alias Stem_Temp_Inner_c(4) = Pre_Temp_Upper_Inner_c : Units Pre_Temp_Upper_Inner_c=deg_C

'Alias Stem_Temp_Inner_c(5) = Max_Temp_Upper_Inner_c : Units
Max_Temp_Upper_Inner_c=deg_C

'Alias Stem_Temp_Inner_c(6) = Post_Temp_Upper_Inner_c : Units
Post_Temp_Upper_Inner_c=deg_C

Public Stem_Temp_Outer_d(6)

'Public Stem_Temp_Inner_d(6)

'Alias Stem_Temp_Outer_d(1) = Pre_Temp_Down_Outer_d : Units
Pre_Temp_Down_Outer_d=deg_C

'Alias Stem_Temp_Outer_d(2) = Max_Temp_Down_Outer_d : Units
Max_Temp_Down_Outer_d=deg_C

'Alias Stem_Temp_Outer_d(3) = Post_Temp_Down_Outer_d : Units
Post_Temp_Down_Outer_d=deg_C

'Alias Stem_Temp_Outer_d(4) = Pre_Temp_Upper_Outer_d : Units
Pre_Temp_Upper_Outer_d=deg_C

'Alias Stem_Temp_Outer_d(5) = Max_Temp_Upper_Outer_d : Units
Max_Temp_Upper_Outer_d=deg_C

'Alias Stem_Temp_Outer_d(6) = Post_Temp_Upper_Outer_d : Units
Post_Temp_Upper_Outer_d=deg_C

'Alias Stem_Temp_Inner_d(1) = Pre_Temp_Down_Inner_d : Units Pre_Temp_Down_Inner_d=deg_C

'Alias Stem_Temp_Inner_d(2) = Max_Temp_Down_Inner_d : Units
Max_Temp_Down_Inner_d=deg_C

'Alias Stem_Temp_Inner_d(3) = Post_Temp_Down_Inner_d : Units
Post_Temp_Down_Inner_d=deg_C

'Alias Stem_Temp_Inner_d(4) = Pre_Temp_Upper_Inner_d : Units
Pre_Temp_Upper_Inner_d=deg_C

'Alias Stem_Temp_Inner_d(5) = Max_Temp_Upper_Inner_d : Units
Max_Temp_Upper_Inner_d=deg_C

'Alias Stem_Temp_Inner_d(6) = Post_Temp_Upper_Inner_d : Units
Post_Temp_Upper_Inner_d=deg_C

Public Stem_Temp_Outer_e(6)

'Public Stem_Temp_Inner_e(6)

'Alias Stem_Temp_Outer_e(1) = Pre_Temp_Down_Outer_e : Units
Pre_Temp_Down_Outer_e=deg_C

'Alias Stem_Temp_Outer_e(2) = Max_Temp_Down_Outer_e : Units
Max_Temp_Down_Outer_e=deg_C

'Alias Stem_Temp_Outer_e(3) = Post_Temp_Down_Outer_e : Units
Post_Temp_Down_Outer_e=deg_C

'Alias Stem_Temp_Outer_e(4) = Pre_Temp_Upper_Outer_e : Units
Pre_Temp_Upper_Outer_e=deg_C

'Alias Stem_Temp_Outer_e(5) = Max_Temp_Upper_Outer_e : Units
Max_Temp_Upper_Outer_e=deg_C

'Alias Stem_Temp_Outer_e(6) = Post_Temp_Upper_Outer_e : Units
Post_Temp_Upper_Outer_e=deg_C

'Alias Stem_Temp_Inner_e(1) = Pre_Temp_Down_Inner_e : Units Pre_Temp_Down_Inner_e=deg_C

'Alias Stem_Temp_Inner_e(2) = Max_Temp_Down_Inner_e : Units
Max_Temp_Down_Inner_e=deg_C

'Alias Stem_Temp_Inner_e(3) = Post_Temp_Down_Inner_e : Units
Post_Temp_Down_Inner_e=deg_C

'Alias Stem_Temp_Inner_e(4) = Pre_Temp_Upper_Inner_e : Units
Pre_Temp_Upper_Inner_e=deg_C

'Alias Stem_Temp_Inner_e(5) = Max_Temp_Upper_Inner_e : Units
Max_Temp_Upper_Inner_e=deg_C

'Alias Stem_Temp_Inner_e(6) = Post_Temp_Upper_Inner_e : Units
Post_Temp_Upper_Inner_e=deg_C

Public Stem_Temp_Outer_f(6)

'Public Stem_Temp_Inner_f(6)

'Alias Stem_Temp_Outer_f(1) = Pre_Temp_Down_Outer_f : Units Pre_Temp_Down_Outer_f=deg_C

'Alias Stem_Temp_Outer_f(2) = Max_Temp_Down_Outer_f : Units
Max_Temp_Down_Outer_f=deg_C

'Alias Stem_Temp_Outer_f(3) = Post_Temp_Down_Outer_f : Units
Post_Temp_Down_Outer_f=deg_C

'Alias Stem_Temp_Outer_f(4) = Pre_Temp_Upper_Outer_f : Units
Pre_Temp_Upper_Outer_f=deg_C

'Alias Stem_Temp_Outer_f(5) = Max_Temp_Upper_Outer_f : Units
Max_Temp_Upper_Outer_f=deg_C



'Alias Stem_Temp_Outer_f(6) = Post_Temp_Upper_Outer_f : Units
Post_Temp_Upper_Outer_f=deg_C

'Alias Stem_Temp_Inner_f(1) = Pre_Temp_Down_Inner_f : Units Pre_Temp_Down_Inner_f=deg_C

'Alias Stem_Temp_Inner_f(2) = Max_Temp_Down_Inner_f : Units
Max_Temp_Down_Inner_f=deg_C

'Alias Stem_Temp_Inner_f(3) = Post_Temp_Down_Inner_f : Units
Post_Temp_Down_Inner_f=deg_C

'Alias Stem_Temp_Inner_f(4) = Pre_Temp_Upper_Inner_f : Units Pre_Temp_Upper_Inner_f=deg_C

'Alias Stem_Temp_Inner_f(5) = Max_Temp_Upper_Inner_f : Units
Max_Temp_Upper_Inner_f=deg_C

'Alias Stem_Temp_Inner_f(6) = Post_Temp_Upper_Inner_f : Units
Post_Temp_Upper_Inner_f=deg_C

Public Stem_Temp_Outer_g(6)

'Public Stem_Temp_Inner_g(6)

'Alias Stem_Temp_Outer_g(1) = Pre_Temp_Down_Outer_g : Units
Pre_Temp_Down_Outer_g=deg_C

