Heat Ratio Method Sapflow

The Heat Ratio Method (HRM) is a modification of the Compensation Heat Pulse Method (CHPM). The HRM improves on the CHPM by allowing **very slow flow rates** and even **reverse sap flow** to be measured. This allows water flows to be monitored in stems and roots of a wide range of different species, sizes and environmental conditions, including drought.

Developed by the University of Western Australia and partner organisations, ICRAF and CSIRO, the HRM sensor has been validated against gravimetric measurements of transpiration and used in published sapflow research since 1998. Burgess, S.S.O., et.al. 2001 “An improved heat pulse method to measure low and reverse rates of sapflow in woody plants”, Tree Physiology 21, 589-598.

Principle of measurement

HRM is a thermometric method of measuring sap flow in xylem tissue which uses a short pulse of heat as a tracer. By measuring the ratio of heat transported to two symmetrically placed temperature sensors, the magnitude and direction of water flux can be calculated.

Sensor design

The HRM sensor consists of three 35 mm long needles or probes integrally connected to a 16-bit microprocessor. The top and bottom probes contain two thermistors located at 7.5 mm and 22.5 mm from the tip of each probe. The third and centrally located probe is a line heater that runs the full length of the probe to deliver a uniform pulse of heat through the sapwood.

The integrated microprocessor forms the heart of the HRM sensor making it a fully autonomous, Plug & Play Smart Sensor. All areas of the sensor’s operation and calculations are controlled by the microprocessor which automatically converts the analogue nanovolt signals to a calibrated serial output. Programming variables such as heat pulse interval, energy input, probe spacings, and measurement frequency are all held resident in memory. Using the SL5 Smart Logger the HRM sensor provides a complete sensor report containing detailed information such as on-load draw from the external battery, the duration of time of the heat pulse required to deliver the exact amount of heat energy in joules, the temperature rise following the previous heat pulse, temperature ratios between thermistors and all variables used in calculations of sap velocity or sapflow.

APPLICATIONS

- Low & zero sapflow rates
- Reverse sapflow rates
- Sapflow in roots
- Arid ecosystems & drought
- Nighttime water loss
- Radial sap velocity profiles
- Stem sizes > 10 mm
- Sapflow of grapevines

FEATURES

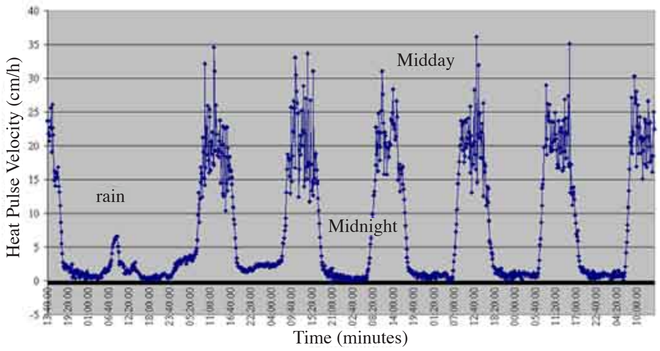
- Plug & Play operation
- Microprocessor controlled
- Measurement options:
  - Raw Heat Pulse Velocities
  - Corrected Sap Velocity
  - Calculated Sapflow
- Raw heat pulse velocity data post-processing spreadsheet
- Requires no thermal insulation
- Independent of thermal gradient effects
- Integrated voltage regulation
- Known and repeatable energy input in joules
- User variable energy input options
- Auto-scaling heat pulse duration
- Auto heat pulse mode option
- Very low power consumption
- 2 milli-degree temperature resolution

Data output

The HRM sensor can provide three levels of transpiration measurement: raw heat pulse velocities, corrected sap velocities (both in cm per hour) and calibrated sapflow given in litres per hour.

The raw heat pulse velocity measurement is perhaps the simplest mode of operation. All that is required is the installation of the sensor and the press of a button and the sensor automatically begins logging data. Once downloaded the raw data can be post-processed using an Excel spreadsheet with all the necessary conversion factors to provide measurements in either sap velocity or sapflow. Alternatively, if all of the necessary variables (such as base-line asymmetry multiplier and offset, thermal diffusivity, wounding correction coefficent, fresh weight volume factor, and sapwood area) are already known then these values can be entered directly into the microprocessor and stored in memory. The measurements are then automatically calculated and logged in calibrated units of either corrected sap velocity or sapflow.

Diurnal Sapflow of **Eucalyptus** ***camaldulensis***



Influence of placement

Probe spacings are the most significant source of error in all heat pulse velocity techniques. Because HRM probes can resolve zero flows, simple calibrations can be made when flow has stopped (determined by meteorological conditions or, more accurately, by stopping flow using incisions into the xylem) that allow flow rates and baselines to be corrected. This permits very accurate discrimination of flow direction and allows correct estimates of the contribution of nighttime water loss to a plant's water balance.

Influence of time

Due to varying wound responses to probe implantation and the usually slight asymmetries caused by installation procedures, heat ratios vary over time. For this reason readings are sampled multiple times between 60–100 seconds after the heat pulse when heat ratios are most stable and linear. Multiple sampling and the use of the 16-bit microprocessor with ultra-low noise preamplifier eliminates all signal noise resulting in highly accurate measurements.

Wound response

Implanted sensor techniques cause mechanical damage and interrupt flow by occlusion or blocking of the plant's vascular tissues. This results in an area of non-conducting tissue directly surrounding the probe; correction for this response is important to achieve accurate results. Wound correction coefficients applicable to a range of wound sizes have been generated using numerical models which allow accurate corrections to be made. These corrections can be made automatically by the sensor producing corrected sap velocities or manually by using a spreadsheet after collecting raw heat pulse velocities.

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SPECIFICATIONS

Measurement range: -10 to 100 cm hr^{-1}

Sensor output:

Smart Output: Serial data

Raw Temperatures: °C

Heat Pulse Velocity: cm hr^{-1}

Sap Velocity: cm hr^{-1}

Sapflow: Litres hr^{-1}

Heat pulse:

User Adjustable Heat Pulse: 25 joules (default) approx. equivalent to a 2.5 second heat pulse duration. Autoscaling

Minimum Interval: 10 minutes

Sensor Design:

Probe Diameter: 1.3 mm

Probe Length: 35 mm

Thermistors: 2 per probe

Weight: 250 g

Top Probe: Consists of two thermistors

Middle Probe: Consists of an 18 ohm nichrome line heater

Bottom Probe: Consists of two thermistors

Thermistor Spacings: 7.5 mm & 22.5 mm from the tip

Power requirements:

Power Supply: 12 V DC

Heater Resistance: 18 ohms

Current Drain: 667 mA for 2.5 s

Power Consumption: 33 mW

Cable lengths:

Standard cable length is 5 m
Maximum cable length 4 km using Databus communications

Dimensions:

Length: 125 mm

Width: 50 mm

Depth: 25 mm

Weight: 250 g (including cable)

Related products:

Plant Field Station Unlimited channel logging system

EnviroStation Automatic Weather Station

SL5 Smart Logger

SHY Stem Psychrometer

Model 3005 Scholander Pressure Bomb