Efficiency Answers.

Regular readers will know that I have referred to the efficiency of brushless outrunners at different voltages twice in recent issues. The original question arose from an anomaly in the test results of the Tornado Thumper motors in the September issue, and this was followed by some further work in the December issue where I unsuccessfully attempted to relate the problem to the controllers used by brushless motors. I have since received what I hope if a definitive explanation of the effect from Wayne Giles and I print it here for those who, like me, are irritated by unanswered questions.

"The problem is to decide why the 4 cell pack is at a disadvantage when compared to the 3 cell pack. When the motor is running at a constant rpm (thrust) the duty cycle of the ESC is lower at the higher voltage. This means that the FETS are switched on for a shorter period and the flywheel diodes are therefore on for a longer period. The saturation
voltage across the FETs is a lot less than the volt drop across the diodes (about 0.2V compared to about 1V) and the saturation losses are proportional to these voltages. I discussed this analysis with a colleague who is experienced in this area and he agreed that this was correct, but he also pointed out that at the higher voltage, the rate of change of flux in the motor is proportionately higher and therefore the iron losses in the stator are higher. We think that the extra losses are about 1/3 the former (diode and FET) and 2/3 the latter (iron losses in motor). The combination of the two effects is well able to override the expected efficiency gains of the higher voltage and leave the higher voltage operation at an overall lower efficiency."

Thank you very much for that Wayne. I know that it is a fairly complex explanation but it does seem very logical and hopefully it will bring that particular irritation to a conclusion.

Principles of Test Analysis.

I have some more Lipo testing results available later, but I thought I would spend a little time assessing the relevance of my approach to testing. Some of you may know that my former (many years former now!) profession involved a good deal of laboratory testing, much of it on a commercial basis. The scale of the work (involving construction materials such as concrete and steel) was somewhat larger than I tend to cover in this column, but the principle is the same. If the results of the testing are to be commercially applied, and even more so if they are to be published, then the testing needs to be carried out using strictly controlled procedures, with accurately calibrated equipment, and involving sufficient samples to allow statistical analysis of the results.

You will realise on reading this, that my testing for this column falls well short of these ideal principles, but does that imply that my work is unreliable? You will have your own opinions about this, but I will defend my efforts from at least one point of view, and that is expediency. I would be delighted if I had the opportunity (and funds) to carry out my work in a fully equipped and accredited laboratory with an unlimited number of test samples, but since I do not, I attempt to do the best I can in my much more limited facilities. I hope that those who read the published results will appreciate this situation and interpret them accordingly, as guidance rather than as gospel.

There is one particular form of testing which illustrates the situation perfectly, and that is trial and error testing. Whenever you are attempting to determine the effect of one particular variable upon a complex system, the simplest form of testing is simply to change that variable and see what it does to the system. This is trial and error (or suck it and see – SIAS) and this will tell you what happens, but not why it happens. Again this should be looked on simply as guidance, but that is often enough to solve the immediate problem.

LiPo charge rates.

The standard recommendation for charging lipos is that the maximum rate of charge should be 1C (i.e. a maximum charge current of 2.2 amps for a 2200 mAh pack). Using this means a charge period of well over an hour (allowing for the decreasing current after the volts/cell reaches 4.2) and this is much longer than it used to take to fast charge nickel-based packs. I do not know the origin of this limitation but I suspect that it is linked to the chemistry of the cell rather that to its physical behaviour. Some manufacturers have been experimenting with faster charge rates but there is no consistent pattern here and there has not been a big publicity drive to promote such a change.

If you are familiar with my previous testing, you will know that I have obtained very good results from the Overtec Tornado Professional packs, and I was pleased when Overtec asked me if I would look into the effects of accelerated charging on these packs. This, incidentally, is a great example of SIAS testing and I will comment on this fact later. I was sent a set of three Tornado Professional 2200 mAh 3S 25C packs and asked to test them at increasing charge rates. I had already tested this particular pack as one of the set involved in the 100 cycle tests last year so was familiar with the performance expected at 1C and was happy that this kind of performance would be an ideal starting point.

Testing.

The aim of the testing was to investigate the pack performance over a reasonable range of charge/discharge cycles when the charge element of the cycle was higher than the 1C recommendation. I wanted to complete the testing within a reasonable time scale and therefore decided to set 50 cycles as the testing range. Although these packs are rated at 25C discharge, they carry the very sensible recommendation that the maximum discharge in day-to-day usage be limited to 20C. This would give a 44 amp load and I rounded this down to 40 amps (actually 41 amps due to a minor calibration problem). The charging was similarly rounded to 2 amps (equivalent to 1C), 4 amps (equivalent to 2C), and 6 amps (equivalent to 3C), for the three packs.

