SEM 550
EvapoMeter

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1   INTRODUCTION

This EvapoMeter is intended to be connected to a Skye Evapo sensor (model SKTS 500/I) and will record and display readings in Degree Hours.

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 temperature difference between the two `leaves' is measured and recorded by the EvapoMeter. Degree Hours of temperature difference is calculated and accumulated in memory.

One Degree Hour is defined as a one degree Celsius difference in temperature between the dry and wet 'leaves' for a period of one hour. (For example, a 0.5 deg difference for 2 hours, or 0.25 deg difference for 4 hours would also give an accumulated 1 Degree Hour).

Degree Hours are only accumulated in the EvapoMeter if the dry 'leaf' is a higher temperature than the wet 'leaf'. If the dry 'leaf' is a lower temperature than the wet 'leaf' then nothing is added to or subtracted from the accumulated total.

Accumulated Degree Hours can be displayed in several modes, such as the temperature difference accumulated so far in the present 24 hours, total in previous 24 hours, total since last reset by user and previous total in memory just before last reset by user.

The Alarm function can be set to flash a red LED light when a user-set accumulated total threshold has been reached.

Other EvapoMeter models will also accept inputs from soil moisture tensiometers, solar radiation sensors and tipping bucket raingauges, which can all contribute to the calculation as required.

The EvapoMeter is waterproof and easy to use by technical and non-technical personnel alike.

2   INSTALLATION

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

The 3 pin socket on the EvapoMeter and the corresponding plug on the Evapo sensor are only waterproof when mated or covered by a dustcap, so please ensure this is always the case when in use.

The EvapoMeter may be installed in any position or orientation as is convenient.

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.

2.2   Connecting the Evapo sensor to the EvapoMeter

Connect the 3 pin plug at the end of the Evapo sensor cable into the corresponding 3 pin socket on the side of the EvapoMeter box.

Note that there is a small pip which allows connection in one orientation only. Do not force the plug, rotate until it connects easily.

Screw up the knurled section to make the connection watertight – gently finger tight is sufficient, there is an internal O ring seal which can be damaged by overtightening.

3   OPERATION

3.1   Power

The EvapoMeter is powered by a PP3 9 volt battery. Skye Instruments always recommend the use of quality alkaline batteries (such as Duracell) as these do last up to 6 times as long and are not prone to leakage of corrosive chemicals as are some cheaper batteries.

The EvapoMeter is operational as soon as power is applied. To install the supplied PP3 battery, unscrew the 4 corner screws securing the lid of the meter housing. Gently remove the lid and note that the housing has a 'double skin'. The inner compartment is sealed against water ingress by a soft rubber O ring seal. It is important to keep this O ring clean and intact to ensure water tightness.

Insert the PP3 battery in the black holder, in the correct orientation indicated. Carefully replace the lid and tighten the 4 corner screws.

When the EvapoMeter is operational the green LED marked 'sleeping' will flash once a second.

You may check the battery voltage at any time via the display and scrolling through the Next menus. Actual battery voltage will be displayed plus an indication of Battery OK, Battery Low or Battery Expiring. (See Figure 1 for details of the display menus.) Obviously it is advisable to change the battery if you see the Battery Expiring message.

All settings and stored measurements in memory are preserved if the battery expires.

Typical battery life of a quality alkaline cell is 1125 hours (over 6.5 weeks), assuming the display is checked once or twice a day. The battery life will be reduced if the display is activated more frequently, or if the red Alarm LED is continually flashing.

If you wish to switch off the instrument, for example if it is not going to be in use in the off season, simply remove the battery and carefully replace the lid.

3.2   Display

The EvapoMeter Display is switched off unless in use to conserve power. It is activated by passing a magnet over reed switches under the meter's lid. For convenience a small magnet is attached via a cord to the EvapoMeter box.

