SKTS 500
Evapo Sensor

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1 INTRODUCTION

The Evapo Sensor is fitted with two temperature sensors, built into two flat, black arms to simulate leaf surfaces. One `leaf' is kept wet by means of a wick whilst the second `leaf' remains dry.

The simulated 'leaves' are affected by their local environment just like plant leaves and so react to the four weather factors which drives water loss from plants, namely relative humidity, air temperature, wind speed and solar radiation.

The temperature difference between the two 'leaves' is can be measured and recorded by the Skye EvapoMeter, Skye DataHog logger or other manufacturer's loggers.

Evapo Sensor readings illustrate the fluctuations in daily water loss of plants caused by the weather and time of year and can be used for irrigation scheduling and management.

There are eight models of the SKTS 500 Evapo Sensor fitted with a choice of temperature elements or connections to the DataHog datalogger:

SKTS 500D/I	This model uses semiconductor temperature elements and is fitted with a waterproof connector suitable for use with the Skye EvapoMeter
SKTS 500/10k	This model uses 10kohm thermistor temperature elements and has 2 channels of temperature output as resistances direct from the thermistor
SKTS 500/10k/I	This model uses 10kohm thermistor temperature elements and is fitted with a waterproof connector suitable for use with a special 2-channel temperature socket of the Skye DataHog logger
SKTS 500/10k/D	This model uses 10kohm thermistor temperature elements but has added electronics to give a non linear mV output
SKTS 500/10k/D/I	This model uses 10kohm thermistor temperature elements but is converted to a mV output and fitted with a waterproof connector suitable for use with a standard differential voltage socket of the Skye DataHog logger
SKTS 500/10k/V/I	This model uses 10kohm thermistor temperature elements but is converted to a mV output and fitted with 2 waterproof connectors suitable for use with 2 standard single ended (0-2V) voltage sockets of the Skye DataHog logger
SKTS 500/PT100	This model uses PT100 (Platinum Resistance Thermometer) temperature elements and has 2 channels of temperature output as resistances direct from the PT100. 4 wire outputs from each PT100 sensor are given for optimum measurement accuracy
SKTS 500/PT100/4	This model uses PT100 (Platinum Resistance Thermometer) temperature elements and has 2 channels of temperature output as resistances direct from the PT100. 2 wire outputs from each PT100 sensor are given for easier connection when measuring only the temperature difference between the sensors

2 INSTALLATION

The Evapo Sensor has a waterproof rating of IP65 which means it can safely withstand being hosed with a strong jet of water without damage. However, this does not mean that sensors are submergible and so they must not be located in a position where it is possible they may ever sit in a puddle of water.

The Evapo Sensor must be mounted with black ‘leaves’ uppermost as it is fitted with a water reservoir.

2.1 Filling the Evapo Sensor water reservoir

This sensor operates by measuring the temperature difference between a dry ‘leaf’ and a wet ‘leaf’. In order to keep one of the ‘leaves’ wet it is covered by a wick which is dipping into a water reservoir within the sensor housing.

To fill the reservoir, use the syringe provided and simply squirt distilled (or deionised) water through the hole where the wick emerges from the sensor housing, until it is full.

Allow several hours for the wick to become fully saturated before beginning measurements.

Refill the reservoir at regular intervals as above. It is important that the wick does not dry out as this will greatly effect the measurements.

For maximum reproducibility, it is important to replace the wick regularly particularly if it becomes noticeable bleached or encrusted. If possible, avoid exposure to wetting from irrigation water which will contaminate the water in the wick and in the reservoir and sop shorten the useful life of the wick.

Please see Appendix 2 for wiring details, connections and outputs for the different Evapo Sensor models.