'Alias Stem_Temp_Outer_g(2) = Max_Temp_Down_Outer_g : Units
Max_Temp_Down_Outer_g=deg_C

'Alias Stem_Temp_Outer_g(3) = Post_Temp_Down_Outer_g : Units
Post_Temp_Down_Outer_g=deg_C

'Alias Stem_Temp_Outer_g(4) = Pre_Temp_Upper_Outer_g : Units
Pre_Temp_Upper_Outer_g=deg_C

'Alias Stem_Temp_Outer_g(5) = Max_Temp_Upper_Outer_g : Units
Max_Temp_Upper_Outer_g=deg_C

'Alias Stem_Temp_Outer_g(6) = Post_Temp_Upper_Outer_g : Units
Post_Temp_Upper_Outer_g=deg_C

'Alias Stem_Temp_Inner_g(1) = Pre_Temp_Down_Inner_g : Units Pre_Temp_Down_Inner_g=deg_C

'Alias Stem_Temp_Inner_g(2) = Max_Temp_Down_Inner_g : Units
Max_Temp_Down_Inner_g=deg_C

'Alias Stem_Temp_Inner_g(3) = Post_Temp_Down_Inner_g : Units
Post_Temp_Down_Inner_g=deg_C

'Alias Stem_Temp_Inner_g(4) = Pre_Temp_Upper_Inner_g : Units
Pre_Temp_Upper_Inner_g=deg_C

'Alias Stem_Temp_Inner_g(5) = Max_Temp_Upper_Inner_g : Units
Max_Temp_Upper_Inner_g=deg_C

'Alias Stem_Temp_Inner_g(6) = Post_Temp_Upper_Inner_g : Units
Post_Temp_Upper_Inner_g=deg_C

Public Stem_Temp_Outer_h(6)

'Public Stem_Temp_Inner_h(6)

'Alias Stem_Temp_Outer_h(1) = Pre_Temp_Down_Outer_h : Units
Pre_Temp_Down_Outer_h=deg_C

'Alias Stem_Temp_Outer_h(2) = Max_Temp_Down_Outer_h : Units
Max_Temp_Down_Outer_h=deg_C

'Alias Stem_Temp_Outer_h(3) = Post_Temp_Down_Outer_h : Units
Post_Temp_Down_Outer_h=deg_C

'Alias Stem_Temp_Outer_h(4) = Pre_Temp_Upper_Outer_h : Units
Pre_Temp_Upper_Outer_h=deg_C

'Alias Stem_Temp_Outer_h(5) = Max_Temp_Upper_Outer_h : Units
Max_Temp_Upper_Outer_h=deg_C

'Alias Stem_Temp_Outer_h(6) = Post_Temp_Upper_Outer_h : Units
Post_Temp_Upper_Outer_h=deg_C

'Alias Stem_Temp_Inner_h(1) = Pre_Temp_Down_Inner_h : Units Pre_Temp_Down_Inner_h=deg_C

'Alias Stem_Temp_Inner_h(2) = Max_Temp_Down_Inner_h : Units
Max_Temp_Down_Inner_h=deg_C

'Alias Stem_Temp_Inner_h(3) = Post_Temp_Down_Inner_h : Units
Post_Temp_Down_Inner_h=deg_C

'Alias Stem_Temp_Inner_h(4) = Pre_Temp_Upper_Inner_h : Units
Pre_Temp_Upper_Inner_h=deg_C

'Alias Stem_Temp_Inner_h(5) = Max_Temp_Upper_Inner_h : Units
Max_Temp_Upper_Inner_h=deg_C

'Alias Stem_Temp_Inner_h(6) = Post_Temp_Upper_Inner_h : Units
Post_Temp_Upper_Inner_h=deg_C

Public Stem_Temp_Outer__A(6)

'Public Stem_Temp_Inner__A(6)

'Alias Stem_Temp_Outer__A(1) = Pre_Temp_Down_Outer__A : Units
Pre_Temp_Down_Outer__A=deg_C



'Alias Stem_Temp_Outer__A(2) = Max_Temp_Down_Outer__A : Units
Max_Temp_Down_Outer__A=deg_C

'Alias Stem_Temp_Outer__A(3) = Post_Temp_Down_Outer__A : Units
Post_Temp_Down_Outer__A=deg_C

'Alias Stem_Temp_Outer__A(4) = Pre_Temp_Upper_Outer__A : Units
Pre_Temp_Upper_Outer__A=deg_C

'Alias Stem_Temp_Outer__A(5) = Max_Temp_Upper_Outer__A : Units
Max_Temp_Upper_Outer__A=deg_C

'Alias Stem_Temp_Outer__A(6) = Post_Temp_Upper_Outer__A : Units
Post_Temp_Upper_Outer__A=deg_C

'Alias Stem_Temp_Inner__A(1) = Pre_Temp_Down_Inner__A : Units
Pre_Temp_Down_Inner__A=deg_C

'Alias Stem_Temp_Inner__A(2) = Max_Temp_Down_Inner__A : Units
Max_Temp_Down_Inner__A=deg_C

'Alias Stem_Temp_Inner__A(3) = Post_Temp_Down_Inner__A : Units
Post_Temp_Down_Inner__A=deg_C

'Alias Stem_Temp_Inner__A(4) = Pre_Temp_Upper_Inner__A : Units
Pre_Temp_Upper_Inner__A=deg_C

'Alias Stem_Temp_Inner__A(5) = Max_Temp_Upper_Inner__A : Units
Max_Temp_Upper_Inner__A=deg_C

'Alias Stem_Temp_Inner__A(6) = Post_Temp_Upper_Inner__A : Units
Post_Temp_Upper_Inner__A=deg_C

Public Stem_Temp_Outer__B(6)

'Public Stem_Temp_Inner__B(6)

'Alias Stem_Temp_Outer__B(1) = Pre_Temp_Down_Outer__B : Units
Pre_Temp_Down_Outer__B=deg_C

'Alias Stem_Temp_Outer__B(2) = Max_Temp_Down_Outer__B : Units
Max_Temp_Down_Outer__B=deg_C

'Alias Stem_Temp_Outer__B(3) = Post_Temp_Down_Outer__B : Units
Post_Temp_Down_Outer__B=deg_C

'Alias Stem_Temp_Outer__B(4) = Pre_Temp_Upper_Outer__B : Units
Pre_Temp_Upper_Outer__B=deg_C

'Alias Stem_Temp_Outer__B(5) = Max_Temp_Upper_Outer__B : Units
Max_Temp_Upper_Outer__B=deg_C