TO ACTIVATE THE DISPLAY, POINT THE MAGNET TO 12 O'CLOCK AND PLACE OVER THE YELLOW 'WAKE' BUTTON. It is not necessary to touch the EvapoMeter lid with the magnet, simply 'waving' the magnet over the button is sufficient.

If the green LED marked 'sleeping' is flashing then the meter is operational. (If there is no flashing, the battery probably requires replacing.) To activate the display pass the magnet over the 'Wake' button.

Use the Next or Enter / Confirm button to scroll through the display menus as required. Brief instructions will be given on screen where appropriate. Please see Figure 1 for a detailed flow chart of the menus.

NOTE - the display returns to 'sleep' mode after 10 seconds if no magnet swipe is detected.

'Enter' can be used to return to 'sleep' mode when in the display screens.

3.3   To Set the Clock

The EvapoMeter has a 24 hour clock, this will be factory set for the current UK time before leaving Skye.

To change the clock settings, use the magnet and activate Wake, Enter, Next and <enter> to Set the Clock.

The current time is displayed. Use the Next button to increment each clock digit and the Confirm button to move on to the next clock digit.

Enter to set this new time, or next to return and redo. If you simply leave the display alone until it 'times out' and switches off after 10 seconds, no changes will be made.

3.4   To Set the 24 Hour Integrating Period

Degree Hours temperature differential can be displayed as a total accumulated time, or in periods of 24 hours. The accumulation so far in the current 24 hour period is measured, calculated and displayed, and also the total accumulation in the previous total 24 hour period.

The user can set up the EvapoMeter to choose the time this 24 hour will begin and end, for example 0900 to 0859, midnight to midnight etc. The factory default setting is 0800 to 0759.

To change the 24 hour period start time, use the magnet and activate Wake, Enter, Next, Next and <enter> to Set the 24 Hour Integrating Period..

Use the Enter button to continue, or Next to return to display mode without changes

The current 24 hour period start time is displayed. Use the Next button to increment each clock digit and the Confirm button to move on to the next clock digit.

Enter to set this new time, or next to return and redo. If you simply leave the display alone until it 'times out' and switches off after 10 seconds, no changes will be made.

3.5 To Set the Alarm Threshold

It is possible to set a threshold level of accumulated Degree Hours that will cause the red LED marked 'Alarm!' to flash once a second, once the threshold level has been reached or exceeded. This is useful if you need to irrigate the crop after a certain set of conditions have been met, for example.

This Alarm Threshold levels applies to the Total Accumulated Degree Hours only. It is not triggered by the previous total or the 24 hour period values.

The factory default value is 3000.0. This is generally far too high for most uses, but is set to delay the alarm activating unnecessarily. Remember, leaving the red Alarm LED flashing continuously over a long period will reduce battery life.

To change the Alarm Threshold, use the magnet and activate Wake, Enter, Next, Next, Next and <enter> to set Alarm Threshold.

Use the Enter button to continue, or Next to return to display mode without changes.

The current Alarm Threshold is displayed. Use the Next button to increment each digit and the Confirm button to move on to the next digit. Thresholds may be set between 0 and 3999.0

Enter to set this new Threshold, or next to return and redo. If you simply leave the display alone until it 'times out' and switches off after 10 seconds, no changes will be made.

3.6 Using the EvapoMeter

Once you are happy the clock, 24 hour integrating period and alarm threshold have been set as required, the EvapoMeter is ready to use.

Connect the Evapo sensor plug to the EvapoMeter socket and install.

The EvapoMeter will automatically take temperature readings every 1 minute and calculate and store the accumulated differences between the dry and wet 'leaves'.

You may check the actual temperature or accumulated difference at any time by activating the display with the magnet. Following the flow chart in Figure 1, the display menus are:

1. Wake – this is the default display. It shows the current clock time plus the actual temperature of both the dry (d) and wet (w) 'leaves'. (If no sensor is connected or there is a fault with the sensor the display will read –0.006 deg)
2. Next – this shows the total accumulated temperature difference in Degree Hours since the last user reset
3. Next - this shows the previous total accumulated temperature difference in Degree Hours just before the last user reset (useful in case of accidental reset!)

