Lithium power (non-polymer).

Most readers will, like me, be interested in all forms of electric flight power systems and will already know that lithium polymer cells are not the only lithium-based systems which are being developed. They were certainly the first to be manufactured in large quantities and have made significant inroads in the mobile phone, laptop, and power tool markets. Their power/weight ratio is so high that these developments are very logical, but readers will also be aware of the problems which have arisen in this area with several, well publicised, recall announcements leading to a reputation for unreliability. Some equally well publicised accidents in the modelling world have made modellers very cautious, and have led to a search for alternatives which have at least some of the advantages of lithium polymer, but which are reliable and safe in comparison.

There have already been a number of cells and packs introduced to the market, often with claimed performance which was never achieved in practice. I am currently testing two particular cells which may well be a viable solution to achieving lithium performance with reliability and safety. Both of these have been supplied to me by Alan Fry of ImporTeknik and I think you will be interested in my test results.

A123

I actually did a very brief test on a pack of these cells from a different supplier back in the July Q&EFI but it was a very limited introduction to the system so I am going to start from scratch on this occasion. These cells (M1 is the only size available at the moment although there are rumours of a smaller cell in the future) are based upon Lithium Iron Phosphate chemistry (LiFe or LiFePo4). A123 Systems claim that the “nano” technology used in the production of these cells is the secret of their extreme performance and their application within many new technologies (e.g. hybrid cars) seems to support this. The specification of the cells (including size and weight) is given in the table and the samples I had available to test were a 3S1P and a 3S2P pack. There is one aspect of the A123 specification which needs some care, and that is the charging voltage. The specified maximum value is 3.6 volts which is well below the LiPo value of 4.2 volts. If these cells are to be used optimally then a charger which has a suitable programme should be used although I have seen the use of LiPo charge programmes recommended. It is true that these cells are much more resistant to voltage variations (both over and under voltages for charge and discharge) than LiPos, and can be occasionally taken outside of the specified range (3.6 to 2.0 volts), but this should not be a regular procedure. I used the Bantam BC6 charger which has an LiFe programme and there is a typical charge pattern in the first graph. I did use the balancing lead but it is recommended that balancing need only be an occasional process. Two other features of the cell which the user needs to know are the reversed polarity (the cell outer case is the positive electrode whilst the top button is the negative) and the fact that although appearing loose, this top button should not be rotated as this leads to cell damage.

My initial testing needed to be based upon one-off test runs of the type I have used many times in the past, but I do hope to do some long term cyclic testing at sometime in the future. I started by testing the discharge capacity of the two packs at both typical and higher loads with the results shown in the graphs. My intention was to look at the performance of the packs under the loads commonly used by electric flyers so chose 30 amps and 60 amps. You will see from the specs that the maximum continuous current draw for these cells is 70 amps (which in the case of the 2P pack would be a rather unrealistic 140 amps) so I was well inside the limits. In the case of the 3S pack I only used 30 amps but used both 30 and 60 amps for the 3S2P. Charging was another area where there was more flexibility than we expect from Lithium based systems so I was able to charge at both 5 amps and 20 amps without any problem, at least in the short term.

All of these tests are shown in the graphs, graphs 1 and 2 showing the charging patterns for 5 and 20 amp charging, graphs 3 and 4 showing typical discharge curves for the 3S2P pack. Graph 5 is a comparison of 30 and 60 amp discharges for the 3S2P pack and shows the voltage depression which results from increased load. Graph 6 is a comparison of the 3S pack discharged at 30 amps and the 3S2P pack discharged at 60 amps (which is effectively subjecting the cells to the same load). You will see how close the discharge curves are, although, of course, the 2P pack has almost twice the capacity of the smaller 1P pack. The other points which are worth mentioning as they might be important in some situations are the particularly flat discharge plateau for these packs (such constant voltage is usefully linked to a consistent power run for the mid 80% of an in-flight discharge), and the relatively sharp drop off at the end of discharge (which may be important if using BEC).

LiMn.

These cells use a very different chemistry to the A123 lithium phosphate system (and, of course, to the lithium polymer one). They are based on lithium manganese dioxide and are produced under the Molicel tradename as Moli IMR 18650 cells. You will see from the specification that they are the same length as the A123s but this particular cell is only 70% of the diameter and 60% of the mass of the larger cell. There are other sizes of cell in this range but only the 18650 is under test. These units have a normal polarity (-ve case and +ve button) and are charged/discharged in an identical manner to LiPo packs (4.2 maximum charge voltage). There are some subtle differences between the charge patterns of the different types of cell and you will see this in the graphs. I will comment on this later.

The pack I had for testing was a 3S2P flatpack (again from Alan Fry) and I followed the same test pattern as I had used for the A123 cells. I chose limits appropriate to the specification so that the pack was charged initially at 5 amps and subsequently at 9 amps (using a 4.2 volt upper limit on the BC6 charger) and the details are in graphs 7 and 8. Note that this pack is not fitted with a balancing lead and although the manufacturer of the pack indicates that this is not required, I would keep a sharp eye on the individual cell voltages as the pack was used. As with LiFe, there seems to be less chance of damage to the cells if you accidentally take them outside of the maximum/minimum voltage specification, but this is still best avoided if possible.

The discharge tests were set at 20 and 40 amps and the pack handled these without problems. The curves are shown in graph 9 and the shape of the discharge curve is very similar to the A123s (and to LiPo packs as a matter of fact) so the only differences are in terms of the numbers. In this respect these cells are clearly different in performance from the A123s and you will also see from the specs that they have less ability to handle high loads (the maximum continuous current is 14C for LiMn and 30C for LiFePo4). When, however, you look at the power available from the **2P** pack then you might conclude that 40 amps at 9 volts (360 watts) is plenty for the majority of club flyers.

Comparison.