'Alias Stem_Temp_Outer__B(6) = Post_Temp_Upper_Outer__B : Units
Post_Temp_Upper_Outer__B=deg_C

'Alias Stem_Temp_Inner__B(1) = Pre_Temp_Down_Inner__B : Units
Pre_Temp_Down_Inner__B=deg_C

'Alias Stem_Temp_Inner__B(2) = Max_Temp_Down_Inner__B : Units
Max_Temp_Down_Inner__B=deg_C

'Alias Stem_Temp_Inner__B(3) = Post_Temp_Down_Inner__B : Units
Post_Temp_Down_Inner__B=deg_C

'Alias Stem_Temp_Inner__B(4) = Pre_Temp_Upper_Inner__B : Units
Pre_Temp_Upper_Inner__B=deg_C

'Alias Stem_Temp_Inner__B(5) = Max_Temp_Upper_Inner__B : Units
Max_Temp_Upper_Inner__B=deg_C

'Alias Stem_Temp_Inner__B(6) = Post_Temp_Upper_Inner__B : Units
Post_Temp_Upper_Inner__B=deg_C

Public Stem_Temp_Outer__C(6)

'Public Stem_Temp_Inner__C(6)

'Alias Stem_Temp_Outer__C(1) = Pre_Temp_Down_Outer__C : Units
Pre_Temp_Down_Outer__C=deg_C

'Alias Stem_Temp_Outer__C(2) = Max_Temp_Down_Outer__C : Units
Max_Temp_Down_Outer__C=deg_C

'Alias Stem_Temp_Outer__C(3) = Post_Temp_Down_Outer__C : Units
Post_Temp_Down_Outer__C=deg_C

'Alias Stem_Temp_Outer__C(4) = Pre_Temp_Upper_Outer__C : Units
Pre_Temp_Upper_Outer__C=deg_C

'Alias Stem_Temp_Outer__C(5) = Max_Temp_Upper_Outer__C : Units
Max_Temp_Upper_Outer__C=deg_C

'Alias Stem_Temp_Outer__C(6) = Post_Temp_Upper_Outer__C : Units
Post_Temp_Upper_Outer__C=deg_C

'Alias Stem_Temp_Inner__C(1) = Pre_Temp_Down_Inner__C : Units
Pre_Temp_Down_Inner__C=deg_C

'Alias Stem_Temp_Inner__C(2) = Max_Temp_Down_Inner__C : Units
Max_Temp_Down_Inner__C=deg_C

'Alias Stem_Temp_Inner__C(3) = Post_Temp_Down_Inner__C : Units
Post_Temp_Down_Inner__C=deg_C



'Alias Stem_Temp_Inner__C(4) = Pre_Temp_Upper_Inner__C : Units
Pre_Temp_Upper_Inner__C=deg_C

'Alias Stem_Temp_Inner__C(5) = Max_Temp_Upper_Inner__C : Units
Max_Temp_Upper_Inner__C=deg_C

'Alias Stem_Temp_Inner__C(6) = Post_Temp_Upper_Inner__C : Units
Post_Temp_Upper_Inner__C=deg_C

Public Stem_Temp_Outer__D(6)

'Public Stem_Temp_Inner__D(6)

'Alias Stem_Temp_Outer__D(1) = Pre_Temp_Down_Outer__D : Units
Pre_Temp_Down_Outer__D=deg_C

'Alias Stem_Temp_Outer__D(2) = Max_Temp_Down_Outer__D : Units
Max_Temp_Down_Outer__D=deg_C

'Alias Stem_Temp_Outer__D(3) = Post_Temp_Down_Outer__D : Units
Post_Temp_Down_Outer__D=deg_C

'Alias Stem_Temp_Outer__D(4) = Pre_Temp_Upper_Outer__D : Units
Pre_Temp_Upper_Outer__D=deg_C

'Alias Stem_Temp_Outer__D(5) = Max_Temp_Upper_Outer__D : Units
Max_Temp_Upper_Outer__D=deg_C

'Alias Stem_Temp_Outer__D(6) = Post_Temp_Upper_Outer__D : Units
Post_Temp_Upper_Outer__D=deg_C

'Alias Stem_Temp_Inner__D(1) = Pre_Temp_Down_Inner__D : Units
Pre_Temp_Down_Inner__D=deg_C

'Alias Stem_Temp_Inner__D(2) = Max_Temp_Down_Inner__D : Units
Max_Temp_Down_Inner__D=deg_C

'Alias Stem_Temp_Inner__D(3) = Post_Temp_Down_Inner__D : Units
Post_Temp_Down_Inner__D=deg_C

'Alias Stem_Temp_Inner__D(4) = Pre_Temp_Upper_Inner__D : Units
Pre_Temp_Upper_Inner__D=deg_C

'Alias Stem_Temp_Inner__D(5) = Max_Temp_Upper_Inner__D : Units
Max_Temp_Upper_Inner__D=deg_C

'Alias Stem_Temp_Inner__D(6) = Post_Temp_Upper_Inner__D : Units
Post_Temp_Upper_Inner__D=deg_C

Public Stem_Temp_Outer__E(6)



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'Public Stem_Temp_Inner__E(6)

'Alias Stem_Temp_Outer__E(1) = Pre_Temp_Down_Outer__E : Units
Pre_Temp_Down_Outer__E=deg_C

'Alias Stem_Temp_Outer__E(2) = Max_Temp_Down_Outer__E : Units
Max_Temp_Down_Outer__E=deg_C

'Alias Stem_Temp_Outer__E(3) = Post_Temp_Down_Outer__E : Units
Post_Temp_Down_Outer__E=deg_C

'Alias Stem_Temp_Outer__E(4) = Pre_Temp_Upper_Outer__E : Units
Pre_Temp_Upper_Outer__E=deg_C

'Alias Stem_Temp_Outer__E(5) = Max_Temp_Upper_Outer__E : Units
Max_Temp_Upper_Outer__E=deg_C

'Alias Stem_Temp_Outer__E(6) = Post_Temp_Upper_Outer__E : Units
Post_Temp_Upper_Outer__E=deg_C

'Alias Stem_Temp_Inner__E(1) = Pre_Temp_Down_Inner__E : Units
Pre_Temp_Down_Inner__E=deg_C

'Alias Stem_Temp_Inner__E(2) = Max_Temp_Down_Inner__E : Units
Max_Temp_Down_Inner__E=deg_C

'Alias Stem_Temp_Inner__E(3) = Post_Temp_Down_Inner__E : Units
Post_Temp_Down_Inner__E=deg_C