4. Next - this shows the accumulated temperature difference in Degree Hours so far in the current 24 hour period
5. Next - this shows the total accumulated temperature difference in Degree Hours in the previous 24 hour period
6. Next - this shows the start time of the 24 hour integration period and the alarm threshold level.
7. Next – this shows the battery voltage and its status interpretation
8. Next – returns to the default display described in 1 above

You can use the Enter button in any of the above displays to return the EvapoMeter to 'sleep' mode. Otherwise just leave and the display will 'time out' back to sleep mode after 10 seconds.

3.7   To Clear the Accumulated Total

You may wish to reset or clear the accumulated total of temperature difference occasionally, for example if your alarm threshold has been reached, you have taken the appropriate action and now want to know when the threshold is reached again.

If you do not clear this accumulated total it will reach a value of 4095.9 before 'rolling over', resetting itself to zero and beginning again.

The action of clearing the accumulated total will switch off the red 'Alarm!' LED if it is flashing.

To clear the accumulated total, use the magnet and activate Wake, Enter and <enter> to Clear the Accumulated Total.

Use the Enter button to continue and clear the total, or use Next to return to display mode without changes.

If you now scroll through the displays, you will see that the (current) Accumulated total is now zero and the Previous Accumulated Total has become the value before you did the reset.

The 24 hour period values are not reset or cleared by this function.

4   TECHNICAL OVERVIEW

## 4.1   Comparisons of Evapo Sensors 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:
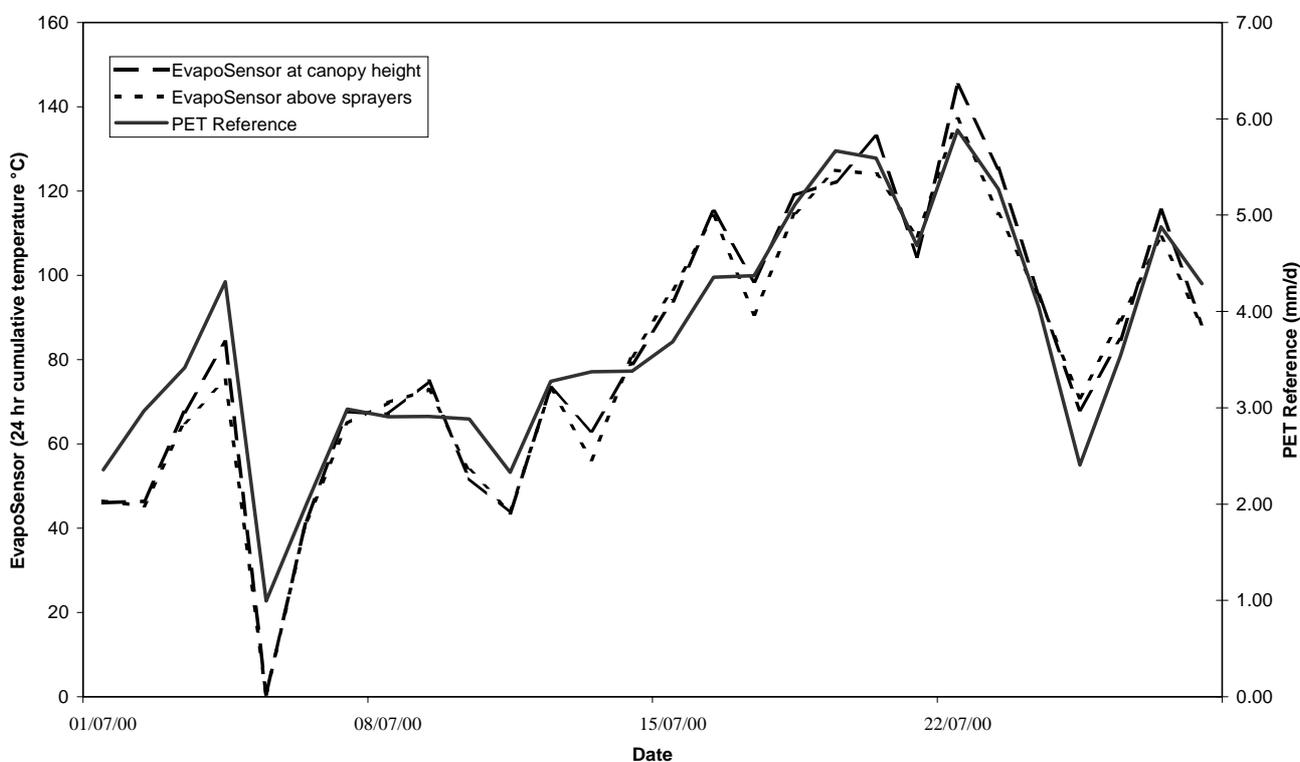
Reference: More for the Pots. Article in The Grower magazine, p14&15, issue March 14 2002.

