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B.E.F.A. Guide to Electric Flight for Beginner's - Volume 1

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THE BEFA GUIDE TO ELECTRIC FLIGHT FOR BEGINNERS
(11/4/95)

INTRODUCTION
(Last Revision 7/4/95)

Limitations of Electric Power

1) To those unfamiliar with electric flight, the normal perception is of a model, grossly underpowered and staggering on the verge of stalling just a few feet above the ground.

While this is certainly true of some models, it is nowadays very far from the norm. It is possible, though expensive, for electric motors to equal glow motors in power output, with two horsepower being possible, though only for shorter periods.

As compared with other types of powered models, this is one of the first trade-offs which must be accepted. One can have a lot of power for a short time, as already indicated. Or, at the other extreme, one can have a little power for a long time; say one tenth of a horsepower for between four and fourteen minutes, depending on the capacity of the flight pack.

Most beginners' models, using model car 540/550 types of motor which are about 1.3 inches in diameter, 2.5 inches in length and running on seven cells, will be operating at about 0.1 to 0.2 horsepower, with motor runs of about five minutes at full power.

Depending on the type of model, one may fit a throttle (speed controller) to increase the motor run by some 30 to 50 percent. It can be seen that quite reasonable flight times, without any thermal assistance, can be expected.

2. The next limitation, as compared with internal combustion power, that the electric flyer must accept, is that the power to weight ratio of typical electric motors is poor, being only some 30% - 60% of what might be expected from a modern internal combustion engine.

The important factor here being the weight comparison between the electric motor plus battery pack on the one hand; and the glow motor, fuel and tank on the other.

In practice, the electric model's adverse comparison is frequently offset, to a large degree, by the fact that, in general, internal combustion powered models have considerably heavier structures compared to equivalent electric models. This is partly because of the more rigid structure necessitated by the considerable vibration of the internal combustion motors and partly because, since so much power is available, the designers and builders of these models do not usually bother to save structural weight and are quite happy to carry around large amounts of lead, if necessary, to correct any error in centre of gravity placement.

Power Comparisons

3. As a matter of interest, the writer has a 94” span electric model powered by 28 cells, (the model on the cover) weighing 16.75 pounds ready to fly. This is only ten ounces heavier than would be the case if it were to be powered by a 22cc petrol engine. The electric motor swings an 16 x 10 prop as opposed to the 16 x 8 which would be used by the petrol engine.

Of course, it will not fly for 30 minutes, as would the petrol engined version, but flights of some seven to fourteen minutes are regarded as being quite acceptable for a semi scale model of this type.

4. While on the subject of power, it may not be out of place to point out at this stage that one of the main problems of giving guidance on what power is needed for various models is that there are so many variables involved:- Wing loading; aerodynamic cleanliness; Reynolds number (scale effect); whether direct drive or geared motor; required performance in terms of rate of climb, endurance, aerobatic performance and speed; minimum motor running time required; and last, but not least, pilot proficiency.

As a generality, it might be said that for reasonable performance, the power input to the motor should be 50 Watts per pound of all-up weight and 70 to 80 Watts per pound for fighter-type performance. However, a friend of the writer flies two 124" span gliders, each weighing about 4 pounds, using a Speed 600 motor, 7 cells and 7 x 4 prop. The power input to the motor being about 112 Watts - only 28 Watts per pound. The rate of climb is painfully slow, speed being only just above stalling speed with no margin for handling errors. He gets away with it because he has been flying for some 20 years and just does not make mistakes.

Advantages of Electric Power

5. In view of these disadvantages why do so many people fly electric often to the complete exclusion of other types of powered models?

It is a great advantage to be able to switch the motor on and off in the air at will. Because they are clean, you can fly while wearing your best suit, if you so wish. They are quiet and this is assuming an ever greater importance as more flying sites are being lost through noise nuisance. Furthermore, there are many sites where electric flight is permitted because these models are quiet, whereas glow models are banned owing to noise restrictions. There are also those who consider electric models to be a greater challenge and take delight in finding ways of overcoming the comparative weight and power problems.

The front end of an electric model is very clean, there are no long pipes protruding like gigantic warts from their noses.