'Alias Stem_Temp_Inner__E(4) = Pre_Temp_Upper_Inner__E : Units
Pre_Temp_Upper_Inner__E=deg_C

'Alias Stem_Temp_Inner__E(5) = Max_Temp_Upper_Inner__E : Units
Max_Temp_Upper_Inner__E=deg_C

'Alias Stem_Temp_Inner__E(6) = Post_Temp_Upper_Inner__E : Units
Post_Temp_Upper_Inner__E=deg_C

Public Stem_Temp_Outer__F(6)

'Public Stem_Temp_Inner__F(6)

'Alias Stem_Temp_Outer__F(1) = Pre_Temp_Down_Outer__F : Units
Pre_Temp_Down_Outer__F=deg_C

'Alias Stem_Temp_Outer__F(2) = Max_Temp_Down_Outer__F : Units
Max_Temp_Down_Outer__F=deg_C

'Alias Stem_Temp_Outer__F(3) = Post_Temp_Down_Outer__F : Units
Post_Temp_Down_Outer__F=deg_C

'Alias Stem_Temp_Outer__F(4) = Pre_Temp_Upper_Outer__F : Units
Pre_Temp_Upper_Outer__F=deg_C



'Alias Stem_Temp_Outer__F(5) = Max_Temp_Upper_Outer__F : Units
Max_Temp_Upper_Outer__F=deg_C

'Alias Stem_Temp_Outer__F(6) = Post_Temp_Upper_Outer__F : Units
Post_Temp_Upper_Outer__F=deg_C

'Alias Stem_Temp_Inner__F(1) = Pre_Temp_Down_Inner__F : Units
Pre_Temp_Down_Inner__F=deg_C

'Alias Stem_Temp_Inner__F(2) = Max_Temp_Down_Inner__F : Units
Max_Temp_Down_Inner__F=deg_C

'Alias Stem_Temp_Inner__F(3) = Post_Temp_Down_Inner__F : Units
Post_Temp_Down_Inner__F=deg_C

'Alias Stem_Temp_Inner__F(4) = Pre_Temp_Upper_Inner__F : Units
Pre_Temp_Upper_Inner__F=deg_C

'Alias Stem_Temp_Inner__F(5) = Max_Temp_Upper_Inner__F : Units
Max_Temp_Upper_Inner__F=deg_C

'Alias Stem_Temp_Inner__F(6) = Post_Temp_Upper_Inner__F : Units
Post_Temp_Upper_Inner__F=deg_C

Public Stem_Temp_Outer__G(6)

'Public Stem_Temp_Inner__G(6)

'Alias Stem_Temp_Outer__G(1) = Pre_Temp_Down_Outer__G : Units
Pre_Temp_Down_Outer__G=deg_C

'Alias Stem_Temp_Outer__G(2) = Max_Temp_Down_Outer__G : Units
Max_Temp_Down_Outer__G=deg_C

'Alias Stem_Temp_Outer__G(3) = Post_Temp_Down_Outer__G : Units
Post_Temp_Down_Outer__G=deg_C

'Alias Stem_Temp_Outer__G(4) = Pre_Temp_Upper_Outer__G : Units
Pre_Temp_Upper_Outer__G=deg_C

'Alias Stem_Temp_Outer__G(5) = Max_Temp_Upper_Outer__G : Units
Max_Temp_Upper_Outer__G=deg_C

'Alias Stem_Temp_Outer__G(6) = Post_Temp_Upper_Outer__G : Units
Post_Temp_Upper_Outer__G=deg_C

'Alias Stem_Temp_Inner__G(1) = Pre_Temp_Down_Inner__G : Units
Pre_Temp_Down_Inner__G=deg_C

'Alias Stem_Temp_Inner__G(2) = Max_Temp_Down_Inner__G : Units
Max_Temp_Down_Inner__G=deg_C



'Alias Stem_Temp_Inner__G(3) = Post_Temp_Down_Inner__G : Units
Post_Temp_Down_Inner__G=deg_C

'Alias Stem_Temp_Inner__G(4) = Pre_Temp_Upper_Inner__G : Units
Pre_Temp_Upper_Inner__G=deg_C

'Alias Stem_Temp_Inner__G(5) = Max_Temp_Upper_Inner__G : Units
Max_Temp_Upper_Inner__G=deg_C

'Alias Stem_Temp_Inner__G(6) = Post_Temp_Upper_Inner__G : Units
Post_Temp_Upper_Inner__G=deg_C

Public Stem_Temp_Outer__H(6)

'Public Stem_Temp_Inner__H(6)

'Alias Stem_Temp_Outer__H(1) = Pre_Temp_Down_Outer__H : Units
Pre_Temp_Down_Outer__H=deg_C

'Alias Stem_Temp_Outer__H(2) = Max_Temp_Down_Outer__H : Units
Max_Temp_Down_Outer__H=deg_C

'Alias Stem_Temp_Outer__H(3) = Post_Temp_Down_Outer__H : Units
Post_Temp_Down_Outer__H=deg_C

'Alias Stem_Temp_Outer__H(4) = Pre_Temp_Upper_Outer__H : Units
Pre_Temp_Upper_Outer__H=deg_C

'Alias Stem_Temp_Outer__H(5) = Max_Temp_Upper_Outer__H : Units
Max_Temp_Upper_Outer__H=deg_C

'Alias Stem_Temp_Outer__H(6) = Post_Temp_Upper_Outer__H : Units
Post_Temp_Upper_Outer__H=deg_C

'Alias Stem_Temp_Inner__H(1) = Pre_Temp_Down_Inner__H : Units
Pre_Temp_Down_Inner__H=deg_C

'Alias Stem_Temp_Inner__H(2) = Max_Temp_Down_Inner__H : Units
Max_Temp_Down_Inner__H=deg_C

'Alias Stem_Temp_Inner__H(3) = Post_Temp_Down_Inner__H : Units
Post_Temp_Down_Inner__H=deg_C

'Alias Stem_Temp_Inner__H(4) = Pre_Temp_Upper_Inner__H : Units
Pre_Temp_Upper_Inner__H=deg_C

'Alias Stem_Temp_Inner__H(5) = Max_Temp_Upper_Inner__H : Units
Max_Temp_Upper_Inner__H=deg_C

'Alias Stem_Temp_Inner__H(6) = Post_Temp_Upper_Inner__H : Units
Post_Temp_Upper_Inner__H=deg_C



'===== STEM WATER CONTENT VARIABLE ====='

'C3! Command

Public Stem_Water_a(6)