The equipment used for the testing was the test bench I have covered in previous lipo cyclic test reports, and this system already involves a dedicated charger (constructed with the full lipo charge program but without the cut-off facility, as this was already included in the control module). This unit allows an adjustable charge current in 0.5 amp steps so was ideal for this particular application. All three of the tests were completed without problems running smoothly to completion at 50 cycles. The results were converted into graphical format and you will find Graph 1 as a typical full 50-cycle sequence (for the 2C test in fact).

Analysis.

The first point to make is that the cycle time is not proportional to the charge rate. Even where the charge period is reduced by a certain factor, the discharge and dwell periods are unchanged and you will see from Graph 2 that the actual cycle times were 5200 seconds, 4000 seconds, and 3000 seconds for the 1C, 2C, and 3C tests respectively. As I have indicated in past columns, the main variable used to assess pack performance is the capacity of the pack at its rated discharge, and even more importantly, the reduction in this capacity as the number of cycles increases. In Graph 1 the capacity for each discharge is shown by the upward step in the green trace. If these are plotted against the cycle number you get the graphs 3, 4, and 5 for 1C, 2c, and 3C charge rates respectively. There is a certain amount of variation in these traces and I have therefore added a trend line to each with the loss in capacity represented by each trend line shown on each graph.

It is only when you compare the trend lines in graph 6 that you begin to see the effects of the increased charge rate. It is clear that the increased rate of charge leads to an increased loss in capacity per cycle. The pack performance at 1C charge is excellent (as it was in the original tests) but increasing the charge rate to 2C leads to a below average performance, and increasing it to 3C results in the pack reaching the nominal failure level (arbitrarily set at 20% loss of rated capacity) within 50 cycles and this must be considered to be a non-viable approach. There is one other feature of Graph 6 which is interesting, and that is the initially increased capacity of the packs with higher charge rates. You will see that the trend lines not only steepen as the charge rate increases, but that the early capacities are greater for the higher charge rate lines. This gives capacities on cycle 1 of 2.18 Ah for 1C charging, 2.23 Ah for 2C charging, and 2.35 Ah for 3C charging, with the trend lines intercepting at between 20 and 25 cycles. This increase is limited to the first 20 cycles so is probably of little practical use.

I mentioned earlier that this was a good example of SIAS testing so please interpret this data in terms of these limitations. I hope it provides the reader with a broad indication of the probable effect of accelerated charging of lipo packs, but it should not be considered as a definitive investigation of this particular aspect of the use of LiPo batteries.

Sources of data – a reminder.

Readers may have noticed some slight anomalies within recent columns in terms of continuity. I normally try to introduce a degree of variety in the column (spice of life?) but also try to set up some links between the variations in the content. Recent issues of the magazine have included versions of the Technology column which, for various editorial reasons, have required last minute changes to the content, and this has led to certain illogical positioning of topics. I apologise if this has confused any readers but I am taking this opportunity to remind you that there is an alternative source for much of the material I cover. This is on my website (http://homepage.ntlworld.com/bobsmith) where I have recently been increasing the content of the site so that you will not only find the graphs and tables to a larger scale for much easier assessment, but you will now find text and photos in support, and additional unpublished material where appropriate. Why not check it out, you might find it interesting.

Contacts.

OverTec, Jesmond Dene Trading Estate, Forton, Nr Lancaster, Lancs PR3 0AT – Tel 01524 793328
website www.overlander.co.uk

Modelec, Wayne Giles, Biggin Hall Lane, Thurlaston, Warwickshire CV23 9LD Tel +44(0) 1788 817 413
email **waynegiles@modelec.co.uk** website **www.modlec.co.uk**

Photographs.