Finally, many people are beginning to see electric models as the future of model flying. Looking back over the past ten years there certainly have been enormous technological improvements made in motors, batteries and electronic items of equipment such as throttles (electronic speed controllers) and field chargers. New developments are constantly in train which will result in improved power to weight ratios and longer motor runs.

6. If you wish to be part of the future then read on. The intention of this booklet is to offer guidance for those, experienced model flyers or not, who have as yet no knowledge of electric flight and may have no knowledge of electrical theory, but who nevertheless wish to participate in this aspect of the hobby and TO HELP ENSURE THAT THEIR FIRST ELECTRIC MODELS ARE SUCCESSFUL.

Whilst free flight electric models are perfectly acceptable, viable and capable of excellent performance, this booklet is concerned with radio control. You may obtain from BEFA another booklet specifically about free flight models, if these are your particular interest.

BASIC ELECTRICAL THEORY

(Last Revision 13/2/95)

7. This section is for those who know absolutely nothing about electrical theory and is intended only to give what is regarded as the minimum essential knowledge to enable them to wire up and operate safely and effectively their first electric models.

Beginners would be well advised to undertake further study, as time permits. It is recommended that they read *From Atoms to Amperes* by F.A.Wilson at a cost of around £3.50. Those having greater inclinations to mathematics and engineering might like to try *Principles of Electricity* by Morley & Hughes at a cost of £12.99. Both are available from Maplin Electronics as well as from various other outlets.

Radio is altogether a different subject and will not be discussed here except for reference to radio interference and its suppression.

8. The first terms which we need to understand are VOLTAGE, RESISTANCE and CURRENT. Starting with a simple analogy, imagine that you have in your back garden, a water tower of 20 feet diameter and 100 feet in height. If tower is half filled with water, it is clear that at ground level the water is under considerable pressure from the weight of the water above.

Now suppose that we have, just above ground level, an outlet pipe whose diameter we can adjust at will. If we now wish to partially empty the tank it will be understood that the job will be done much more quickly if the outlet pipe is adjusted to a diameter of two feet, than would be the case if it were closed down to only 1/2 inch diameter.

The large diameter outlet would permit a much faster flow of water than the very small one because of the latter's comparatively very high resistance. If we now close the outlet and completely fill up the tower, the pressure at ground level will be twice as great as it was before. Consequently, when we now open the outlet to either 2 feet or 1/2 inch diameter we will find that the rate of flow of the water is twice as great as it was before, due to the increased pressure.

9. To return to electrical theory, we can liken VOLTS (sometimes called ELECTROMOTIVE FORCE (EMF) or electrical POTENTIAL) to the water pressure, so that when the water level in the tower is low we have a low voltage and when it is high, we have a high voltage.

VOLTS are normally measured with reference to a ground plane (EARTH) which is regarded as being at zero volts; in the absence of any arithmetical + or - sign it is assumed that the electrical POTENTIAL is positive.

The constriction, or resistance, to the free flow of the water imposed by the variable diameter outlet pipe can be likened to RESISTANCE. Electrical resistance is measured in OHMS.

The rate of flow of the water may be likened to electrical CURRENT which is expressed in AMPS rather than in gallons per hour. As we have seen, in a given arrangement, the CURRENT in AMPS may be altered by changing the VOLTAGE (filling up the water tower or partially draining it), or by changing the RESISTANCE (altering the diameter of the outlet pipe)

10. Increasing the VOLTAGE will increase the CURRENT and vice versa. Increasing the RESISTANCE will reduce the CURRENT and vice versa.

Before continuing it should be mentioned that CURRENT may be direct (as in the case of the water tower), i.e., for practical purposes steady and unvarying in a constant direction; or it may be pulsed, i.e., in one direction but alternatively switched on and off at intervals; or, like the household mains electricity supply, it may be alternating. This means that it is constantly varying in the form of a sine wave between positive through zero to negative and back to positive. For certain purposes, another form of alternating current is used which has square waves rather than sine waves and in this case the switch between positive and negative is instantaneous.