3 TECHNICAL OVERVIEW

3.1 Comparisons with calculated ET values

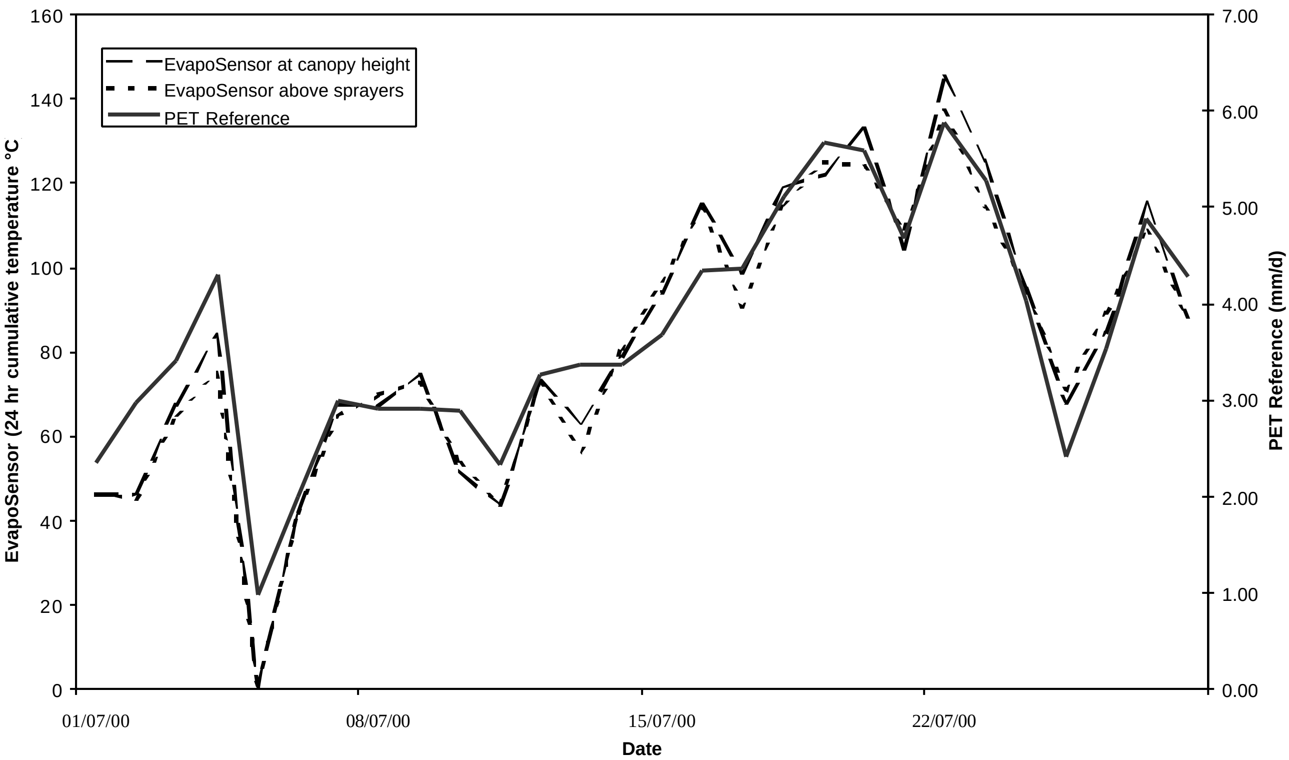
The Evapo Sensor is based on an initial design by Horticulture Research International, East Malling, UK. It was refined and produced by Skye Instruments during their participation in the HortLink project 'Improving the Efficiency of Water Use in Container-Grown Nursery Stock'.

During this project Evapo Sensor measurements were compared directly with Potential EvapoTranspiration values calculated using the Penman-Monteith method from an automatic weather station at the same site.

The temperature difference (wet bulb depression) between the two 'leaves' of the Evapo Sensor were measured and the 24 hour cumulative temperature difference compared to daily ET.

Evapo Sensors were installed in an outdoor site, both at canopy height where they were irrigated upon along with the crop, and also at 1m above the irrigation sprinklers so that no irrigation reached them. Comparisons between measurements made at these two positions agreed within 98% showing that positioning of the sensor was not crucial.