QEFI72-1 **The three Overtec LiPo packs used in the tests.**

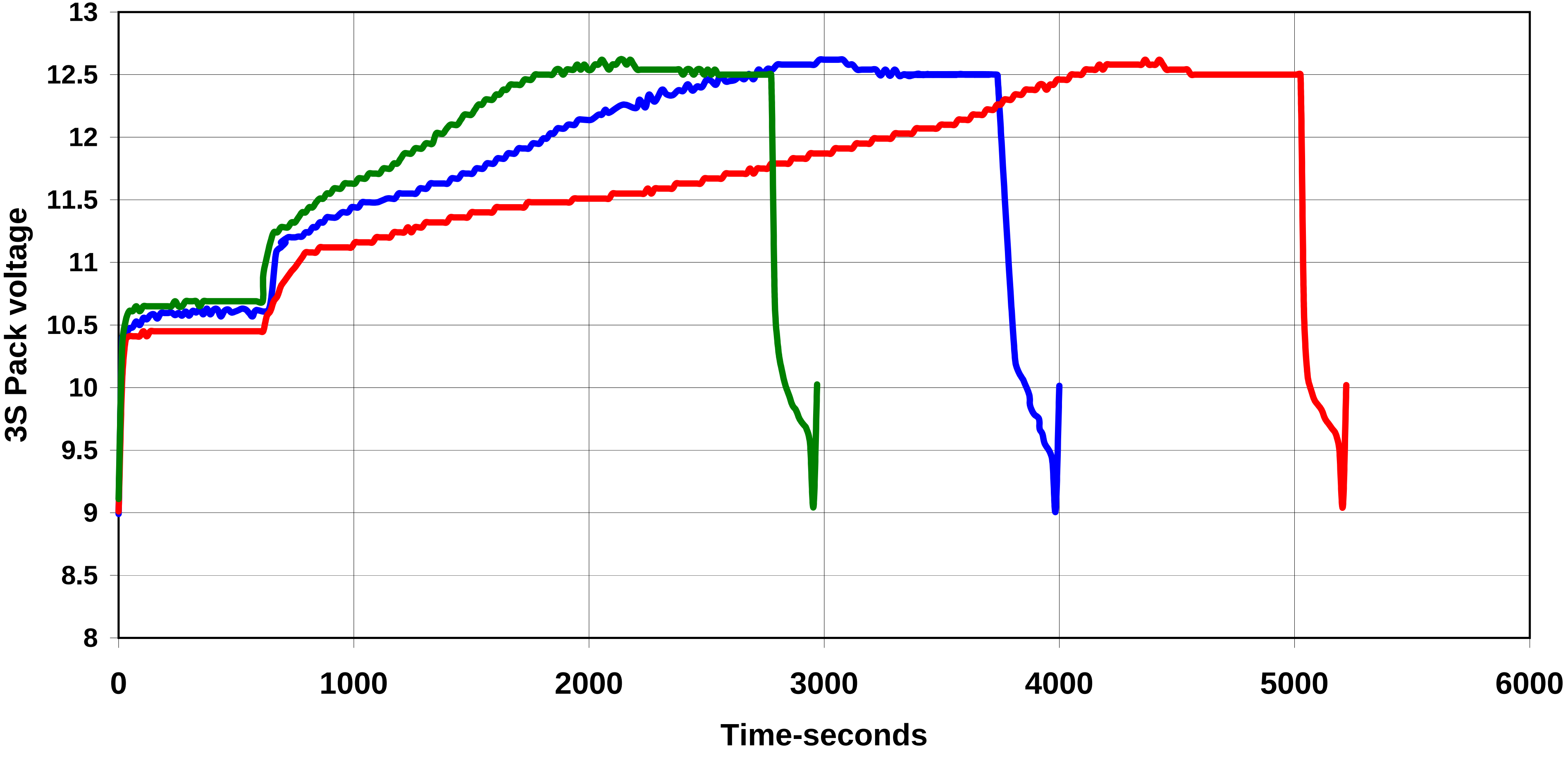
QEFI72-2 **One of the Overtec LiPos as packaged with appropriate safety guide.**