Alias Stem_Water_a(1) = SWC_Outer_a : Units SWC_Outer_a=%

Alias Stem_Water_a(2) = SWC_Inner_a : Units SWC_Inner_a=%

Alias Stem_Water_a(3) = Heat_Capacity_Outer_a : Units Heat_Capacity_Outer_a=kJ/m³

Alias Stem_Water_a(4) = Heat_Capacity_Inner_a : Units Heat_Capacity_Inner_a=kJ/m³

Alias Stem_Water_a(5) = Pulse_Energy_a : Units Pulse_Energy_a=J/m

Alias Stem_Water_a(6) = Pulse_Duration_a : Units Pulse_Duration_a=sec

Public Stem_Water_b(6)

Alias Stem_Water_b(1) = SWC_Outer_b : Units SWC_Outer_b=%

Alias Stem_Water_b(2) = SWC_Inner_b : Units SWC_Inner_b=%

Alias Stem_Water_b(3) = Heat_Capacity_Outer_b : Units Heat_Capacity_Outer_b=kJ/m³

Alias Stem_Water_b(4) = Heat_Capacity_Inner_b : Units Heat_Capacity_Inner_b=kJ/m³

Alias Stem_Water_b(5) = Pulse_Energy_b : Units Pulse_Energy_b=J/m

Alias Stem_Water_b(6) = Pulse_Duration_b : Units Pulse_Duration_b=sec

Public Stem_Water_c(6)

Alias Stem_Water_c(1) = SWC_Outer_c : Units SWC_Outer_c=%

Alias Stem_Water_c(2) = SWC_Inner_c : Units SWC_Inner_c=%

Alias Stem_Water_c(3) = Heat_Capacity_Outer_c : Units Heat_Capacity_Outer_c=kJ/m³

Alias Stem_Water_c(4) = Heat_Capacity_Inner_c : Units Heat_Capacity_Inner_c=kJ/m³

Alias Stem_Water_c(5) = Pulse_Energy_c : Units Pulse_Energy_c=J/m

Alias Stem_Water_c(6) = Pulse_Duration_c : Units Pulse_Duration_c=sec

Public Stem_Water_d(6)

Alias Stem_Water_d(1) = SWC_Outer_d : Units SWC_Outer_d=%

Alias Stem_Water_d(2) = SWC_Inner_d : Units SWC_Inner_d=%

Alias Stem_Water_d(3) = Heat_Capacity_Outer_d : Units Heat_Capacity_Outer_d=kJ/m³

Alias Stem_Water_d(4) = Heat_Capacity_Inner_d : Units Heat_Capacity_Inner_d=kJ/m³

Alias Stem_Water_d(5) = Pulse_Energy_d : Units Pulse_Energy_d=J/m

Alias Stem_Water_d(6) = Pulse_Duration_d : Units Pulse_Duration_d=sec

Public Stem_Water_e(6)

Alias Stem_Water_e(1) = SWC_Outer_e : Units SWC_Outer_e=%

Alias Stem_Water_e(2) = SWC_Inner_e : Units SWC_Inner_e=%

Alias Stem_Water_e(3) = Heat_Capacity_Outer_e : Units Heat_Capacity_Outer_e=kJ/m³

Alias Stem_Water_e(4) = Heat_Capacity_Inner_e : Units Heat_Capacity_Inner_e=kJ/m³

Alias Stem_Water_e(5) = Pulse_Energy_e : Units Pulse_Energy_e=J/m

Alias Stem_Water_e(6) = Pulse_Duration_e : Units Pulse_Duration_e=sec

Public Stem_Water_f(6)

Alias Stem_Water_f(1) = SWC_Outer_f : Units SWC_Outer_f=%

Alias Stem_Water_f(2) = SWC_Inner_f : Units SWC_Inner_f=%

Alias Stem_Water_f(3) = Heat_Capacity_Outer_f : Units Heat_Capacity_Outer_f=kJ/m³

Alias Stem_Water_f(4) = Heat_Capacity_Inner_f : Units Heat_Capacity_Inner_f=kJ/m³

Alias Stem_Water_f(5) = Pulse_Energy_f : Units Pulse_Energy_f=J/m

Alias Stem_Water_f(6) = Pulse_Duration_f : Units Pulse_Duration_f=sec

Public Stem_Water_g(6)

Alias Stem_Water_g(1) = SWC_Outer_g : Units SWC_Outer_g=%

Alias Stem_Water_g(2) = SWC_Inner_g : Units SWC_Inner_g=%

Alias Stem_Water_g(3) = Heat_Capacity_Outer_g : Units Heat_Capacity_Outer_g=kJ/m³

Alias Stem_Water_g(4) = Heat_Capacity_Inner_g : Units Heat_Capacity_Inner_g=kJ/m³

Alias Stem_Water_g(5) = Pulse_Energy_g : Units Pulse_Energy_g=J/m

Alias Stem_Water_g(6) = Pulse_Duration_g : Units Pulse_Duration_g=sec

Public Stem_Water_h(6)



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Alias Stem_Water_h(1) = SWC_Outer_h : Units SWC_Outer_h=%

Alias Stem_Water_h(2) = SWC_Inner_h : Units SWC_Inner_h=%

Alias Stem_Water_h(3) = Heat_Capacity_Outer_h : Units Heat_Capacity_Outer_h=kJ/m³

Alias Stem_Water_h(4) = Heat_Capacity_Inner_h : Units Heat_Capacity_Inner_h=kJ/m³

Alias Stem_Water_h(5) = Pulse_Energy_h : Units Pulse_Energy_h=J/m

Alias Stem_Water_h(6) = Pulse_Duration_h : Units Pulse_Duration_h=sec

Public Stem_Water__A(6)

Alias Stem_Water__A(1) = SWC_Outer__A : Units SWC_Outer__A=%

Alias Stem_Water__A(2) = SWC_Inner__A : Units SWC_Inner__A=%

Alias Stem_Water__A(3) = Heat_Capacity_Outer__A : Units Heat_Capacity_Outer__A=kJ/m³

Alias Stem_Water__A(4) = Heat_Capacity_Inner__A : Units Heat_Capacity_Inner__A=kJ/m³

Alias Stem_Water__A(5) = Pulse_Energy__A : Units Pulse_Energy__A=J/m

Alias Stem_Water__A(6) = Pulse_Duration__A : Units Pulse_Duration__A=sec

Public Stem_Water__B(6)

Alias Stem_Water__B(1) = SWC_Outer__B : Units SWC_Outer__B=%

Alias Stem_Water__B(2) = SWC_Inner__B : Units SWC_Inner__B=%

Alias Stem_Water__B(3) = Heat_Capacity_Outer__B : Units Heat_Capacity_Outer__B=kJ/m³