For our purposes we shall only be considering direct current. This is a good point to introduce Ohm's law which has very valuable applications in our hobby and should be thoroughly understood before progressing to any further in your study of electricity.

Ohm's Law

11. Dr. G.S. Ohm discovered the relationship between current, voltage and resistance in any circuit. The symbols used to designate these terms being I for current (Amps), E for ELECTROMOTIVE FORCE, more commonly called voltage (Volts), and R for resistance (Ohms)

The AMPERE (more commonly referred to as the Amp, originated by Andre Marie Ampere) being the current which will flow through a resistance of one ohm under the pressure of one volt.

The Ohm is the resistance offered by a column of mercury 14.452 grams in mass, with uniform cross section and with a length of 106.3 cm, at the temperature of melting ice. You can now forget this latter piece of information since it has no practical value! Thus, when an electrical pressure of one volt is required to force a current of one amp though a circuit, that circuit is said to have a resistance of one ohm.

The basic formula in Ohm's law is that current is equal to the voltage divided by the resistance, using the units already described. This is written as $I = E/R$
By simple algebraic evaluation from this formula we can evolve two others, viz $E = I \times R$ and $R = E/I$

These are shown at Figure 1 together with other relevant information.

Applications of Ohm' Law

12. There are further applications of Ohm's law which are used to calculate the combined resistance of groups of resistors, either in series or in parallel, and likewise for groups of capacitors, but we shall leave this for your future study if you are interested. For the moment, all you need to know is that the term 'series connection'. This means that the components; motor, fuse and batteries or whatever, are in line one after the other, with the current flowing through them one after the other like a line of people passing fire buckets from hand to hand.

The term 'parallel connection' means that the circuit components are, in effect, placed side by side with the component wires at the right hand end of the group being both soldered to the single wire supplying the current, while the other ends of the component wires are both soldered to the single wire passing on the current to the remainder of the circuit. Thus, when components are in parallel the current is passing through them simultaneously rather than in train one after the other.

When resistors are connected in series, the total resistance is the sum of the individual resistance values. But, when they are in parallel, the calculation of the combined resistance is a little more complicated.

The formula for parallel connected resistors is:
$1/R = 1/R1 + 1/R2$, also shown in Figure 1.

You will realise that, when two resistances are connected in parallel, the combined resistance must always be less than the value of the lower of the two resistors; and, from Ohm's law, you will see that the lower value resistance will be passing more current than the other.

13. Refer to Figure 1 and remember that care must be taken to ensure that resistors are NEVER forced to take currents above their rated power, that is their rating in W (Watts). If they are over-run, they will get hot and smoke: if they are grossly over-run they will burn out instantly.

The power, called wattage, being absorbed by a resistor may be calculated by the simple formula $W = I^2 \times R$

For example, if we have a circuit in which a current of 2 Amps is driven through a resistor of 3 Ohms, the wattage will be $2 \times 2 \times 3 = 12$ Watts.

This resistor would therefore need to be selected to have a greater wattage than 12 Watts and in practice a 25 Watt wire wound resistor, or one of even greater power, would have to be used.

Ohm's law will also tell us what voltage would be needed to drive 2 Amps through a 3 Ohm resistor; viz: $E = I \times R$, or, $E = 2 \times 3 = 6V$.

Current may be found by $I = E/R$, or, $6/3 = 2$ Amps, so that we have come back to our starting point.

It is important to realise that all electrical and electronic components have manufacturing tolerances so that their values are never exact. This means that the calculated arithmetical answers will rarely prove to be completely accurate. But, if you note the tolerances, you will find the calculations to have been satisfactory. This will be referred to again later in the discussion of a cheap method of fast charging NICAD packs.

14. **Measuring Instruments.** The instruments used to measure these electrical units are: an ammeter for measuring current, a voltmeter for measuring voltage and an ohmmeter for measuring resistance.

For practical purposes, and user convenience, these instruments are usually combined (except for special purposes) into a single instrument known as a multimeter. These may have analogue indications, with a needle, or digital readouts, the latter usually being much more accurate.