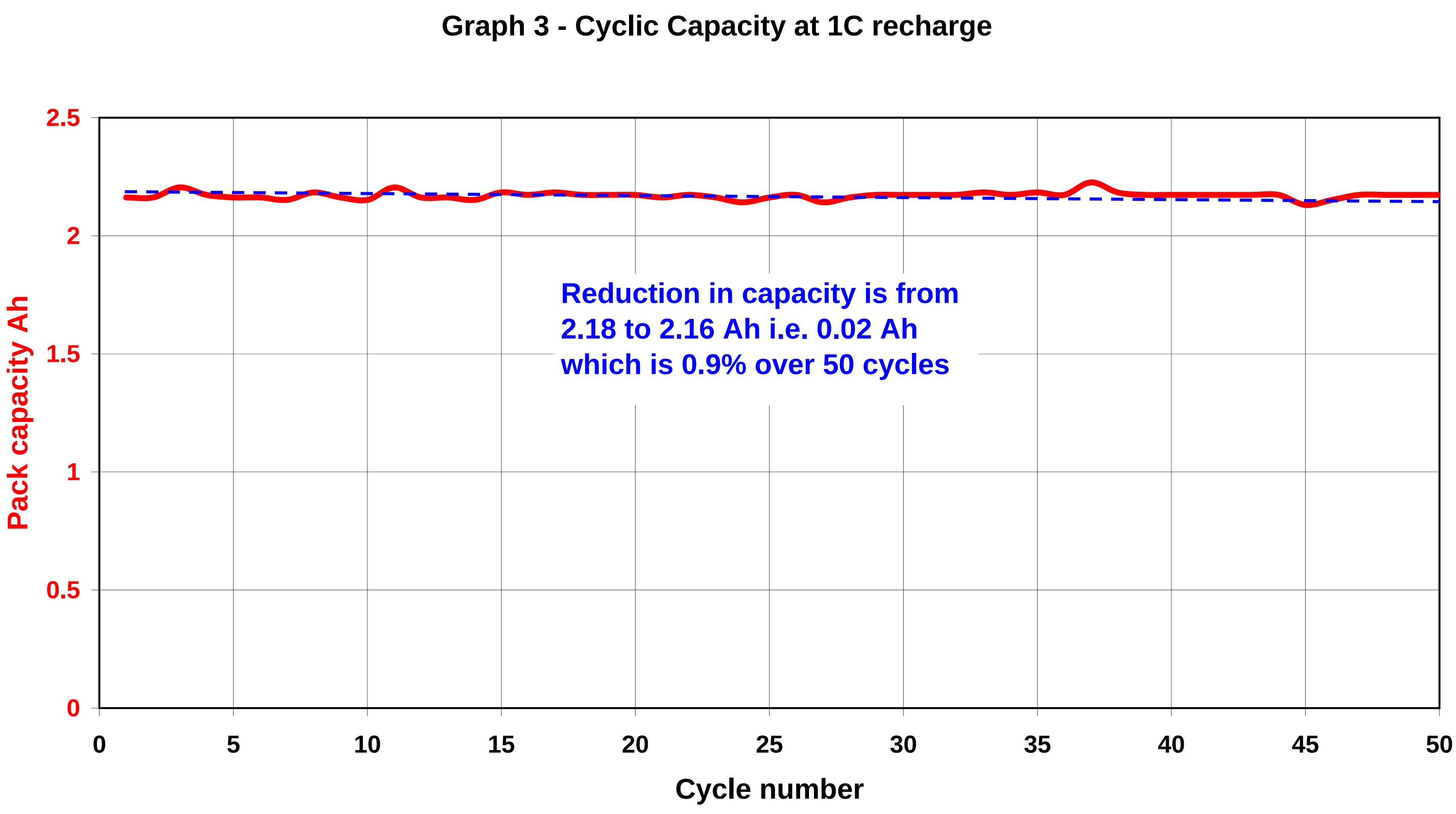
QEFI72-3 **Labelling of the Overtec LiPo with all relevant data.**

QEFI72-4 **Graph 1 – The data plot for the voltage and capacity over a 50 cycle test.**

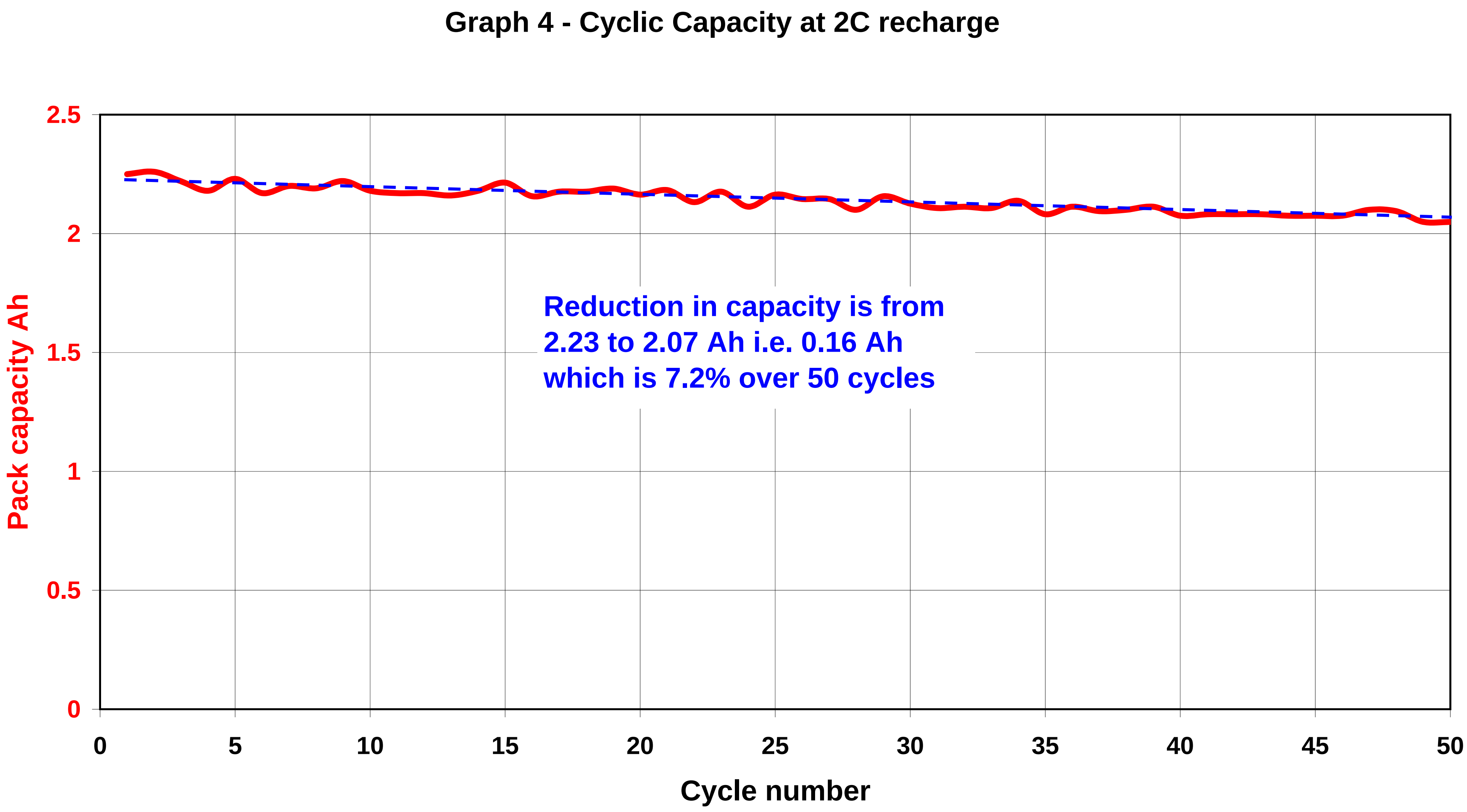
QEFI72-5 **The dedicated charger set-up for a 4 amp charge (equivalent to 2C for the 2200mAh pack).**