It is not always logical to attempt to draw too many conclusions from the comparison of test results like this. It depends how you use the comparisons you draw, but I will make some in this case, if only out of interest. The first and most obvious one is in terms of energy density. If we look back at our previous NiMH systems then a typical sub-C cell would weigh 70 grams and have a 4.3 Ah capacity. Assuming a discharge at an average voltage of 1 volt gives 4.3 watt hours for 70 grams or 61 Wh/kg. A typical LiPo cell might have 7.9 watt hours for 55 grams or 144 Wh/kg, the A123 cell has 7.1 watt hours for 70 grams or 102 Wh/kg, and the 18650 has 5.32 watt hours for 42 grams or 120 Wh/Kg. This does not mean that the usefulness of any cell can be considered purely in terms of the energy density however as there are many other factors to consider (volume, maximum discharge, cyclic life, robustness, and safety in use for example) but these figures are interesting.

There are other factors which emerge from my testing which are less clear cut. One of the problems which all lithium based cells create for electric flight enthusiasts is the limitations on charging rates. I have referred to this in previous columns and have done some testing in this area, but for LiPo packs I would still recommend a 1C charge rate to optimise the cyclic life of the pack. Both of the cells tested here are considered to be able to be charged at rates higher than 1C without problems but my test results have shown an interesting outcome regarding this. Graphs 1 and 2 show the A123 pack charged at 5 amps (around 1C for a 2P pack) and at 20 amps (around 4C for the 2P pack). Note that at 1C the total time is 57 minutes (reaching 100% capacity) and the time to the 4.2 volt plateau is 50 minutes (with 95% capacity). At 4C the total is 15 minutes (100%) and to the plateau is 12 minutes (with 86% capacity).
Now look at graphs 7 and 8 which show the LiMN pack charged at 5 amps (around 1.8C for the 2P pack) and at 9 amps (around 3.2C for the 2P pack). At 1.8C the total time is 45 minutes (100%) and to the plateau is 33 minutes (85% capacity). At 3.2C the total time is 30 minutes (100%) and to the plateau is 6 minutes (less than 50% capacity). What this means overall is that there are significant differences between the various chemistries as to how the higher charge rates affect charging times, and the oft-quoted simplification that one can charge only up to the plateau and sacrifice a small portion of the capacity to achieve quicker charges is only partially true, and may, in the case of LiMN cells, be totally misleading.

Contacts.