Alias Stem_Water__B(4) = Heat_Capacity_Inner__B : Units Heat_Capacity_Inner__B=kJ/m³

Alias Stem_Water__B(5) = Pulse_Energy__B : Units Pulse_Energy__B=J/m

Alias Stem_Water__B(6) = Pulse_Duration__B : Units Pulse_Duration__B=sec

Public Stem_Water__C(6)

Alias Stem_Water__C(1) = SWC_Outer__C : Units SWC_Outer__C=%

Alias Stem_Water__C(2) = SWC_Inner__C : Units SWC_Inner__C=%

Alias Stem_Water__C(3) = Heat_Capacity_Outer__C : Units Heat_Capacity_Outer__C=kJ/m³

Alias Stem_Water__C(4) = Heat_Capacity_Inner__C : Units Heat_Capacity_Inner__C=kJ/m³

Alias Stem_Water__C(5) = Pulse_Energy__C : Units Pulse_Energy__C=J/m

Alias Stem_Water__C(6) = Pulse_Duration__C : Units Pulse_Duration__C=sec



Public Stem_Water__D(6)

Alias Stem_Water__D(1) = SWC_Outer__D : Units SWC_Outer__D=%

Alias Stem_Water__D(2) = SWC_Inner__D : Units SWC_Inner__D=%

Alias Stem_Water__D(3) = Heat_Capacity_Outer__D : Units Heat_Capacity_Outer__D=kJ/m³

Alias Stem_Water__D(4) = Heat_Capacity_Inner__D : Units Heat_Capacity_Inner__D=kJ/m³

Alias Stem_Water__D(5) = Pulse_Energy__D : Units Pulse_Energy__D=J/m

Alias Stem_Water__D(6) = Pulse_Duration__D : Units Pulse_Duration__D=sec

Public Stem_Water__E(6)

Alias Stem_Water__E(1) = SWC_Outer__E : Units SWC_Outer__E=%

Alias Stem_Water__E(2) = SWC_Inner__E : Units SWC_Inner__E=%

Alias Stem_Water__E(3) = Heat_Capacity_Outer__E : Units Heat_Capacity_Outer__E=kJ/m³

Alias Stem_Water__E(4) = Heat_Capacity_Inner__E : Units Heat_Capacity_Inner__E=kJ/m³

Alias Stem_Water__E(5) = Pulse_Energy__E : Units Pulse_Energy__E=J/m

Alias Stem_Water__E(6) = Pulse_Duration__E : Units Pulse_Duration__E=sec

Public Stem_Water__F(6)

Alias Stem_Water__F(1) = SWC_Outer__F : Units SWC_Outer__F=%

Alias Stem_Water__F(2) = SWC_Inner__F : Units SWC_Inner__F=%

Alias Stem_Water__F(3) = Heat_Capacity_Outer__F : Units Heat_Capacity_Outer__F=kJ/m³

Alias Stem_Water__F(4) = Heat_Capacity_Inner__F : Units Heat_Capacity_Inner__F=kJ/m³

Alias Stem_Water__F(5) = Pulse_Energy__F : Units Pulse_Energy__F=J/m

Alias Stem_Water__F(6) = Pulse_Duration__F : Units Pulse_Duration__F=sec

Public Stem_Water__G(6)

Alias Stem_Water__G(1) = SWC_Outer__G : Units SWC_Outer__G=%

Alias Stem_Water__G(2) = SWC_Inner__G : Units SWC_Inner__G=%

Alias Stem_Water__G(3) = Heat_Capacity_Outer__G : Units Heat_Capacity_Outer__G=kJ/m³

Alias Stem_Water__G(4) = Heat_Capacity_Inner__G : Units Heat_Capacity_Inner__G=kJ/m³

Alias Stem_Water__G(5) = Pulse_Energy__G : Units Pulse_Energy__G=J/m

Alias Stem_Water__G(6) = Pulse_Duration__G : Units Pulse_Duration__G=sec

Public Stem_Water__H(6)

Alias Stem_Water__H(1) = SWC_Outer__H : Units SWC_Outer__H=%

Alias Stem_Water__H(2) = SWC_Inner__H : Units SWC_Inner__H=%

Alias Stem_Water__H(3) = Heat_Capacity_Outer__H : Units Heat_Capacity_Outer__H=kJ/m^3

Alias Stem_Water__H(4) = Heat_Capacity_Inner__H : Units Heat_Capacity_Inner__H=kJ/m^3

Alias Stem_Water__H(5) = Pulse_Energy__H : Units Pulse_Energy__H=J/m

Alias Stem_Water__H(6) = Pulse_Duration__H : Units Pulse_Duration__H=sec

'===== DATA TABLES lower =====

DataTable (Sap_Flow_lower,1,-1)

DataInterval (0,MEAST_INTERVAL_MIN,Min,10)

Sample (1,Batt_volt(),FP2)

Sample (1,PTemp(),FP2)

Sample (9,SapFlow_a()),IEEE4)

Sample (9,SapFlow_b()),IEEE4)

Sample (9,SapFlow_c()),IEEE4)

Sample (9,SapFlow_d()),IEEE4)

Sample (9,SapFlow_e()),IEEE4)

Sample (9,SapFlow_f()),IEEE4)

Sample (9,SapFlow_g()),IEEE4)

Sample (9,SapFlow_h()),IEEE4)

EndTable

DataTable (Stem_Data_lower,1,-1)

DataInterval (0,MEAST_INTERVAL_MIN,Min,10)

Sample (1,Stem_Temp_Outer_a(1),IEEE4)



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'Sample (1,Pre_Temp_Down_Outer_a()),IEEE4)
Sample (6,Stem_Water_a()),IEEE4)
Sample (1,Stem_Temp_Outer_b(1),IEEE4)
'Sample (1,Pre_Temp_Down_Outer_b()),IEEE4)
Sample (6,Stem_Water_b()),IEEE4)
Sample (1,Stem_Temp_Outer_c(1),IEEE4)
'Sample (1,Pre_Temp_Down_Outer_c()),IEEE4)
Sample (6,Stem_Water_c()),IEEE4)
Sample (1,Stem_Temp_Outer_d(1),IEEE4)
'Sample (1,Pre_Temp_Down_Outer_d()),IEEE4)
Sample (6,Stem_Water_d()),IEEE4)
Sample (1,Stem_Temp_Outer_e(1),IEEE4)
'Sample (1,Pre_Temp_Down_Outer_e()),IEEE4)
Sample (6,Stem_Water_e()),IEEE4)
Sample (1,Stem_Temp_Outer_f(1),IEEE4)
'Sample (1,Pre_Temp_Down_Outer_f()),IEEE4)
Sample (6,Stem_Water_f()),IEEE4)
Sample (1,Stem_Temp_Outer_g(1),IEEE4)
'Sample (1,Pre_Temp_Down_Outer_g()),IEEE4)
Sample (6,Stem_Water_g()),IEEE4)
Sample (1,Stem_Temp_Outer_h(1),IEEE4)
'Sample (1,Pre_Temp_Down_Outer_h()),IEEE4)
Sample (6,Stem_Water_h()),IEEE4)
EndTable