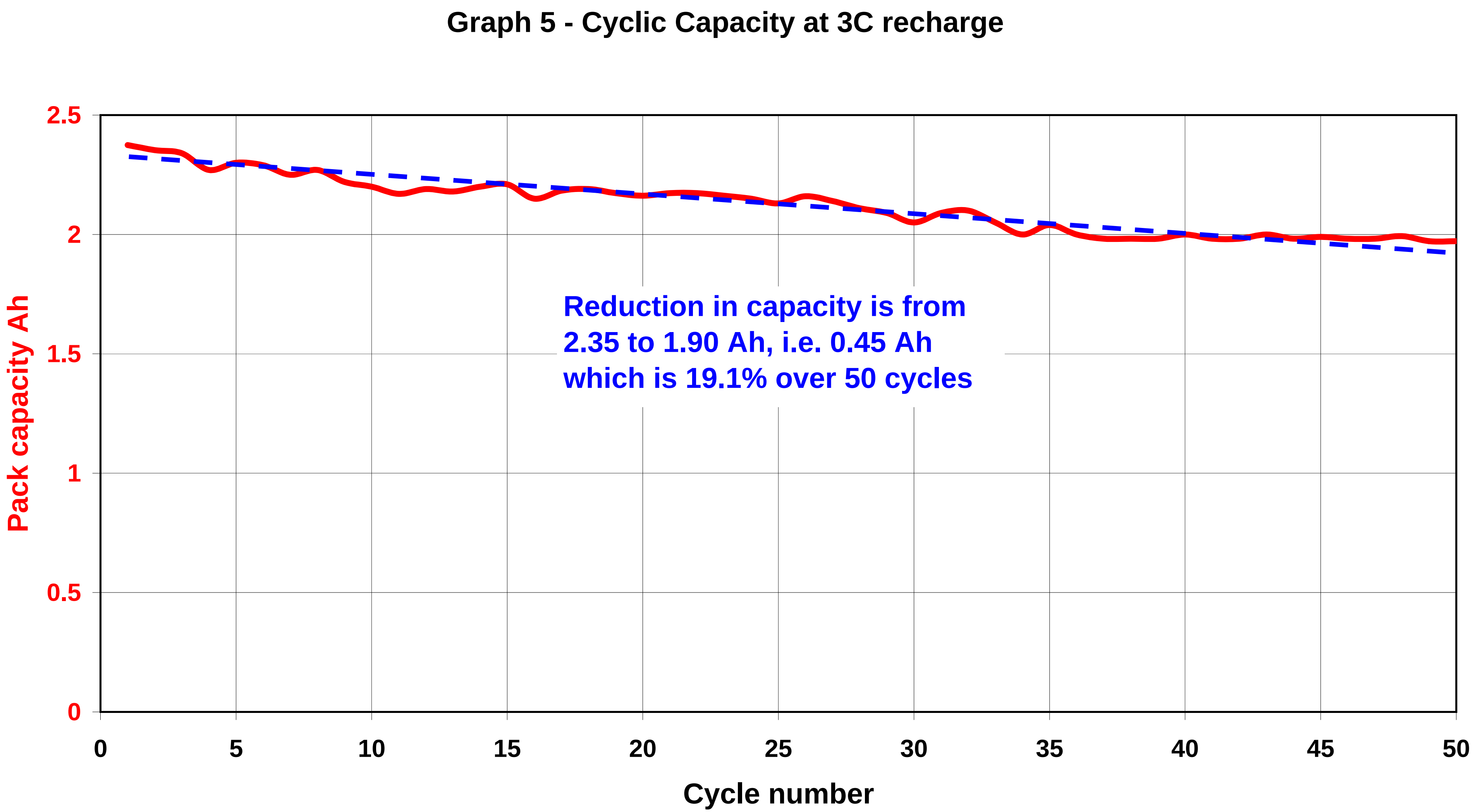
Graph 2 - Single cycle comparison for 1, 2, and 3C charging.