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4.2   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).
Zero (reset) the EvapoMeter accumulated total.
When the crop is next due irrigation (as per usual practice in this case) note the EvapoMeter accumulative 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 EvapoMeter accumulative temperature difference noted above, and apply as much water also as noted above to bring the crop back to capacity with repeated consistency.

4.3   EvapoMeter Measurement and Calculation

The EvapoMeter will measure the temperature of a solid state device between –55 deg C and +125 deg C. However, most probes (including the Evapo sensor) will not operate at these extremes.

Temperature measurements are made at a resolution of 0.0625 deg C, but rounded to 0.01 degrees on the instrument's display.

Calculations of Degree Hours are also done at a resolution of 0.0625 deg C (a 64 bit calculation), and rounded to 0.1 Degree Hours on the instrument's display.

The calculation of Degree Hours is based on the subtraction of sensor 2 (wet 'leaf') temperature from sensor 1 (dry 'leaf') temperature in degrees C. The difference is integrated over time and displayed as Total Accumulated Degree Hours.

One Degree Hour is defined as a one degree Celsius difference in temperature between the dry and wet 'leaves' for a period of one hour. (For example, a 0.5 degree difference for 2 hours, or 0.25 degree difference for 4 hours would also give an accumulated 1 Degree Hour).

NOTE – if the sensor 2 (wet 'leaf') temperature is higher than the sensor 1 (dry 'leaf') temperature then the EvapoMeter will display this measurement but will not include the values in the Degree Hours calculation.

4.4   Calibration of Temperature Sensors

There is a sensor calibration feature in the EvapoMeter set up menus. This enables any slight difference between two temperature sensors to be eliminated from the temperature difference calculation by adding a fixed offset to one sensor.

There is usually very little variation between solid state 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 going through the calibration option on the EvapoMeter.

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. After allowing at least an hour (preferable overnight) for temperature equilibration, perform the calibration operation as described below.

To begin the calibration, use the magnet and activate Wake, Enter, Next, Next, Next, Next and <enter> to Start Calibration.

Use the Enter button to continue and calibrate the sensors, or use Next to return to the display mode without changes.

The EvapoMeter will measure both sensors and assume they are at the same temperature. It will then apply a fixed offset to sensor 2 (wet 'leaf') so that both sensors display the same temperature. This offset will be included in all future temperature difference calculations.

The calibration offset value will be set to zero if the EvapoMeter measures more than 1 degree C actual temperature difference between sensor 1 and sensor 2. A warning message is displayed if this is the case. This ensures a 'bad' calibration cannot be made in error, and also gives a method of resetting the calibration if required.

To reset the calibration, simply warm one of the Evapo sensor 'leaves' (by holding with a clean finger!) until you can see the temperature difference in the standard display is greater than 1 degree C. Then proceed through the calibration routine described above. The warning message will confirm that the offset is too great, and ask the user to check the setup.