'===== DATA TABLES UPPER =====

DataTable (Sap_Flow_UPPER,1,-1)
DataInterval (0,MEAST_INTERVAL_MIN,Min,10)
Sample (9,SapFlow__A()),IEEE4)



Sample (9,SapFlow__B()),IEEE4)

Sample (9,SapFlow__C()),IEEE4)

Sample (9,SapFlow__D()),IEEE4)

Sample (9,SapFlow__E()),IEEE4)

Sample (9,SapFlow__F()),IEEE4)

Sample (9,SapFlow__G()),IEEE4)

Sample (9,SapFlow__H()),IEEE4)

EndTable

DataTable (Stem_Data_UPPER,1,-1)

DataInterval (0,MEAST_INTERVAL_MIN,Min,10)

'Sample (1,Pre_Temp_Down_Outer__A()),IEEE4)

Sample (1,Stem_Temp_Outer__A(1),IEEE4)

Sample (6,Stem_Water__A()),IEEE4)

'Sample (1,Pre_Temp_Down_Outer__B()),IEEE4)

Sample (1,Stem_Temp_Outer__B(1),IEEE4)

Sample (6,Stem_Water__B()),IEEE4)

'Sample (1,Pre_Temp_Down_Outer__C()),IEEE4)

Sample (1,Stem_Temp_Outer__C(1),IEEE4)

Sample (6,Stem_Water__C()),IEEE4)

'Sample (1,Pre_Temp_Down_Outer__D()),IEEE4)

Sample (1,Stem_Temp_Outer__D(1),IEEE4)

Sample (6,Stem_Water__D()),IEEE4)

'Sample (1,Pre_Temp_Down_Outer__E()),IEEE4)

Sample (1,Stem_Temp_Outer__E(1),IEEE4)

Sample (6,Stem_Water__E()),IEEE4)

'Sample (1,Pre_Temp_Down_Outer__F()),IEEE4)

Sample (1,Stem_Temp_Outer__F(1),IEEE4)

Sample (6,Stem_Water__F()),IEEE4)

'Sample (1,Pre_Temp_Down_Outer__G()),IEEE4)



Sample (1,Stem_Temp_Outer__G(1),IEEE4)

Sample (6,Stem_Water__G(),IEEE4)

'Sample (1,Pre_Temp_Down_Outer__H(),IEEE4)

Sample (1,Stem_Temp_Outer__H(1),IEEE4)

Sample (6,Stem_Water__H(),IEEE4)

EndTable

'===== MAIN PROGRAM =====

SequentialMode

BeginProg

Scan (MEAST_INTERVAL_MIN,Min,0,0)

PanelTemp (PTemp,50)

Battery (Batt_volt)

'Send command to start measurement on C1 for lower sensors

SDI12Recorder (d_SapFlow(),C1,"a","C!",1.0,0,-1,0)

SDI12Recorder (d_SapFlow(),C1,"b","C!",1.0,0,-1,0)

SDI12Recorder (d_SapFlow(),C1,"c","C!",1.0,0,-1,0)

SDI12Recorder (d_SapFlow(),C1,"d","C!",1.0,0,-1,0)

SDI12Recorder (d_SapFlow(),C1,"e","C!",1.0,0,-1,0)

SDI12Recorder (d_SapFlow(),C1,"f","C!",1.0,0,-1,0)

SDI12Recorder (d_SapFlow(),C1,"g","C!",1.0,0,-1,0)

SDI12Recorder (d_SapFlow(),C1,"h","C!",1.0,0,-1,0)

' Get the data from the C! command

Delay (0,130,Sec)

SDI12Recorder (SapFlow_a(1),C1,"a","D0!",1.0,0,-1,1)

SDI12Recorder (SapFlow_a(6),C1,"a","D1!",1.0,0,-1,1)

SDI12Recorder (SapFlow_b(1),C1,"b","D0!",1.0,0,-1,1)

SDI12Recorder (SapFlow_b(6),C1,"b","D1!",1.0,0,-1,1)

SDI12Recorder (SapFlow_c(1),C1,"c","D0!",1.0,0,-1,1)

SDI12Recorder (SapFlow_c(6),C1,"c","D1!",1.0,0,-1,1)

SDI12Recorder (SapFlow_d(1),C1,"d","D0!",1.0,0,-1,1)

SDI12Recorder (SapFlow_d(6),C1,"d","D1!",1.0,0,-1,1)

SDI12Recorder (SapFlow_e(1),C1,"e","D0!",1.0,0,-1,1)

SDI12Recorder (SapFlow_e(6),C1,"e","D1!",1.0,0,-1,1)

SDI12Recorder (SapFlow_f(1),C1,"f","D0!",1.0,0,-1,1)

SDI12Recorder (SapFlow_f(6),C1,"f","D1!",1.0,0,-1,1)

SDI12Recorder (SapFlow_g(1),C1,"g","D0!",1.0,0,-1,1)

SDI12Recorder (SapFlow_g(6),C1,"g","D1!",1.0,0,-1,1)

SDI12Recorder (SapFlow_h(1),C1,"h","D0!",1.0,0,-1,1)

SDI12Recorder (SapFlow_h(6),C1,"h","D1!",1.0,0,-1,1)

' Get the data from the C1! C2! C3! C4! and C5! commands

SDI12Recorder (Stem_Temp_Outer_a(),C1,"a","C1!",1.0,0,-1,1)

SDI12Recorder (Stem_Water_a(),C1,"a","C3!",1.0,0,-1,1)

SDI12Recorder (Stem_Temp_Outer_b(),C1,"b","C1!",1.0,0,-1,1)

SDI12Recorder (Stem_Water_b(),C1,"b","C3!",1.0,0,-1,1)

SDI12Recorder (Stem_Temp_Outer_c(),C1,"c","C1!",1.0,0,-1,1)