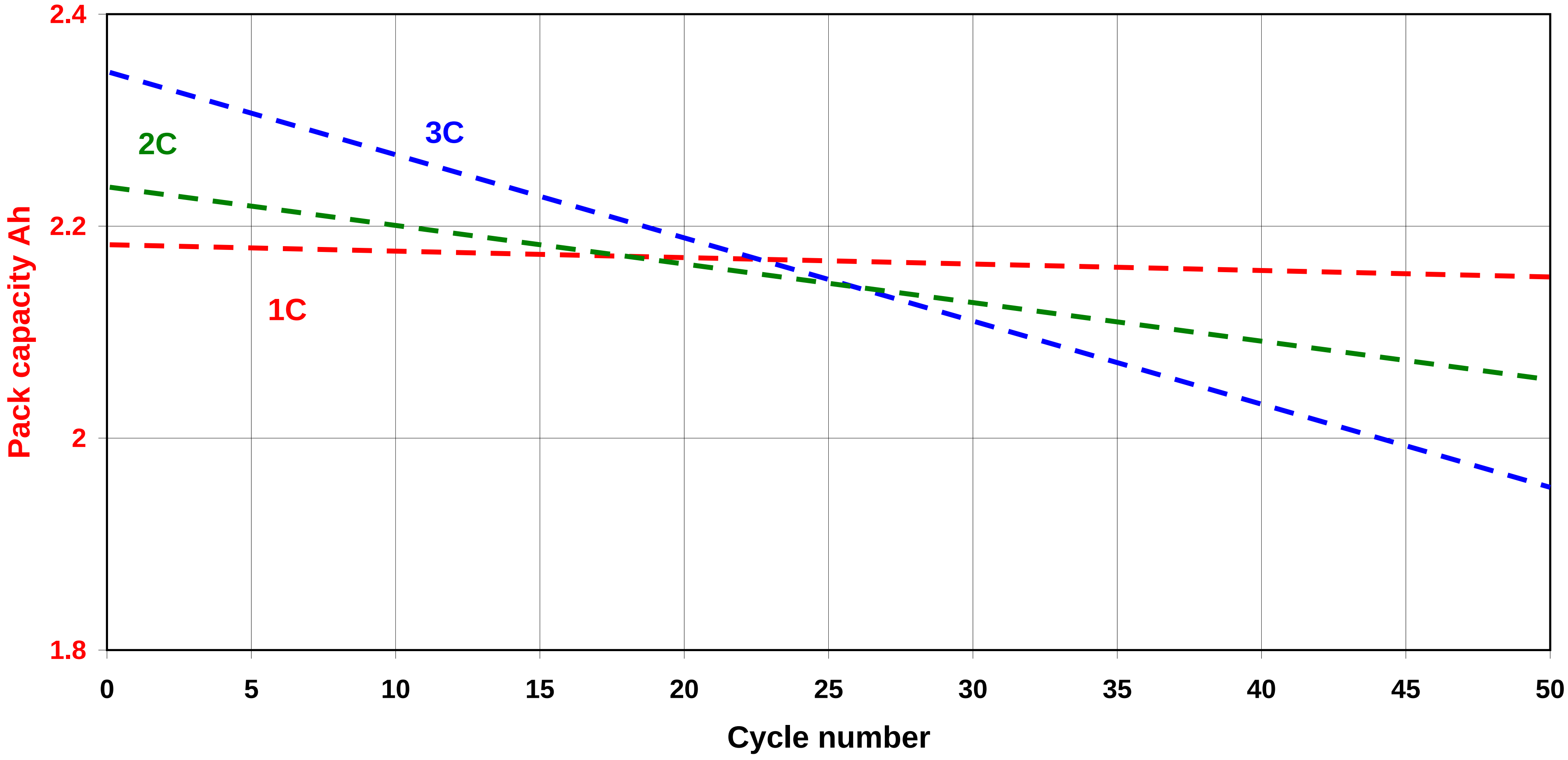


Graph 3 - Cyclic Capacity at 1C recharge
Pack capacity Ah
2.5
2
1.5
1
0.5
0
0
5
10
15
20
25
30
35
40
45
50
Cycle number
Reduction in capacity is from
2.18 to 2.16 Ah i.e. 0.02 Ah
which is 0.9% over 50 cycles