A digital multimeter with a capability of measuring up to at least 10 Amps DC, or preferably 20 Amps DC, is an invaluable aid to the electric flier and is a highly recommended purchase. Again these instruments have tolerances and those with the closer tolerances are, as you might expect, more expensive.

GETTING STARTED

(last Revision 14/2/95)

Electric/Glow Power Comparisons.

15. On initial consideration of electric flight, those who are familiar with glow motors are likely to ask how electric motors may be compared with glow motors in respect of power, possibly with a view to converting a known glow model, or plan, to electric flight. While such conversions are possible and are very often done successfully, it should be remembered that structural designs for glow power are frequently considerably heavier than would be the case if the model had been intended for electric power from the outset. In particular, the nose and general fuselage structure is usually beefed up considerably in order to withstand the vibration of internal combustion engines.

The next thing to consider is that the rated power of the internal combustion engine is that BHP delivered at the RPM given while turning the prop that would fly the model, and not the maximum BHP stated by the manufacturer. In some cases, when a realistic prop is fitted, the operating BHP actually delivered to the prop may be only about 70% (or even less) of the stated maximum BHP.

In the case of a direct drive electric motor, the operating BHP (i.e., the output to the prop) will be the product of Amps, Volts and the efficiency of the motor divided by 746. The 746 arises because there are 746 Watts in one horsepower.

For a Speed 600 motor, running on 7 cells at 22 Amps, the answer would be (22 (Amps) x 7.5(Volts) x 0.65)

746 = 0.144 hp

Recommended Motor

16. Irrespective of past experience with glow models, gliders, etc., it is strongly recommended that your first electric model should be powered by what is known as a 540/550 type of motor such as one of the Graupner Speed 600 series. These come with armature windings for 6 cells, called 7.2 Volt versions and for 7 cells, called 8.4 Volt versions.

The reason for this is because a Nicad cell has a nominal voltage of 1.2 Volts when charged. In practice the individual cell may read 1.35 Volts when not under load, 1.15 Volts when driving your Speed 600 at a modest current of some 14 Amps and only about 0.8 Volts or 0.9 Volts when driving a special competition motor running at 50 Amps or more.

It is very strongly recommended that the novice only uses a motor which will operate correctly on a Nicad battery pack of seven cells.

The reason for this is because seven is the maximum number of cells that can be FULLY charged using the standard 12 Volt car or leisure battery together with a comparatively cheap fast charger which does not have built into it a voltage multiplier. In order to fully charge each Nicad cell, a voltage of at least 1.7 Volts is required.

The luxury of special versions, or ball-raced motors may come later when some experience has been gained.

Chargers For More Than Seven Cells.

17. The voltage multipliers in the more expensive chargers are capable of stepping up the 12 Volts of the supply battery to thirty-five Volts or more, according to how many cells it is designed to charge.

Note from the discussion of Ohm's law and Figure 1, that one expression of power is V x A (often expressed as VA) and, if the charge current is 3 Amps then 3 X 12 is 36VA (or 36 Watts) whereas 3 X 55 is l65VA, almost five times as much power; and this is not taking account of efficiency in the voltage conversion. Thus, instead of drawing only some 3 Amps from the 12 Volt battery as in the case of charging 7 cells, the unit charging 30 cells may be drawing 20 Amps or more from the 12 Volt battery.

Car batteries are not designed to accept deep discharges. Without the alternator supplying top up current the plates are likely to accumulate sulphates which can lead to shorting of the plates, thereby significantly reducing the life of the battery. A leisure or traction battery should therefore be used, in preference to a car battery, particularly if you have a charger designed to charge more than 7 cells.

Six Or Seven Cells?

18. The choice as to whether to use 6 or 7 cells is yours, but the advantage of using 7 is that more power is available for a relatively small increase in weight. The details will be explained later but, for the moment, suffice to say that you will have 20% more power for a power plant weight increase of only 10%. Or, to put it another way, the all-up weight of the aircraft will be increased by 5% while the power increase is 20% - a very worthwhile improvement.

Recommended Cells

19. Various types of Nicad cells are available, but it is strongly recommended that you buy only Sanyo SCR or AR types initially, since these will withstand more abuse than other types.