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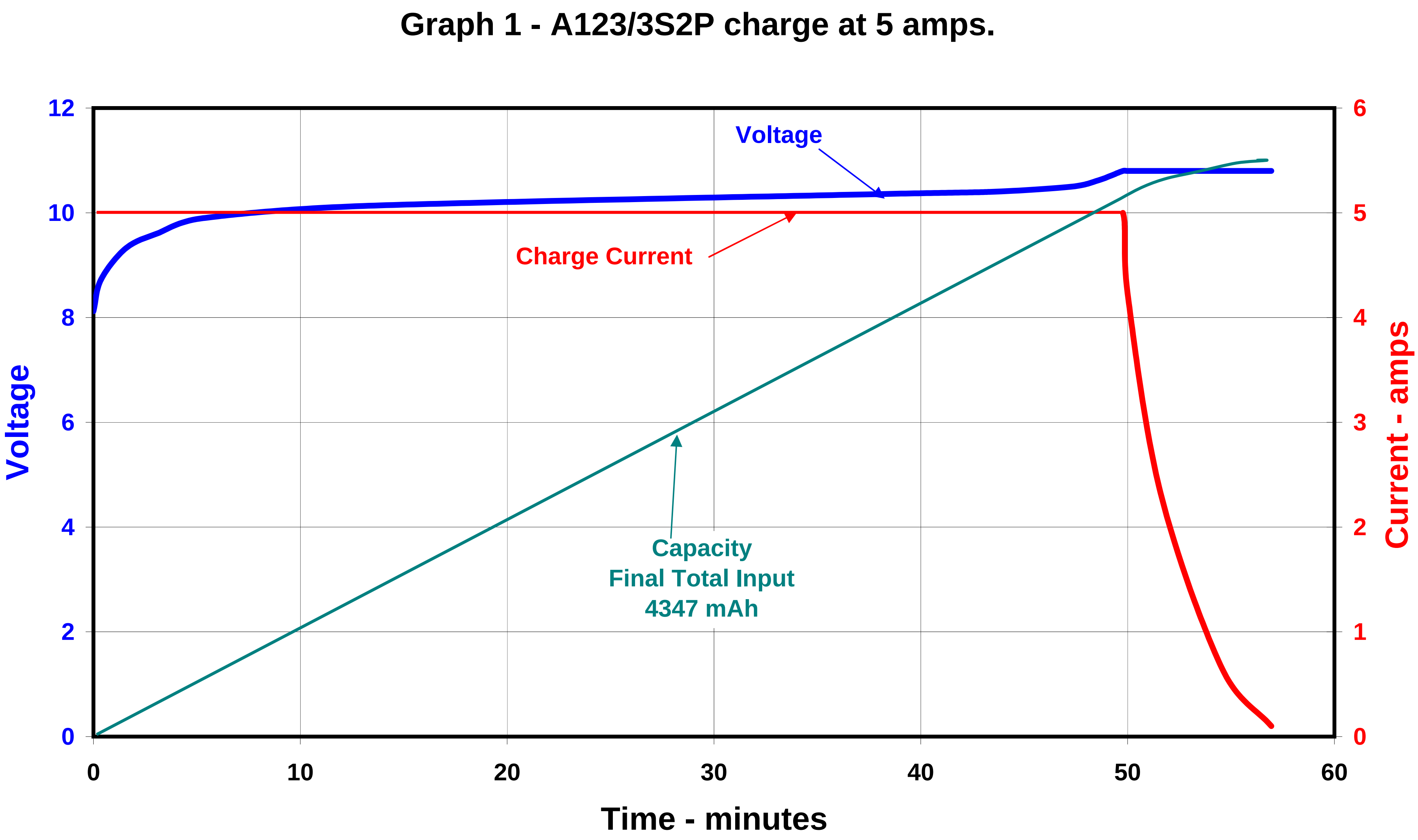
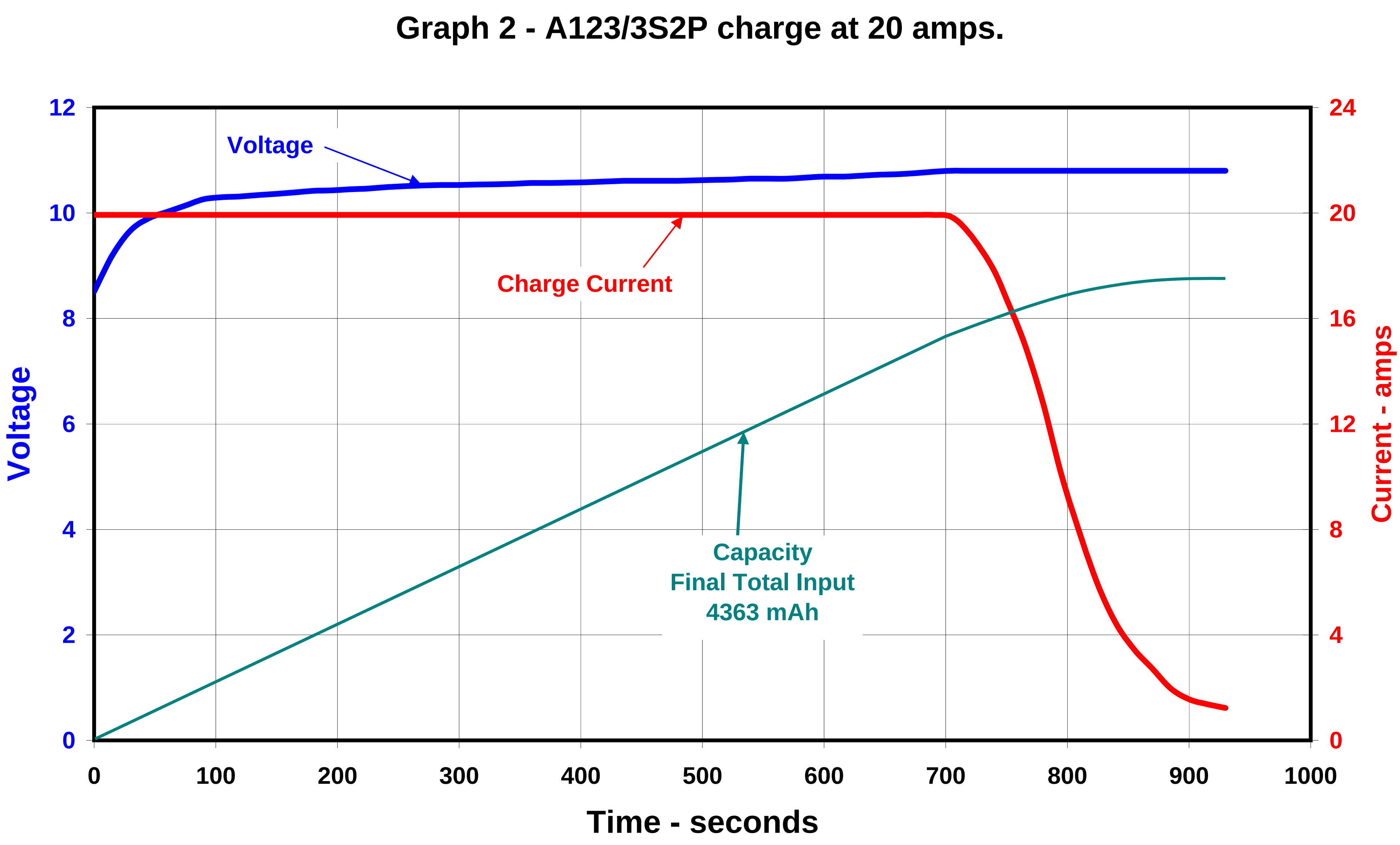
First Connect Ltd. & Co. KG, Grosse Twiete 50, D-25499 Tangstedt, Germany Tel. +49 (0) 4101/591215
email: **info@first-products.de** website **http://www.first-products.de**

Photographs.