Graph 4 - Cyclic Capacity at 2C recharge
Pack capacity Ah
Cycle number
Reduction in capacity is from
2.23 to 2.07 Ah i.e. 0.16 Ah
which is 7.2% over 50 cycles
0
0.5
1
1.5
2
2.5
0
5
10
15
20
25
30
35
40
45
50


Graph 5 - Cyclic Capacity at 3C recharge
Reduction in capacity is from
2.35 to 1.90 Ah, i.e. 0.45 Ah
which is 19.1% over 50 cycles
Pack capacity Ah
Cycle number
0
0.5
1
1.5
2
2.5
0
5
10
15
20
25
30
35
40
45
50

Graph 6 - Comparison of trend lines for 1, 2, and 3C charging.



File information | Graph

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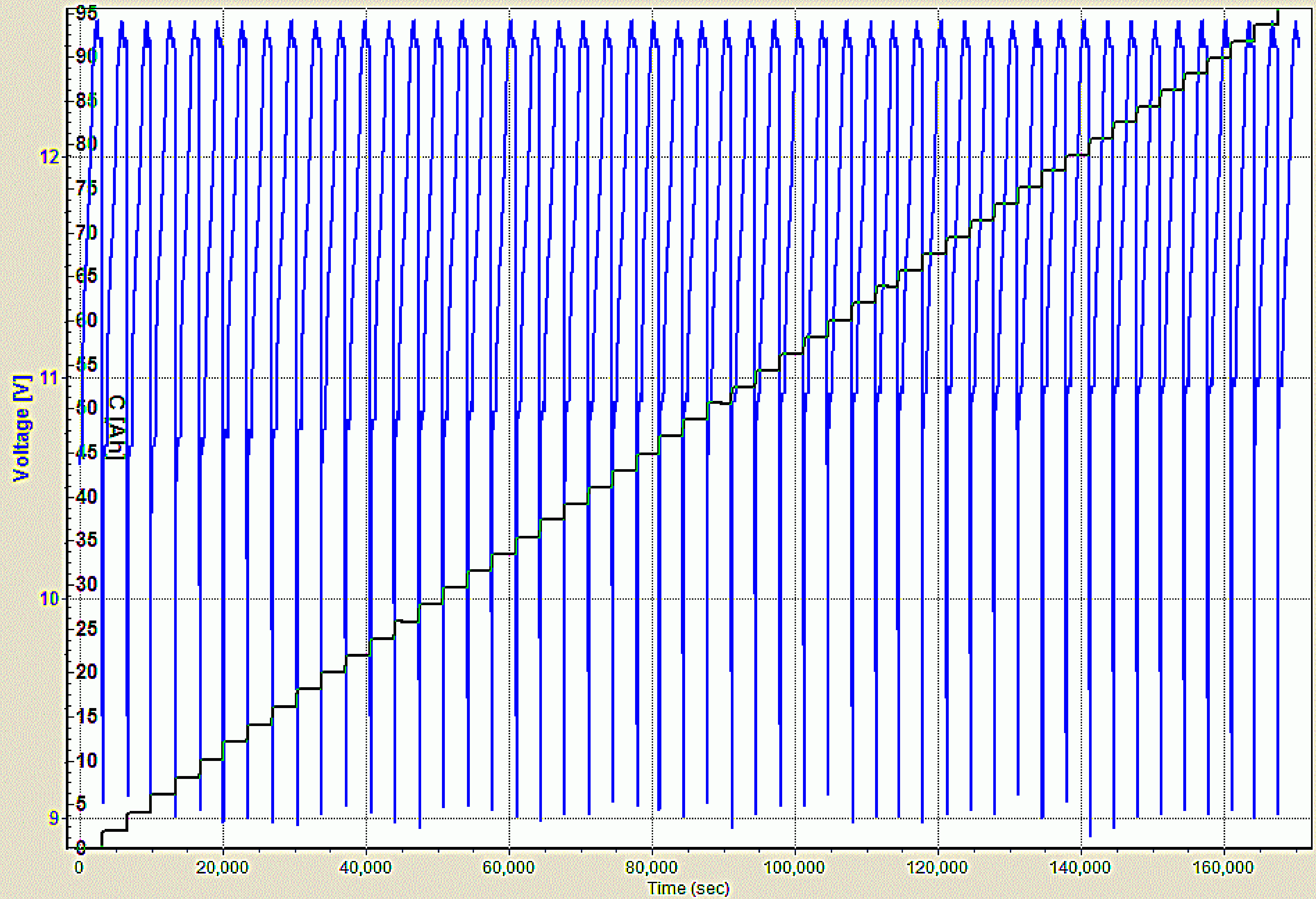
Graph 1 - 50 cycle test at 2C charge - 20C discharge



min:sec

TornP22002Ca

Block Data

Max I	41.33	[A]
Avg I	2.02	[A]
Max U	12.62	[V]
Min U	8.92	[V]
Avg U	11.75	[V]
Max P	449.00	[W]
Avg P	19.65	[W]
Max R	0	[RPM]
Block C	95.55	[Ah]
Block E	930.95	[Wh]
Samp.rate	15.00	[s]
Rec.time	2842:15	