The graph below shows the excellent correlation between an irrigated Evapo Sensor, a non-irrigated sensor and the calculated ET values:



Reference: More for the Pots. Article in The Grower magazine, p14&15, issue March 14 2002.

3.2 Irrigation scheduling

As every crop and its location, whether under protection or outdoor, is unique a site specific ‘calibration’ is required to interpret the Evapo Sensor readings into irrigation requirements.

Firstly irrigate the crop to full capacity and weigh plant pots (where applicable). Begin Evapo Sensor measurements at this point.
When the crop is next due irrigation (as per usual practice in this case) note the Evapo Sensor cumulative temperature difference and again weigh the plant pots.
Now irrigate to full capacity again, or until the plants pots return to their original weight – note how much irrigation this requires.

For future irrigations, begin irrigation at the Evapo Sensor cumulative temperature difference noted above, and apply as much water also as noted above to bring the crop back to capacity with repeated consistency.

Further details and guidance notes for regulating irrigation are available to individuals from the work undertaken during the HortLink project. Please contact Skye Instruments if you would like a copy.

3.2 Calibration of ‘Leaves’

There is usually very little variation between temperature sensors, but calibrating in this way will also take into account any slight differences in the Evapo sensor ‘leaves’.

The Evapo sensor ‘leaves’ must first be brought to the same temperature. A quick and simple method involves immersing the ‘leaves’ in a jug or similar vessel filled to the brim with water (at a temperature close to ambient). It is necessary to remove the tail of the wick from the reservoir but the wick can be left on the ‘leaf’. The Evapo sensor should be tipped up so that the ‘leaves’ are pointing vertically downwards and any water in the reservoir drains out of the filling hole. The Evapo sensor can then be hung on the edge of the jug with the two ‘leaves’ immersed in the water. Stir the water in the jug vigorously for at least 2 minutes to eliminate any temperature gradients before measuring the temperature of each ‘leaf’.

Alternatively, the wick should be removed and both ‘leaves’ allowed to dry thoroughly before placing the Evapo sensor into an enclosed box (an insulated cool box, used without ice or cooling blocks is ideal) away from direct sun or other sources of heat. Allow at least an hour (preferably overnight) for temperature equilibration.

If there is a significant difference in temperature between the two leaves, use this difference as an offset in all future temperature difference calculations.

APPENDIX 1 - EVAPO SENSOR SPECIFICATIONS

Housing:	Grey ABS. Sealed to IP65
Dimensions:	95 x 65 x 80 mm
Weight:	150 grams
Cable:	3m fitted as standard, longer lengths available
Operating Range:	0-100% RH, -20 to +70 °C
Accuracy:	SKTS 500D/I : 0.2°C at 25°C SKTS 500/10k : 0.2°C from 0 to 60°C SKTS 500/10k/I : 0.2°C from 0 to 60°C SKTS 500/10k/D : 0.2°C from 0 to 60°C SKTS 500/10k/D/I : 0.2°C from 0 to 60°C SKTS 500/10k/V/I : 0.2°C from 0 to 60°C SKTS 500/PT100 : 0.05°C at 0°C SKTS 500/PT100/4 : 0.05°C at 0°C

APPENDIX 2 – WIRING CONNECTIONS & SENSOR OUTPUTS

SKTS 500D/I – with semiconductor temperature elements for the EvapoMeter

Connector Pin No.

Pin 1	Red wire	Dry 'leaf' temperature
Pin 2	Blue wire	Wet 'leaf' temperature
Pin 3	Cable screen	Common ground

This sensor is designed to be connected to the EvapoMeter which is programmed to read out temperature difference from the sensor outputs.

SKTS 500/10k – with thermistor temperature elements, wire ended

Red wire) Yellow wire)	Resistance output of Dry 'leaf' temperature
Blue wire) Green wire)	Resistance output of Dry 'leaf' temperature
Grey wire	Uncommitted cable screen

This sensor has non linear resistance outputs. Table 1 shows values of the resistance v temperature.