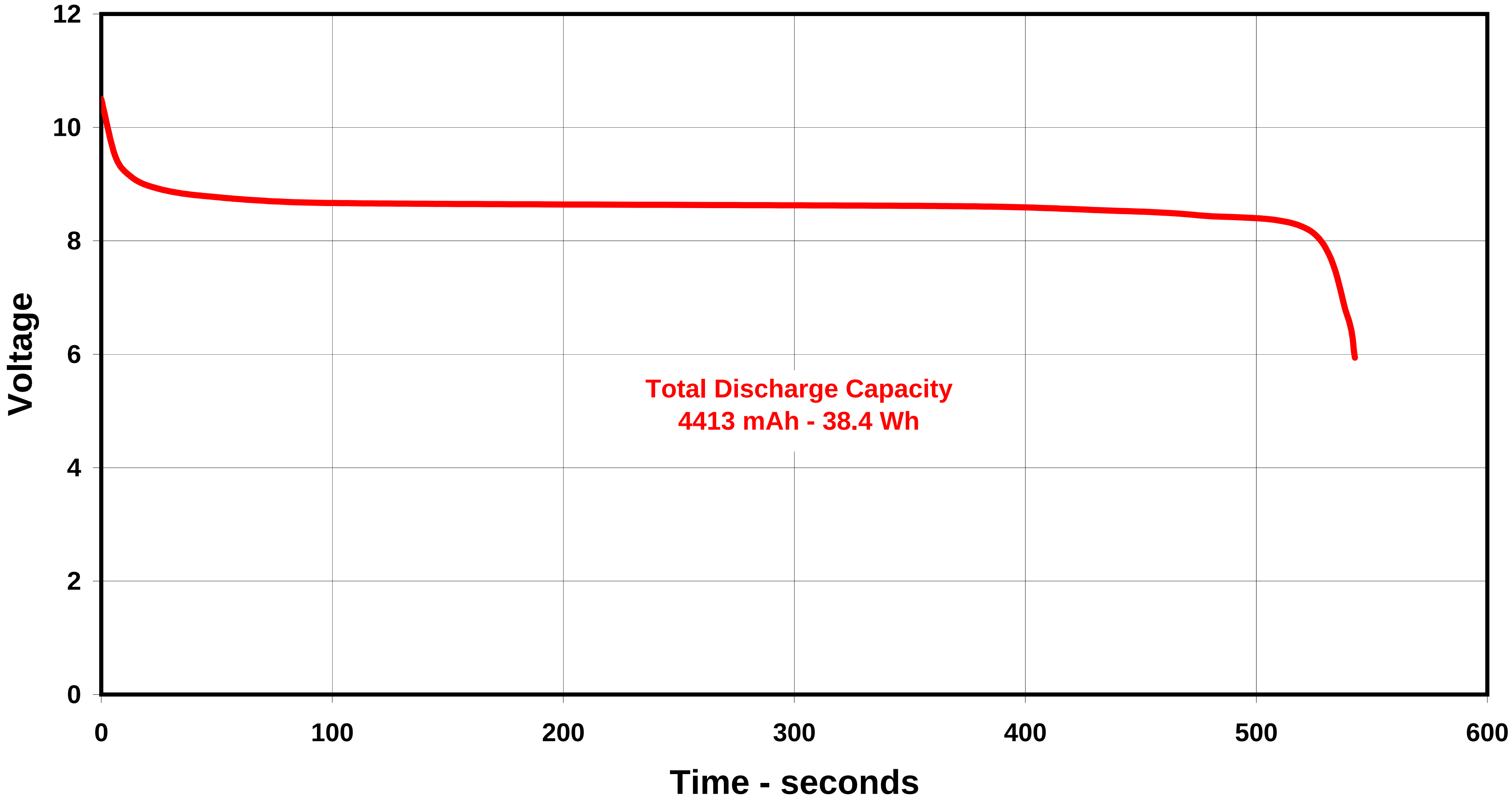
QEFI73-1	**The first A123 pack, a 3S flat pack.**
QEFI73-2	**The second A123 pack, a 3S2P flat pack.**
QEFI73-3	**The Moli IMR18650 LiMN pack, a 3S2P flat pack.**
QEFI73-4	**A single tagged Moli LiMN cell.**
QEFI73-5	**A single A123 tagged LiFePo4 cell.**
QEFI73-6	**The LiMN pack and single cell.**
QEFI73-7	**The A123 pack and single cell.**

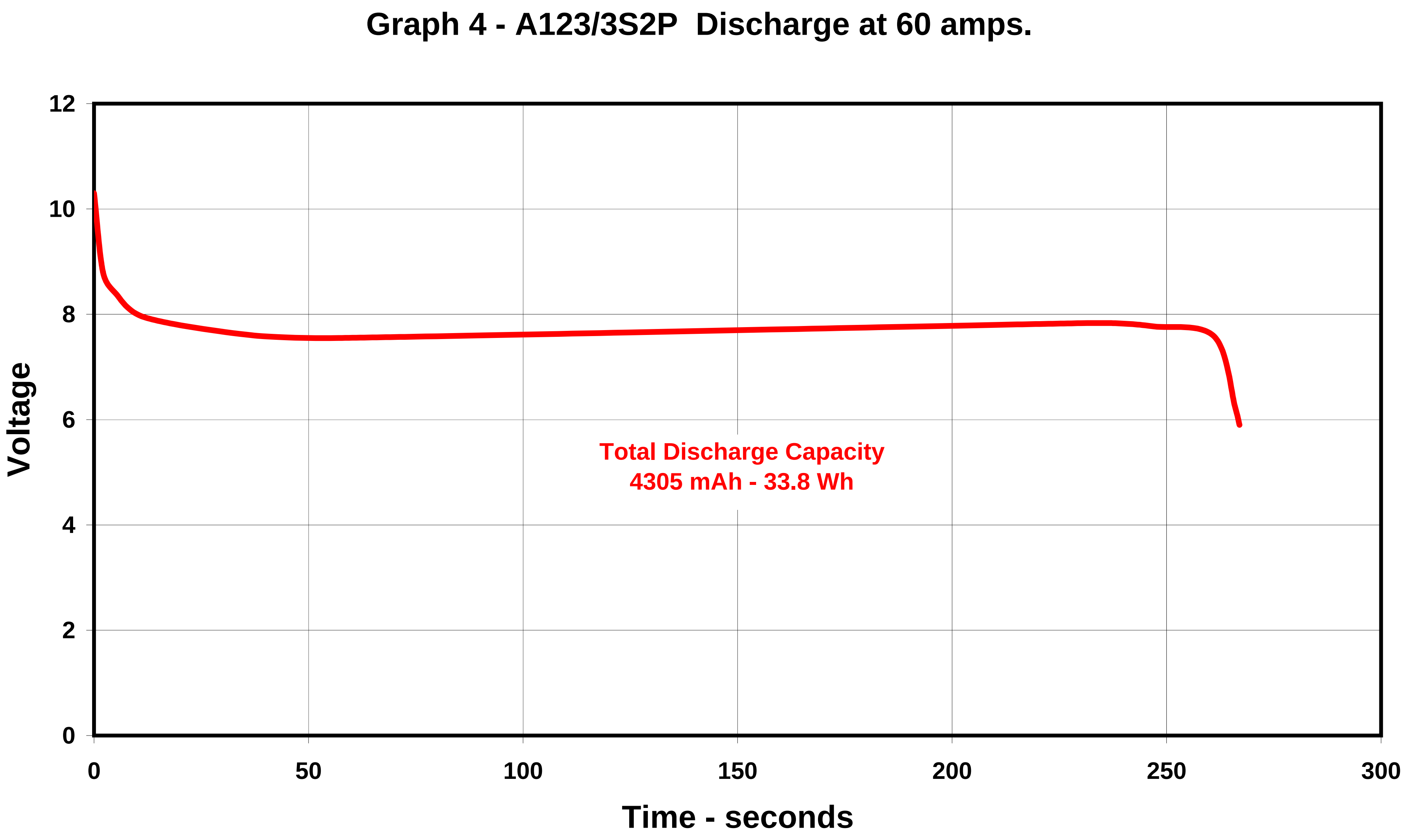


Graph 1 - A123/3S2P charge at 5 amps.
Voltage
Charge Current
Capacity
Final Total Input
4347 mAh
0
2
4
6
8
10
12
0
1
2
3
4
5
6
0
10
20
30
40
50
60
Time - minutes
Current - amps