The capacity of cells is stated in mAh and either 1400 or 1700 mAh types will do. The higher figure denoting greater electrical capacity and, therefore, a longer motor run. With the items being recommended, this would mean a 5.6 minute motor run at full power as against 4.6 minutes.

The expression mAh means "thousandths of ampere hours", so that 1700mAh is the same as 1.7Ah; it also means that the pack will supply a current of 1.7 Amps for one hour or a current of 17 Amps for one tenth of an hour. (In theory, at least)

There are advantages in buying packs consisting of matched cells, but for sports flying this is not really necessary. If you have no experience of soldering Nicads you should buy a ready made commercial pack.

Care of batteries will be dealt with later in this booklet.

Choice of Model

20. Here, the past experience of the individual is an important consideration.

If you have no experience with radio control flying, it is suggested that your first model should be an electric glider with elevator and rudder control only (no ailerons). BEFA can supply plans and detailed instructions for such a model, which may be flown either as a glider or with undercarriage fitted. You will need at least a four channel radio system, however, because you will need to be able to cut the power to the motor on demand.

Do not attempt to fly the model yourself when it is ready. Find an experienced pilot to carry out the first flight, to trim the model and prove it and then have him teach you to fly.

21. If you do have experience with radio controlled models, you could either build the BEFA model, the 'Sonata E' by the Balsa Cabin (which is a glider), or some other proven electric sports model. Here the BEFA Technical Liaison Service could make appropriate recommendations, if no other source of advice is available.

Essential Additional Equipment

22. Irrespective of the type of model, assuming that you will be using a Speed 600 motor for direct drive, (i.e., not with a gear box, because this will come later) you should use a Graupner 8 x 4 folding propeller.

Some essential items of equipment are: a charger (see "Charging and Care of Nicads" below), a multimeter, preferably a digital unit which can be obtained for about £12 to £15, though a more expensive one will be a good investment, a standard car headlight bulb, an electric flight switch or electronic speed controller and a suitable fuse. The fuse could be a 25 or 30 Amp car blade type in an appropriate holder, but a recommended alternative is the electronic fuse type MFR600 that may be purchased from Maplin Electronics. These may seem very expensive at £5.95 each, but they are fit and forget items which, if operated reset themselves after some 20 seconds when it is safe so to do.

23. The problem with the car fuses is that you never seem to have a spare when you most need one and that could mean the end of the day's flying. They can also introduce a significant voltage loss if a poor quality holder is used. Because some of the holders available have comparatively high resistance, it may be preferable to solder the fuse in rather than to use the holder, though this does mean that if the fuse blows, a soldering iron is required to replace it.

The reason for using the fuse is, that if power continues to be applied while the motor is stalled, for example, in an unintended landing immediately after launch, and you have not cut the throttle before the model is on the ground, the motor could be burnt out with subsequent risk of fire.

BUILDING THE MODEL

(Last Revision 9/2/95)

Materials.

24. The balsa wood used in construction of the model should be light but firm wood. It is recommended that, except for wing spars, you discard any hard and heavy wood. It is also recommended that you be sparing in the use of heavy glues, such as PVA or epoxy.

Lightly sand all sheet and strip wood before use. Solarfilm is, perhaps, not the most suitable covering material for lightweight, open structures. These are probably best covered with Litespan for small models or Fibafilm for larger models, using Balsaloc adhesive in each case. These films are much lighter than Solarfilm and add rigidity to open frameworks, which Solarfilm does not.

Fixing Flight Battery.

25. It is imperative that the flight battery does not move in flight. It may be restricted by gluing small blocks of white foam in the bottom of the fuselage to locate it or, possibly, by use of self-adhesive Velcro fastener.

Make no attempt to beef up any of the structure to prevent movement of the battery in a heavy landing. This will add unnecessary weight. It is a futile move as, in a crash, the pack will burst its way through ANY restrictions. Be philosophical and accept the fact that if you make a crash landing there will be some repair work to do. The damage is likely to be much less than would otherwise be the case and the model will fly the better for it.

Reinforcement of Split Wings.