SKTS 500/10k/I – with thermistor temperature elements for a special 2-channel temperature DataHog socket

Connector Pin No.

1	N/C	
2	N/C	
3 5	Red wire) Yellow wire)	Resistance output of Dry 'leaf' temperature
4 5	Blue wire) Green wire)	Resistance output of Wet 'leaf' temperature
5	Grey wire	Uncommitted cable screen

This sensor has non linear resistance outputs. Table 1 shows values of the resistance v temperature. However the DataHog logger can be programmed to automatically convert readings to Degrees C for each “leaf”. Please see Appendix 4 for an example of the DataHog configuration.

SKTS 500/10k/D – with thermistor temperature elements and mV output

Red wire	5 volt sensor excitation
Green wire	Voltage output of Wet ‘leaf’ temperature
Yellow wire	Voltage output of Dry ‘leaf’ temperature
Blue wire	Ground and cable screen

This sensor has non linear mV outputs. Table 1 shows values of the mV output v temperature when used with a 5V regulated power supply. If other values of power supply are used, please see Appendix 5.

SKTS 500/10k/D/I – with thermistor temperature elements and mV output for a standard differential voltage DataHog socket

Connector Pin No.

1	Red wire	5 volt sensor excitation
2	N/C	
3	Green wire	Voltage output of Wet ‘leaf’ temperature
4	Yellow wire	Voltage output of Dry ‘leaf’ temperature
5	Blue wire	Ground and cable screen

This sensor has non linear mV outputs. However the DataHog logger can be programmed to automatically convert readings to Degrees C for each “leaf”. Please see Appendix 4 for an example of the DataHog configuration.

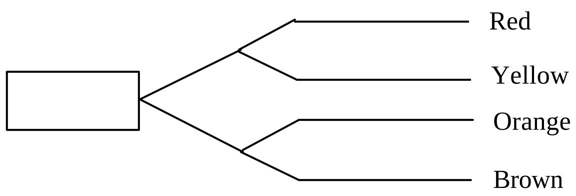
SKTS 500/10k/V/I – with thermistor temperature elements and mV output for 2 standard single ended voltage DataHog socket

Connector Pin No.	(2 connectors, one for wet ‘leaf’, one for dry ‘leaf)	
1	Red wire	5 volt sensor excitation
2	Green wire	Voltage output of ‘leaf’ temperature
3	N/C	
4	N/C	
5	Blue wire	Ground and cable screen

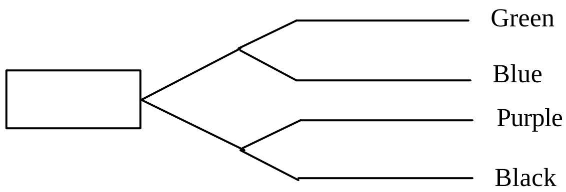
This sensor has non linear mV outputs. However the DataHog logger can be programmed to automatically convert readings to Degrees C for each “leaf”. Please see Appendix 4 for an example of the DataHog configuration.

SKTS 500/PT100 – with PT100 temperature elements, 8 core wire ended cable

Resistance output
Dry ‘leaf’ temperature



Resistance output
Wet ‘leaf’ temperature



Cable screen White wire

This sensor has non linear resistance outputs direct from the PT100 sensor which is 1/3rd DIN BS1904 and DIN 43760.

SKTS 500/PT100/4 – with PT100 temperature elements, 4 core wire ended cable

Red wire)
) Resistance output of Dry 'leaf' temperature
Yellow wire)

Blue wire)
) Resistance output of Dry 'leaf' temperature
Green wire)

White wire Uncommitted cable screen

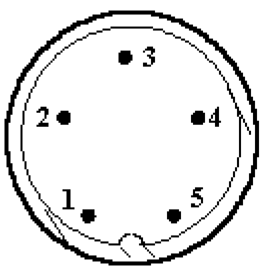
This sensor has non linear resistance outputs direct from the PT100 sensor which is 1/3rd DIN BS1904 and DIN 43760.