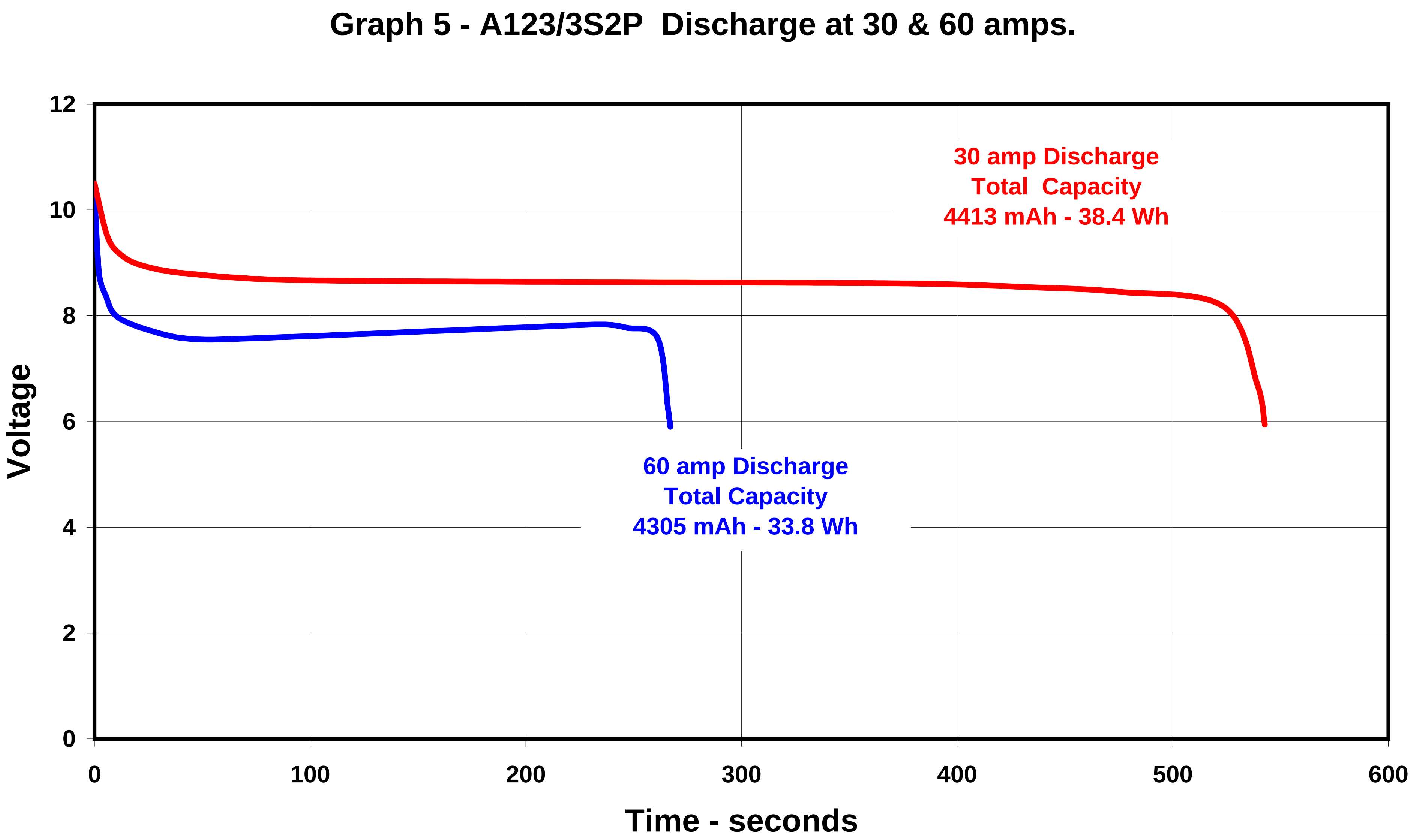

Graph 2 - A123/3S2P charge at 20 amps.
Voltage
Charge Current
Capacity
Final Total Input
4363 mAh
Voltage
Current - amps
Time - seconds
0
2
4
6
8
10
12
0
4
8
12
16
20
24
0
100
200
300
400
500
600
700
800
900
1000

Graph 3 - A123/3S2P Discharge at 30 amps.