SDI12Recorder (Stem_Water_c(),C1,"c","C3!",1.0,0,-1,1)

SDI12Recorder (Stem_Temp_Outer_d(),C1,"d","C1!",1.0,0,-1,1)

SDI12Recorder (Stem_Water_d(),C1,"d","C3!",1.0,0,-1,1)

SDI12Recorder (Stem_Temp_Outer_e(),C1,"e","C1!",1.0,0,-1,1)

SDI12Recorder (Stem_Water_e(),C1,"e","C3!",1.0,0,-1,1)



SDI12Recorder (Stem_Temp_Outer_f()),C1,"f","C1!",1.0,0,-1,1)

SDI12Recorder (Stem_Water_f()),C1,"f","C3!",1.0,0,-1,1)

SDI12Recorder (Stem_Temp_Outer_g()),C1,"g","C1!",1.0,0,-1,1)

SDI12Recorder (Stem_Water_g()),C1,"g","C3!",1.0,0,-1,1)

SDI12Recorder (Stem_Temp_Outer_h()),C1,"h","C1!",1.0,0,-1,1)

SDI12Recorder (Stem_Water_h()),C1,"h","C3!",1.0,0,-1,1)

'Call Output Tables

CallTable Sap_Flow_lower

CallTable Stem_Data_lower

'Send command to start measurement on C2 for UPPER SENSORS

SDI12Recorder (D__SapFlow()),C2,"A","C!",1.0,0,-1,0)

SDI12Recorder (D__SapFlow()),C2,"B","C!",1.0,0,-1,0)

SDI12Recorder (D__SapFlow()),C2,"C","C!",1.0,0,-1,0)

SDI12Recorder (D__SapFlow()),C2,"D","C!",1.0,0,-1,0)

SDI12Recorder (D__SapFlow()),C2,"E","C!",1.0,0,-1,0)

SDI12Recorder (D__SapFlow()),C2,"F","C!",1.0,0,-1,0)

SDI12Recorder (D__SapFlow()),C2,"G","C!",1.0,0,-1,0)

SDI12Recorder (D__SapFlow()),C2,"H","C!",1.0,0,-1,0)

' Get the data from the C! command

Delay (0,130,Sec)

SDI12Recorder (SapFlow__A(1),C2,"A","D0!",1.0,0,-1,1)

SDI12Recorder (SapFlow__A(6),C2,"A","D1!",1.0,0,-1,1)

SDI12Recorder (SapFlow__B(1),C2,"B","D0!",1.0,0,-1,1)

SDI12Recorder (SapFlow__B(6),C2,"B","D1!",1.0,0,-1,1)

SDI12Recorder (SapFlow__C(1),C2,"C","D0!",1.0,0,-1,1)

SDI12Recorder (SapFlow__C(6),C2,"C","D1!",1.0,0,-1,1)

SDI12Recorder (SapFlow__D(1),C2,"D","D0!",1.0,0,-1,1)

SDI12Recorder (SapFlow__D(6),C2,"D","D1!",1.0,0,-1,1)

SDI12Recorder (SapFlow__E(1),C2,"E","D0!",1.0,0,-1,1)

SDI12Recorder (SapFlow__E(6),C2,"E","D1!",1.0,0,-1,1)

SDI12Recorder (SapFlow__F(1),C2,"F","D0!",1.0,0,-1,1)

SDI12Recorder (SapFlow__F(6),C2,"F","D1!",1.0,0,-1,1)

SDI12Recorder (SapFlow__G(1),C2,"G","D0!",1.0,0,-1,1)

SDI12Recorder (SapFlow__G(6),C2,"G","D1!",1.0,0,-1,1)

SDI12Recorder (SapFlow__H(1),C2,"H","D0!",1.0,0,-1,1)

SDI12Recorder (SapFlow__H(6),C2,"H","D1!",1.0,0,-1,1)

' Get the data from the C1! C2! C3! C4! and C5! commands

SDI12Recorder (Stem_Temp_Outer__A(),C2,"A","C1!",1.0,0,-1,1)

SDI12Recorder (Stem_Water__A(),C2,"A","C3!",1.0,0,-1,1)

SDI12Recorder (Stem_Temp_Outer__B(),C2,"B","C1!",1.0,0,-1,1)

SDI12Recorder (Stem_Water__B(),C2,"B","C3!",1.0,0,-1,1)

SDI12Recorder (Stem_Temp_Outer__C(),C2,"C","C1!",1.0,0,-1,1)

SDI12Recorder (Stem_Water__C(),C2,"C","C3!",1.0,0,-1,1)

SDI12Recorder (Stem_Temp_Outer__D(),C2,"D","C1!",1.0,0,-1,1)

SDI12Recorder (Stem_Water__D(),C2,"D","C3!",1.0,0,-1,1)

SDI12Recorder (Stem_Temp_Outer__E(),C2,"E","C1!",1.0,0,-1,1)

SDI12Recorder (Stem_Water__E(),C2,"E","C3!",1.0,0,-1,1)

SDI12Recorder (Stem_Temp_Outer__F(),C2,"F","C1!",1.0,0,-1,1)



SDI12Recorder (Stem_Water__F()),C2,"F","C3!",1.0,0,-1,1)

SDI12Recorder (Stem_Temp_Outer__G()),C2,"G","C1!",1.0,0,-1,1)

SDI12Recorder (Stem_Water__G()),C2,"G","C3!",1.0,0,-1,1)

SDI12Recorder (Stem_Temp_Outer__H()),C2,"H","C1!",1.0,0,-1,1)

SDI12Recorder (Stem_Water__H()),C2,"H","C3!",1.0,0,-1,1)

'Call Output Tables

CallTable Sap_Flow_UPPER

CallTable Stem_Data_UPPER

NextScan

EndProg

Maintenance

Reinstallation

The Implexx Sap Flow Sensor Gen2 should be reinstalled at least every 12 months. Reinstallation is required because the sensor has been installed in an organism that grows and reacts to foreign objects. Plants produce a wound response, and, over time, this affects sap flow measurements. The growth of the plant may also increase probe misalignment leading to inaccurate measurements.

In some species or individuals, there may be a strong wound response evident by the growth of a callous around the sensor installation. Carefully remove the sensor and reinstall in a fresh location.

Recalibration

There is no requirement for recalibration of the Implexx Sap Flow Sensor Gen2 for sap flow, sap flux density or stem water content measurements.

Cleaning

Organic material exuded from the plant may adhere to the stainless steel probes or white enclosure body. Generally, this material should not affect the measurements or performance of the sensor. However, the sensor can be cleaned using a non-abrasive wipe and soapy water.

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