26. If the model has a built-up wing, which is split into two halves for ease of transportation, it is important to ensure that the joint is adequately strong. Ensure that the joiner tubes are boxed into the spars with at least 1/16 inch birch plywood at the front and rear of the main spars. Also ensure that, for good measure, the boxes are bound with thread which should then be smeared lightly with white glue for additional security. This will add some weight but is very worthwhile, whether or not it is shown on the plan.

Keep the Rear End Light.

27. Make a real effort to keep all structural weight behind the centre of gravity to the absolute minimum, so that any small C of G adjustments may be made by some movement of the power pack. NO LEAD MUST BE ADDED, because any weight increase will reduce the performance of the model.

Choice of Servos/BEC.

28. Use of mini or micro types of servo is desirable because of the weight saving, but their use is not essential for the types of model with which we are at present concerned.

Receiver battery packs of 270 mAh may be used in preference to the standard 500 mAh pack to save weight, providing that the reduced operating time is borne in mind.

The use of a BEC system instead of a receiver pack offers a valuable weight saving, but not without a degree of risk and this will be discussed in more detail later.

CHARGING AND CARE OF NICADS

(Last Revision 2/4/95)

Transmitter and Receiver Packs

29. Use and care of the transmitter and receiver packs is normally adequately covered in the manufacturers' manuals and little further need be added. However, it is a good idea to run these batteries down about once every four to six weeks and then give them a full 15 hour recharge at one tenth of the mAh capacity. This means 50mA for a 500mAh pack and 27mA for a 270mAh pack.

To run down the transmitter pack, switch on with the aerial extended and leave until the needle is in the red, or until the digits read about 8 to 9 volts before switching off.

30. Receiver packs may be run down by fitting a 27 Ohm, 7 Watt wirewound resistor in series with the pack and monitoring the voltage until it falls to about 4.0 Volts with the load resistor in place. This load will draw a current of about 185mA and Figure 2 shows the arrangement.

While on this subject, this is a good place to point out that to determine the charge state of a cell, or pack, it must be under an appropriate load. Off load, a receiver pack which is COMPLETELY discharged may measure 4.8V to 4.9V. Load it with the aforementioned resistor and the voltage will, within a few seconds, be below 4.4 Volts and falling rapidly. Attempted flight with such a pack would mean instant disaster.

NICAD packs should not normally be run down to less than about 1.0 Volt per cell because, unless they are computer matched, one cell may run down before the others and be reverse charged by them. This causes damage to the internal structure of the cell and is to be avoided if at all possible.

31. Study Figure 3, which is the voltage plot of a 500mAh receiver pack outputting a constant 85mA. From it, you will see that if a pack under load measures less than about 4.9 volts it would not be safe to fly because it is not possible to determine at which point on the curve the pack is sitting. Be safe and recharge. Even if the pack is towards the charged end of the curve, a full recharge will do no damage, provided it is at the recommended rate of one tenth of the mAh capacity.

Flight Packs

32. Flight Pack Load. Now we come to the reason for having the car headlight bulb. Mount this in a plywood frame and connect it with a plug to accept the power pack and make provision for measuring the voltage in situ as shown at Figure 4. Standard 4mm red and black sockets could be mounted in the ply plate as voltage measuring terminals if more convenient. This bulb provides a suitable load for running down the power pack to 1.0V per cell.

It is a good idea to give a new power pack a full 15 hour charge (10th rate) and then discharge it on the bulb and to repeat this procedure three times (five if you have the patience) before ever using the pack for flight and before fast charging it. You will therefore see that it would be a good idea to be 'running in' your new battery pack whilst you are still building the model.

Trickle Charging

33. There are two ingredients to trickle charging, Amps and time. The Amps should be at 1/10 rate, i.e., capacity in mAh

divided by 10; and the time should be nominally 12 hours (in practice more like 14 hours). The time and rate applies to any pack of a given capacity, irrespective of the number of cells in the pack.

For example, the correct charge rate to trickle charge a pack of 500mAh cells is 50mA, the time will be 14 hours. Note that the rate and time are solely dependent upon the capacity of the pack, regardless of the number of cells it contains.