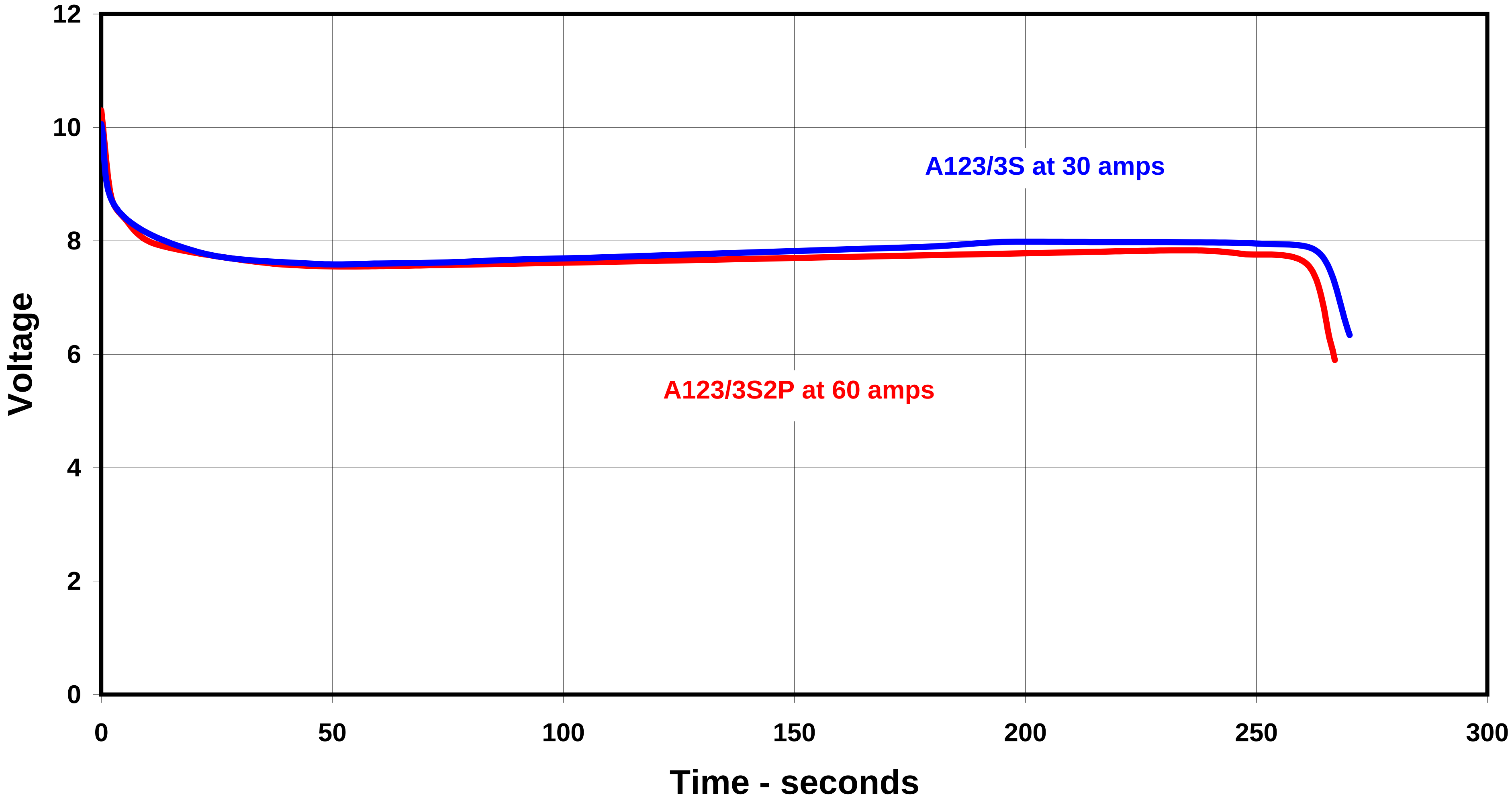


Graph 4 - A123/3S2P Discharge at 60 amps.
Voltage
12
10
8
6
4
2
0
0
50
100
150
200
250
300
Time - seconds
Total Discharge Capacity
4305 mAh - 33.8 Wh