APPENDIX 3 – DATAHOG CONNECTOR PIN IDENTIFICATION

5 PIN SOCKETS
Front (outside) view of socket

OR

5 PIN CONNECTORS
Back (inside) view of connector



HARDWARE CONFIGURATION AND CALIBRATION CERTIFICATE

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DATAHOG2 TYPE : ----------------------------------- **SERIAL NO.:** EXAMPLE --- **Certifcate Issue Date:** ---

Software Channel No.	Hardware Channel No.	Socket No.	Configured for Input Type	Gain Code	Termination Code	Scale Code	Full Scale Value	Zero Offset	Units	Sensor Serial No and/or Calibration Factor (when supplied by Skye)
00	00	1	Evapo Sensor	00	00	02	2000.0	0000	°C	SKTS 500/10k/I DRY
01	01	1	Evapo Sensor	00	00	02	2000.0	0000	°C	SKTS 500/10k/I WET
02										
03	03	2	Evapo Sensor	00	00	02	2000.0	0000	°C	SKTS 500/10k/D/I DRY
04	04	2	Evapo Sensor	00	00	02	2000.0	0000	°C	SKTS 500/10k/D/I WET
05										
06	06	3	Evapo Sensor	00	00	02	2000.0	0000	°C	SKTS 500/10k/V/I DRY
07	07	4	Evapo Sensor	00	00	02	2000.0	0000	°C	SKTS 500/10k/V/I WET
08										

Eprom Version **Datafile Identifier**

Where fitted the following standards apply:
RH/Temperature - This probe has been calibrated for relative humidity and air temperature to standard factory specifications at nominal points -1% and 75.4% RH and 27 degrees celsius.
Pyranometer - Calibrated directly against a calibrated reference World Meteorological Office, First Class Pyranometer under natural daylight conditions. Uncertainty + 5% (typically + 3%) based on an estimated confidence of not less than 95%
Other Light sensors - Calibrated against a National Physical Laboratory UK reference standard lamp. Uncertainty + 5% (typically + 3%) based on an estimated confidence of not less than 95%
Air Pressure - Transducers checked against a NAMAS traceable transducer
Wind Sensors & Raingauges - As per manufacturers supplied calibration information