APPENDIX 1 - EVAPOMETER SPECIFICATIONS

Housing:	Grey ABS base with clear lid. Sealed to IP65.
Dimensions:	122 x 120 x 55 mm
Weight:	450 grams including magnet
Sensor connector:	Binder sub-miniature 3 pin socket, sealed to IP65 when mated with plug or blanking cap
Display:	16 x 2 line alphanumeric liquid crystal display
Controls:	2 magnetically operated reed switches to activate display menus
Operating Temperature:	-20 to +70 °C
Measurement temperature:	-55 to +125 °C
Resolution:	0.0625 °C
Accuracy:	Typically less than 0.2 °C at 25 °C
	Total error of 0.5 °C over the range –55 to + 85 °C
Measurement frequency:	Every 1 minute
Memory:	Stores 4 parameters:-
	Total Accumulated Degree Hours since last reset (maximum 4095.9 before rollover)
	Previous Total Accumulated Degree Hours
	Accumulated Degree Hours in current 24 hour period
	Total Accumulated Degree Hours in previous 24 hour period
	Memory is not lost if main battery fails.
Alarm feature:	Flashing red LED if Degree Hour threshold is met or exceeded
Calibration feature:	To normalise differences between a sensor pair
Power:	PP3 or MN1604 9 volt alkaline battery
	Typical battery life 6.5 weeks
	Display of battery voltage and status indication
	LED display switches off if inactive for 10 seconds to conserve power
Power Consumption:	'Sleeping' mode with green LED flashing – 360 µA
	'Sleeping' mode with green LED and red Alarm LED flashing – 600 µA
Clock:	24 hour real time clock, backed up by separate lithium battery if main battery fails
Input choices:	Temperature, tensiometer, solar radiation, raingauge

APPENDIX 2 – 3 PIN SOCKET CONNECTION

******* NOTE – this applies to SKTS 500D/I Evapo sensors for connection to the
EvapoMeter only *******

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

APPENDIX 3

PLEASE NOTE:

These units are now supplied with additional resistors fitted across the originals to increase the brightness of the red and green L.E.D lights.

There will be a decrease in battery life expected with this modification of perhaps six days.

Feel free to snip out the additional resistors fitted if this decrease in battery life is not acceptable. (The resistors reside either side of the red and green L.E.D's)

FIGURE 1 – Flow Chart of EvapoMeter Display Menus

EVAPOMETER IS SLEEPING
(green LED is flashing once a second)

WAKE

Skye Instruments
EVAPOMETER –

ENTER → <enter> to show
Setup Options…. ← NEXT

12:00   dry 18.63 deg
Time   wet18.05 deg

12:00   dry 18.63 deg
Time   wet18.05 deg

NEXT

0000.0 Deg Hrs
Accum Total

NEXT

0000.0 Deg Hrs
Previous Acc Tot

NEXT

0000.0 Deg Hrs
in current 24Hrs

NEXT

0000.0 Deg Hrs
- previous 24Hrs

NEXT

00:00 24Hr start
0000.0 Alarm set

NEXT

Battery 08.500v.
Battery level OK

<enter> to clear
Accumulated Total   ENTER →   ?Are you sure?
<next> to cancel   NEXT

NEXT   ENTER

<enter> to set
the clock……   ENTER →   ?Are you sure?
<next> to cancel   NEXT

NEXT   ENTER   SET CLOCK
ROUTINE

<enter> to set
24hr Int. Period   ENTER →   ?Are you sure?
<next> to cancel   NEXT

NEXT   ENTER   SET 24HR
ROUTINE

<enter> to set
Alarm Threshold   ENTER →   ?Are you sure?
<next> to cancel   NEXT

NEXT   ENTER   SET ALARM
ROUTINE

<enter> to start
calibration   ENTER →   ?Are you sure?
<next> to cancel   NEXT

NEXT   ENTER   CALIBRATION
COMPLETE

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