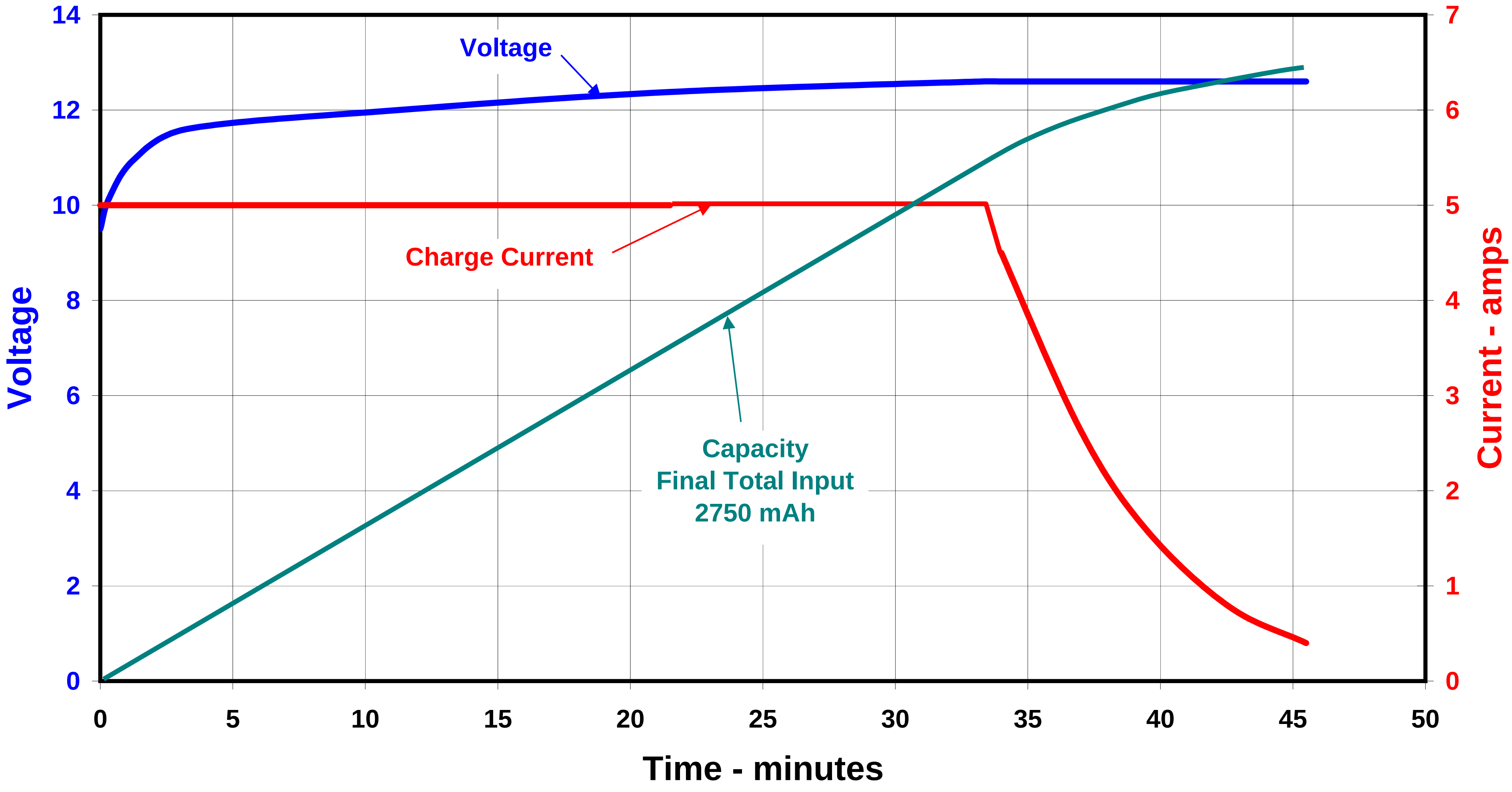


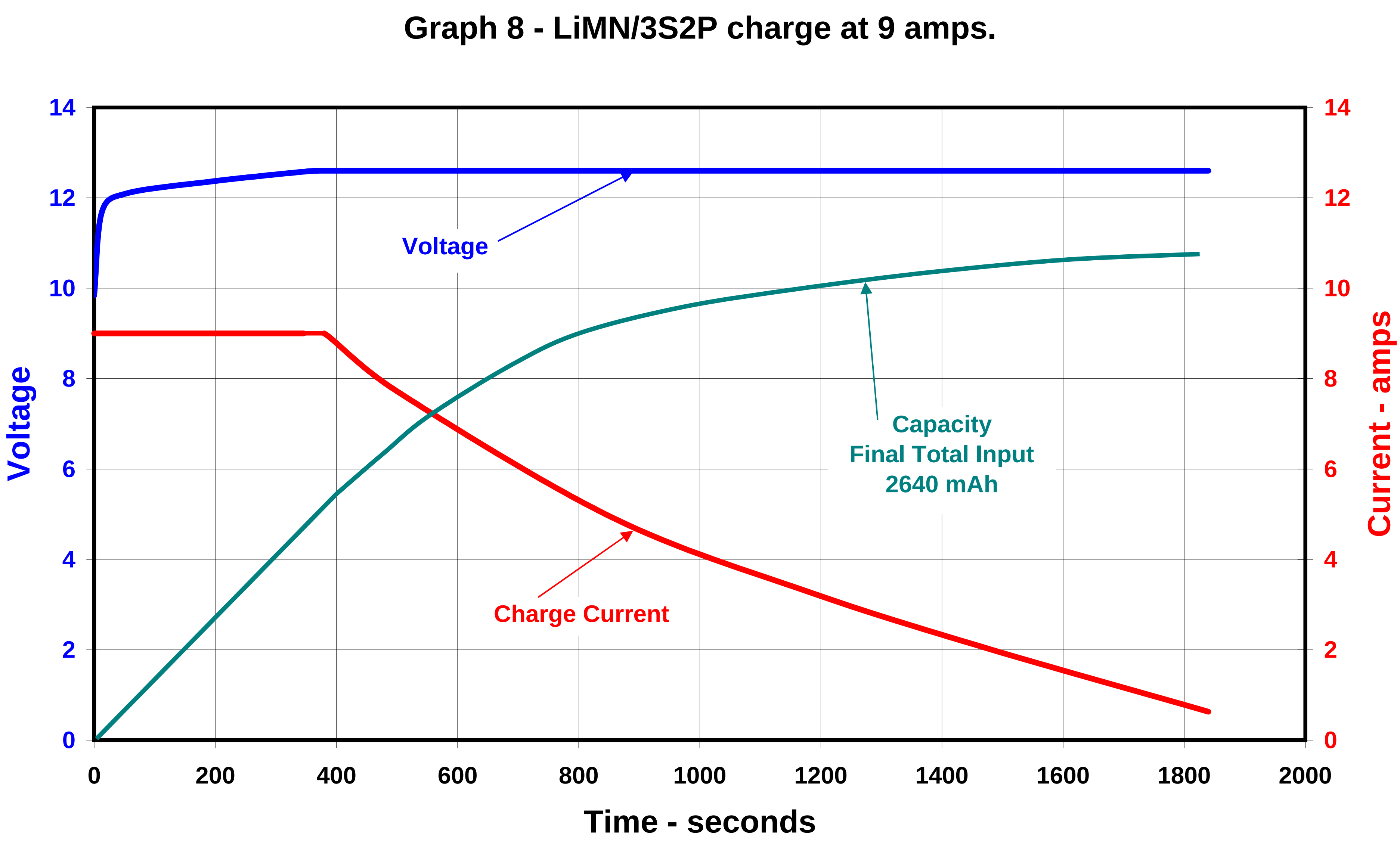
Graph 5 - A123/3S2P Discharge at 30 & 60 amps.
Voltage
12
10
8
6
4
2
0
0
100
200
300
400
500
600
Time - seconds
30 amp Discharge
Total Capacity
4413 mAh - 38.4 Wh
60 amp Discharge
Total Capacity
4305 mAh - 33.8 Wh

Graph 6 - Discharge A123/3S at 30 amps & A123/3S2P at 60 amps.