This may seem odd, but remember that the voltage applied to charge a pack should ideally be between 1.7 and 2.0 volts per cell; so that we might use l.8V at 50mA to charge the single cell, but we would need 54 Volts to charge the 30 cell pack, though still at a current of 50mA.

This also explains why a 12 Volt battery cannot FULLY charge an eight cell pack, since we really ought to have 1.7 X 8 = 13.6 Volts. We can do it, perhaps, if we use our car battery with the engine running! Or with our leisure battery while the mains charger is connected to it.

34. Resistor or Constant Current Drive. Most cheap trickle chargers simply use a resistor, only, to set the current. The value of this resistor is set by the difference between the applied voltage and that of the pack (which varies and hence the charge rate varies)

This resistor can be good ONLY for a pack with the stated number of cells at the stated capacity (though packs of the same number of cells, but differing capacity, may be charged by varying the time, about which more later)

Here is the problem with the simple resistor method and the reason why it is much better to use an electronic circuit giving a constant current. The current will not be absolutely constant, but variations with differing numbers of cells will be so small as to be irrelevant provided there is an adequate applied voltage from the power source.

If the cell capacity differs from that for which the value of the constant current was determined, then a proportional time exercise can be done. For example, the constant current has been set at 120mA for a 1200mAh pack, but it is desired to charge a 1000mAh pack. The charge time will be 14 divided by 1200 multiplied by 1000 = 11.7 hours.

To charge a 1700mAh pack; the arithmetic will be 14/1200 x 1700 = 19.8 hours. Remember that there is no reference to the number of cells in any pack, because we are using a constant current device rather than a simple resistor to control the current.

35. Circuit & Details Of A Trickle Charger. A theoretical circuit for an electronic, constant current trickle charger is given at Figure 5 with constructional assistance given at Figure 6. It will be seen that, for up to seven cells, a very simple unit costing about £3.00 may be constructed which can be powered by a 12V battery.

The text of Figure 5 shows how to determine the value of the resistor which sets the constant current. If it is intended to use the charger with packs of several different capacities, then the appropriate resistor values can be found and wired to a single pole, multi-way switch. This would enable the appropriate current for a particular capacity pack to be selected. This small modification would increase the cost to a total of about £4.50 excluding any case or box, and also excluding the 22 turn pot which would be available for some other project.

If desired to enclose the unit, it could be built into a box of 1/8" ply with numerous holes in the top and bottom for ventilation of the heatsink.

The advantages of having the correct current (1/10 rate) are: firstly, if you put a battery on charge, forget about it and go away for the weekend, no harm will be done to the battery. Provided the 1/10 rate is used, a good flight pack would have to be continuously charged for more than two or three weeks before it could be seriously affected. Secondly, there is no arithmetic to be done to find the charge time - it is always 14 hours.

Fast Charging

36. Recommended Fast Charge Rate. For field use you will need a fast charger able to charge the power pack (flight pack) at about twice the mAh capacity. In other words, to charge a 1400 mAh pack at 2.8 Amps and a 1700mAh pack at 3.4 Amps.

This rate will charge packs in a nominal 30 minutes, assuming a constant current charge. It is no sin if your fast charger is capable of only 2.0 amps, but the charge will then take longer.

Some American and Continental flyers fast charge at three and even five times the mAh rate, but this is not to be recommended because it seriously reduces the life of even the best quality and would very soon destroy the lower quality cells.

If you limit the current to 2 x mAh capacity and follow the advice given you will find that your SCRC and AR packs should give you about five to seven years of good service.

37. Types Of Chargers. The simple chargers usually place a resistor in series between the 12V battery and the power pack to limit the current while the more expensive ones use a constant current circuit which is more efficient.

The simple ones will often have a clockwork timer to cut the fast charge, while the more expensive ones use temperature cut-off or some derivation of voltage peak detectors.

Those with clockwork or electronic timers do not usually fully charge packs which have been fully discharged prior to charging, because the manufacturer must obviously play safe. He does not want to be sued!