Cursor Data

U	10.89	[V]
I	0.00	[A]
R	0	[RPM]
C	37.38	[Ah]
P	0.00	[W]
E	365.07	[Wh]
Time	1081:13.2	[min]


TORNADO
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PROFESSIONAL 11.1V 3S1P
25C (55A) constant discharge, 50C (110A) bursts
We suggest max. 44A
discharge for cool running
and long pack life
25C
BY FULLYMAX®
eXtreme


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BY FULLYMAX®
We suggest max. 44A
discharge for cool running
and long pack


TORNADO
2200
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25C (55A) constant discharge, 50C (110A) bursts
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and long pack life
25C
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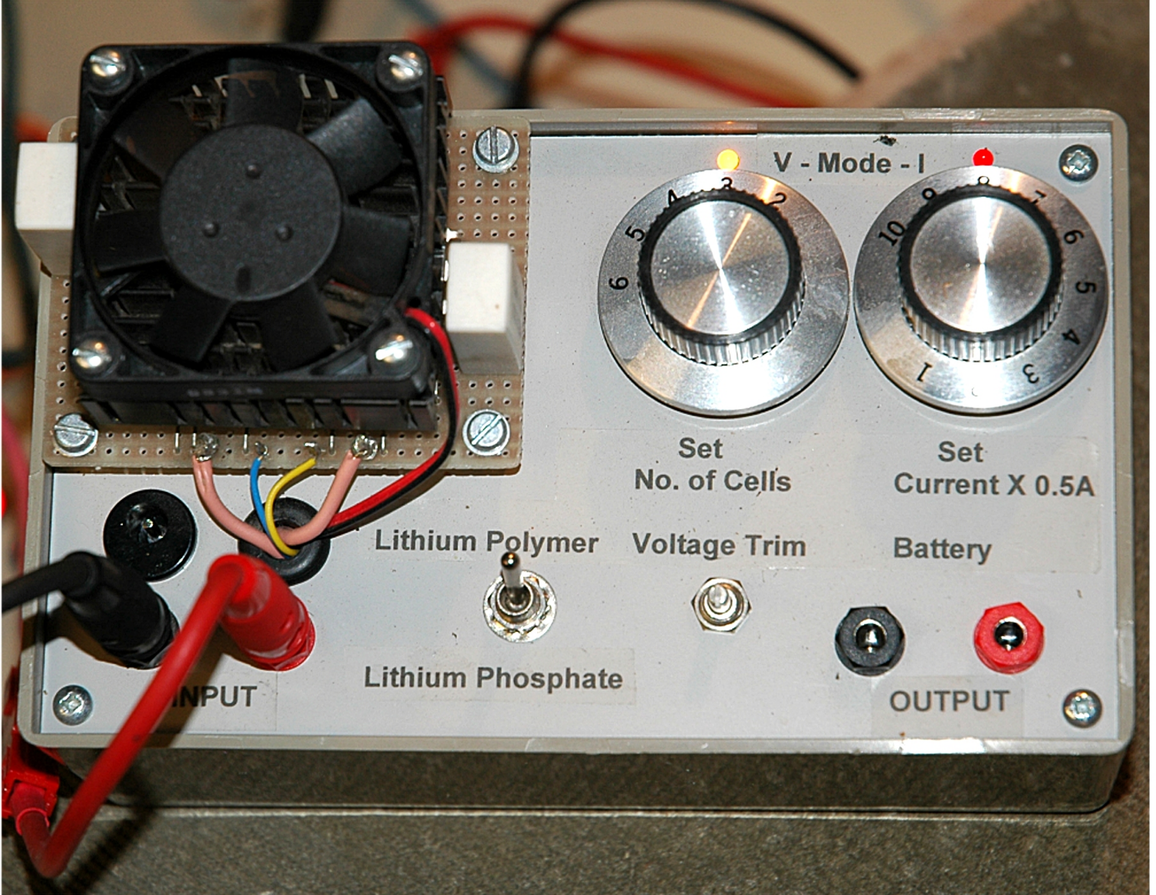
FULLYMAX®
eXtreme


V - Mode - I
Set
No. of Cells
Set
Current X 0.5A
Lithium Polymer
Voltage Trim
Battery
Lithium Phosphate
INPUT
OUTPUT