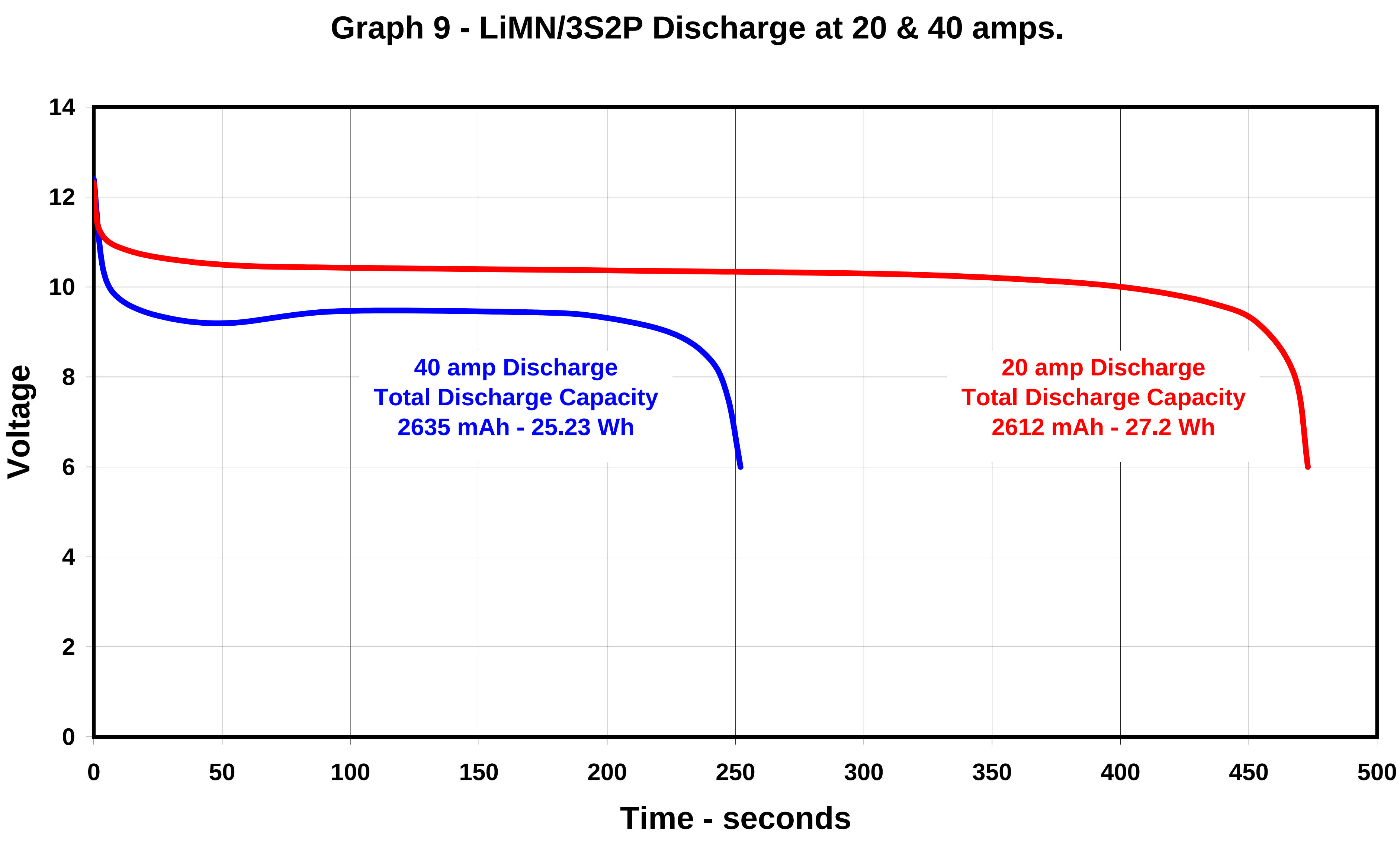


Graph 7 - LiMN/3S2P charge at 5 amps.





Graph 8 - LiMN/3S2P charge at 9 amps.
Voltage
Current - amps
Time - seconds
0
2
4
6
8
10
12
14
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Voltage
Charge Current
Capacity
Final Total Input
2640 mAh



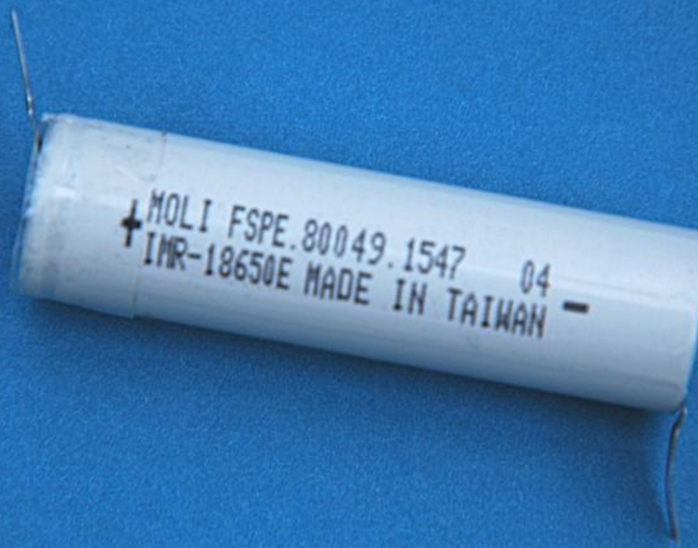
Graph 9 - LiMN/3S2P Discharge at 20 & 40 amps.
14
12
10
8
6
4
2
0
Voltage
40 amp Discharge
Total Discharge Capacity
2635 mAh - 25.23 Wh
20 amp Discharge
Total Discharge Capacity
2612 mAh - 27.2 Wh
0
50
100
150
200
250
300
350
400
450
500
Time - seconds

QEFI73-6


ImporTekniK Li-Ion-Mn Cells
11.4 V 2800mAh.
Max charge 9.0A in Li-Po mode 12.6V
Trickle/Formatting at 200mA
MOLI FSPE.80049.1547 04
IMR-18650E MADE IN TAIWAN

QEFI73-5

QEFI73-4



QEFI73-3


ImporTekniK Li-Ion-Mn Cells
11.4 V 2800mAh.
Max charge 9.0A in Li-Po mode 12.6V
Trickle/Formatting at 200mA

QEFI73-2


LEON-POWER
Li-Ion-FePO4 Akku
9.9 V / 4600 mAh
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29 Braiswick
Colchester CO4 5AU
Essex
England

QEF73-1

First Connect
Li-Ion FEPO4 Akku
9,9 V 2300 mAh
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