# *Spreadsheet Guidance Notes*

***These notes explain the values in each cell in all of the tables and which are entered after data has been recorded on site for a test run.***

***The blue headers indicate the cells where data is entered manually, or in some cases by auto filling from above, and the red those that contain calculations and are automatically derived when you auto-fill the cells by pulling down on the cell handle above. These were created in Numbers for Mac and have been exported to Excel for Windows. I am assuming that all the functions will behave in a similar way.***

***To start the process there is a row labelled '0' to enable 'pull down' in the relevant places.***

## *'Receiving' battery: Discharge:*

*The data relevant to the discharge stage of a test run.*

**Capacity:** enter the battery capacity in Ah

**Current:** This is the discharge current used with the CBA for the first stage of the test run. The value used is a combination of what the battery can easily sustain and the time taken to complete the discharge. For example, if we want to discharge 20% of the capacity from a 7Ah battery, then that is 1.4Ah. At 3A (3,000mA) then that will take 1.4 / 3 = 0.46hr = 28mins.

**Start voltage:** The voltages measured by the CBA, at the start off the Discharge. Note that if you are starting from an already partially discharged state, such as 90%, then this value is the one you used to discharge from 90% and not the one you used to go from fully charged to 90%.

**Energy discharge (Wh):** The results displayed on the end screen or if that does not show then in the box on the right hand side of the screen.

**Energy discharge (J):** This cell multiplies the Wh values by 3,600 to give a reading in Joules.

**Start Ah:** The % capacity that you are beginning the discharge stage from.

**%Ah:** The % capacity that you are discharging.

**Final voltage:** The final voltage showing on the CBA after a 10 min recovery time.

**Test ID:** The file name of the test as saved by the CBA to a selected location (set in Preferences). It is helpful to standardise on a format and so change what default format that is first saved. I used a data followed by a number that was unique, especially if more

than one test ruin is conducted in a day. E.g. 181022_Discharge_1-1.bt2, 181022_Discharge_1-2. bt2.

**Screen grab:** A valuable back up that can be also used for reports and annotated in an editor.

**Comments:** Any useful identifying comments regarding the test run. When there are many records this assets zooming in on required results.

## *'Run' battery - Supply:*

*The data relevant to the supply from the battery (or PSU) to the generator*

**PRF:** The pulse repetition frequency of the HV pulses delivered to the receiving battery.

**Duty:** The % duty cycle as set on the PWM module, or measured on a scope if using other triggering methods.

**Circuit V:** The 'no-load' voltage being supplied to the circuit components, in contrast to that supplied to the coils.

**Circuit current:** The current displayed by the RDM unit when the unit is on but the FET switch is off and the coils are not operating.

**Circuit power:** A calculation based on the power demand of just the PCB circuit.

**Coil V:** The 'no-load' voltage supplied to the coils

**$I_{av}$:** The average current supplied to the whole circuit, PCB and coils, and derived from the set of measurements exported from the RDM unit after a test run is completed. then entered here. Details of this process are given in the relevant section 'Current Table' below

**Run time:** The duration in seconds that the generator was producing HV pulses to the battery.

**E supplied:** A calculation of the total energy supplied to the generator from the supply, battery or PSU, serviced from the voltages, average current and run time.

**RDM export file name:** A suitable file name for the current table exported from the RDM unit.

**Comments:** Any useful comments or test identifier

## *'Receiving' battery - Charging:*

*The data relevant to the charging stage of a test run*

**Capacity:** Battery capacity taken from table 1

**HV:** Peak voltage of HV pulses

**E discharged:** Taken from Table 1

**$V_{(pk)}$:** Voltage at the start of the first discharge stage. Serves as a reference for the return to a full, or near full, charged state.

**Start voltage:** Voltage measured by the CBA at the start of the pulse charging, which is the same as that at the end of the Discharge stage.

**Finish voltage:** Voltage measured by the CBA after pulse charging and 1 hour stabilisation.

**dV:** Difference between the finish and start voltages

**Test ID:** As per for Discharge but for the 'Charge Monitor' files

**Screen grab:** As per above

**Comments:** Any useful comments or test identifier

## *Interpolation graph:*

*This small table carries the data to allow a graph of voltage against energy supplied by the supply battery to the generator to be plotted. This can then be extrapolated, or in some case interpolated, to give the value of energy supplied to the generator for the battery to reach $V_{(pk)}$*

**E supplied:** The energy supplied taken from Table 2 (Supply). The first value is set as zero and the figure beneath the calculated value for energy delivered to the generator.