Signed……………………………..………………………. For and on behalf of Skye Instruments Ltd

TABLE 1 - 10KOHM PRECISION TEMPERATURE THERMISTOR TABLES

Temp Deg C	Thermistor value kohms	Output at 5V mV	Temp Deg C	Thermistor value kohms	Output at 5V mV
-20.00	97.08	991.64	41.00	5.12	212.30
-19.00	91.62	979.71	42.00	4.92	205.37
-18.00	86.50	967.47	43.00	4.73	198.66
-17.00	81.70	954.91	44.00	4.54	192.16
-16.00	77.19	942.05	45.00	4.37	185.88
-15.00	72.96	928.89	46.00	4.20	179.75
-14.00	68.98	915.46	47.00	4.04	173.86
-13.00	65.25	901.76	48.00	3.89	168.22
-12.00	61.73	887.80	49.00	3.74	162.72
-11.00	58.43	873.61	50.00	3.60	157.40
-10.00	55.33	859.19	51.00	3.47	152.21
-9.00	52.41	844.56	52.00	3.34	147.29
-8.00	49.66	829.75	53.00	3.22	142.48
-7.00	47.07	814.77	54.00	3.10	137.84
-6.00	44.63	799.63	55.00	2.99	133.35
-5.00	42.33	784.36	56.00	2.88	129.02
-4.00	40.16	768.98	57.00	2.77	124.83
-3.00	38.12	753.51	58.00	2.68	120.80
-2.00	36.19	737.96	59.00	2.58	116.88
-1.00	34.37	722.36	60.00	2.49	113.12
0.00	32.65	706.73	61.00	2.40	109.48
1.00	31.03	691.13	62.00	2.32	105.96
2.00	29.50	675.50	63.00	2.24	102.56
3.00	28.05	659.91	64.00	2.16	99.28
4.00	26.68	644.37	65.00	2.08	96.11
5.00	25.39	628.90	66.00	2.01	93.05
6.00	24.17	613.52	67.00	1.94	90.10
7.00	23.01	598.25	68.00	1.88	87.24
8.00	21.92	583.10	69.00	1.81	84.49
9.00	20.88	568.09	70.00	1.75	81.83
10.00	19.90	553.24	71.00	1.69	79.26
11.00	18.97	538.57	72.00	1.64	76.78
12.00	18.09	524.07	73.00	1.58	74.38
13.00	17.25	509.77	74.00	1.53	72.07
14.00	16.46	495.69	75.00	1.48	69.82
15.00	15.71	481.82	76.00	1.43	67.66
16.00	15.00	468.18	77.00	1.38	65.57
17.00	14.32	454.77	78.00	1.34	63.57
18.00	13.68	441.61	79.00	1.30	61.63
19.00	13.07	428.71	80.00	1.26	59.75
20.00	12.49	416.06	81.00	1.22	57.93
21.00	11.94	403.68	82.00	1.18	56.19
22.00	11.42	391.56	83.00	1.14	54.50
23.00	10.92	379.71	84.00	1.10	52.86
24.00	10.45	368.14	85.00	1.07	51.29
25.00	10.00	356.84	86.00	1.04	49.74
26.00	9.57	345.81	87.00	1.00	48.27
27.00	9.17	335.06	88.00	0.97	46.85
28.00	8.78	324.58	89.00	0.94	45.48
29.00	8.41	314.38	90.00	0.92	44.14
30.00	8.06	304.45	91.00	0.89	42.86
31.00	7.72	294.79	92.00	0.86	41.61
32.00	7.40	285.40	93.00	0.84	40.41
33.00	7.10	276.25	94.00	0.81	39.25
34.00	6.81	267.38	95.00	0.79	38.12
35.00	6.53	258.76	96.00	0.76	37.03
36.00	6.27	250.35	97.00	0.74	35.98
37.00	6.02	242.33	98.00	0.72	34.96
38.00	5.78	234.47	99.00	0.70	33.98
39.00	5.55	226.85	100.00	0.68	33.02
40.00	5.33	219.46	101.00	0.66	32.10

APPENDIX 5 - USING WITH VOLTAGE POWER SUPPLIES OTHER THAN 5V

SKTS 500/10k/D, SKTS 500/10k/D/I, SKTS 500/10k/V/I

The above EvapoSensor models have been optimised for use with the Skye DataHog logger which gives a regulated 5V excitation supply to the sensor. However, there is a simple ratio calculation when used with other value power supplies.

CALCULATION

The resistance output is calculated from the temperature variable resistance thermistor T and the 33.2 kohm resistor in parallel as:

$$\text{Output resistance (R)} = \frac{(T \times 33.2)}{(T + 33.2)} \text{ kohm}$$

Used with an excitation voltage V volts, the output voltage is:

$$\text{Output voltage (mV)} = (V \times 1000) \text{ mV} \times \frac{R}{100 + R}$$

The values given in Table 1 are for use with a 5V excitation supply. From the formula given above it can be seen that the mV output of the probe is directly proportional to the excitation voltage V supplied.

So the given table can be easily converted for other supplies as follows:

For example,

At -20°C with 5V excitation, the probe reads 991.64 mV.

So at 12V excitation, multiply the given mV output by 12 / 5,
the probe will read 2379.94 mV

And at 2V excitation, multiply the given mV output by 2 / 5,
the probe will read 396.66 mV