**'Rec' Batt V:** The upper value is the start voltage and the lower the stablised finch voltage. Depending on the values, the 'Axis scale' of the graph for 'Value Y' [terms used in Numbers for Mac] might need to be adjusted to show all of the line.

**$V_{(pk)}$:** The reference value for the return of there battery to ‘full’ charge or, if not full charge the starting voltage for the test at the beginning of the first discharge stage.

When you have a coloured line plotted, then the thin black line is laid over it and where this line intersects the red dotted horizontal line depicting $V_{(pk),}$ then the reading taken off the X axis, by dropping a vertical line to it, is the extrapolated value of the energy supplied to the generator to return the receiving battery to the starting voltage.

## *CoP & Uncertainties:*

*Derives the CoP values and the associated uncertainties*

**Capacity:** Battery capacity taken from table 1

**%Ah:** The %capacity discharged

**HV:** The peak HV used

**PRF:** The pulse frequency

**E received:** The energy discharge and therefore replaced in the charing process, even if in part this is being extrapolated from a partial recharge.

Δ**Er:** The Absolute Uncertainty in the Energy received. Calculated by combining the individual Relative Uncertainties in the appropriate manner and multiplying this by the total energy received. (See the Uncertainty Analysis document in the Appendices)

δ**Er:** The Relative (Fractional) Uncertainty in the Energy received. Calculated as the uncertainty divided by the total energy value.

**E supplied:** The extrapolated or interpolated value from the graph in the previous step

δ**V:** The Relative (Fractional) Uncertainty in the Energy received. Calculated as the uncertainty divided by the total energy value.

**δi:** The Relative (Fractional) Uncertainty in the Energy received. Calculated as the uncertainty divided by the total energy value.

**δt:** The Relative (Fractional) Uncertainty in the Energy received. Calculated as the uncertainty divided by the total energy value.

**δEs:** The Relative (Fractional) Uncertainty in the Energy received. Calculated as the uncertainty divided by the total energy value.

**ΔEs:** The Absolute Uncertainty in the Energy received. Calculated by combining the individual Relative Uncertainties in the appropriate manner and multiplying this by the total energy received.

**CoP:** The derived Coefficient of Performance calculated from the energy received by the battery / energy supplied to the generator

**δCoP:** The Relative (Fractional) Uncertainty in the Energy received. Calculated as the uncertainty divided by the total energy value.

**ΔCoP:** The Absolute Uncertainty in the Energy received. Calculated by combining the individual Relative Uncertainties in the appropriate manner and multiplying this by the total energy received.

**CoP & ΔCoP:** Final figures of CoP and uncertainty

**Comments:** Relevant notes.

## *Summary Table:*

This brings together all the useful data into a single table and includes additional calculations regarding the theoretical amount of power that could be produced.

For nine columns, **'Capacity'** to **'CoP'** as described before. Then:

**Energy available:** This is derived from the energy returned to the battery minus the energy delivered to the generator. In theory, the difference is the amount that could be

used by an external load and still result in the batteries maintaining their voltages over a series of swap cycles.

**Time taken:** Calculated as the time taken to reach back up to $V_{(pk)}$ based on the voltage actually reached after the run time.

**Max Power available:** Calculated as energy available / time taken

## *CoP and Available power vs variables:*

This brings together useful data into a single table with regard to meeting a specific %capacity discharge

First eight columns, **'Capacity'** to **'%Ah'** as before. Then:

**Charge time:** The actual time charged which is the same as the swap time in normal operation

**CoP:** As before

**Time to replace E:** As **'Time Taken'** above

**Load I:** Total load current required to achieve %Ah discharge in the full recharge time where
I = (Discharge x %Ah) / t

**Ext Load I:** Total load current minus that required to run the generator. This equates with what is available for the external load.

**Ext Power:** The external load value above  times an average assumed battery voltage over the run time. This is taken to be 12.5V but is an estimate and will be higher for part of the charge period and also lower, due to the load, for a proportion of the time. It is not supposed to be very accurate and the actual power tests will provide useful figures and also incorporate hidden factors not observed or accounted for in the CoP tests.

**Comments:**  As above.

## *Current table:*

*The cells in a column are copied in from the exported XLS file from the Owon RDM. Once in the cells the ADC characters need to be removed so the data can be processed. Depending on your operating system it is possible to set up a macro or file that will zip through the values and remove these characters. Once done, at the bottom of the column, the average and Standard Deviation are calculated as well as the Min, Max and Range, the Absolute Uncertainty in the current value and the Relative Uncertainty.*

**Data points:** Copied from the RDM export file

**Mean, SD etc:** The Mean current value is manually entered into Table 2 (Supply) using this value.