Other types may use both peak detector and temperature cut-off together as a belt and braces safety measure. Why the safety measure? Because charged NICADS are potential bombs waiting for an opportunity to explode! Treat them with great care - to put them in your trouser pocket with your keys and coins is to invite instant emasculation.

38. What Happens When a Pack Is Fast Charged? When a pack is charged, a chemical reaction takes place within the cells and in simple terms the following is what happens.

When fast charged the temperature of the cells initially drops slightly. As the charge continues the voltage slowly increases and when it is approximately half charged, the temperature begins to rise, slowly at first.

At about 80 - 85% of charge, the rate of temperature rise increases as internal gas pressure increases and the voltage rise continues.

As the state of full charge is reached, the voltage reaches a peak and then begins to fall again. At this stage, the temperature will be in the region of 6 or 7 degrees Centigrade above the starting temperature, assuming that everything was at ambient temperature to begin with.

At about this point, the peak detector circuits in the more expensive chargers will operate, but temperature cut-off chargers will operate at whatever temperature was set.

If the cut-off detector, of whatever type, were to fail and the fast charge continued, the safety blow out valves in the ends of the cells would open and permit excess gas to be vented. This would cause permanent loss of capacity.

If the vent holes were inadvertently blocked (or if there were none, as is the case with many cell types), there could be an explosion which could scatter highly poisonous (cadmium) pieces of shrapnel around.

I hope you will now realise why it is unwise to leave unattended packs being fast charged, unless you are using an "all singing and dancing" charger with belt and braces. i.e., a peak detector of some sort as well as an independent temperature cut-off device.

BE SAFE.

39. Temperature Cut-off. This is probably an appropriate place to discuss temperature cut-off. Firstly, the question of temperatures about which, as usual, there are varying opinions.

What is beyond any doubt, is that you should not charge Nicads at temperatures below the freezing point. It is recommended that the temperature should not be below 10^0C for fast charging. In winter, the writer stops fast charging when the temperature drops to two Centigrade and has not experienced any problems over the last 8 years. You may, however, discharge the cells at temperatures below freezing.

40. The maximum cut off temperature that should ever be used is 40^0C. In view of the fact that, especially when fitted with a probe, the temperature sensing of an electronic temperature module will be accurate to only about 2 or 3 degrees, it is recommended that you never set the cut-off to more than 38^0 centigrade.

What you should set in practice (assuming you have a variable temperature control) is not quite so straight forward. It is advised that you NEVER fast charge with only a temperature cut off charger, any unvented or unmarked cells - use only good ones, preferably SCRC or AR types, especially at the higher temperatures.

If you use SCE cells it is recommended that you do not exceed 25^0C, if possible, limit it to 20^0C.

Here is the less straightforward bit. Assuming everything is at ambient temperature and that the charging pack is sheltered from hot sun in summer and cold wind (and the ground) in winter, most packs will be fully charged when their temperature has risen by about seven degrees, with five being quite enough for sports flying.

Of course, once you start flying and recharging cells used a short time after they have flown, then nothing is at ambient temperature. Normally the cells should be left to cool for at least 20 minutes and preferably half an hour or more after use.

This is particularly important for SCE cells which, in theory, should be charged only once per week. The car enthusiasts use them for 24 hour races during which they are charged 15 to 20 times, but they live dangerously and do not mind short pack lives.

Choice of Fast Charger

41. Think Before You Buy A Fast Charger. Give some serious thought to the question of how many cells you may wish to use in the future.

Many electric flyers are quite content to stay with seven cells for the rest of their lives - and there is absolutely nothing wrong with this. However, probably about half will at some time wish to fly models which will require 10 to 14 cells, or even more.

While it is possible to plug charged packs together in series to make up the required number of cells, there are disadvantages in using this system. First you will not usually be able to charge all of the two or three required packs simultaneously without a special charger. Secondly, this method increases the risk of certain cells being run down before others with the resulting risk of damaging reverse charge.

If you buy a fast charger capable of charging a maximum of seven cells now and, in the near future, wish to charge more, you will have to buy a more expensive charger. This means that you will probably lose money on your original charger purchase. There is a way of avoiding this loss.

42. Consider Starting With A DIY Fast Charger. Also, if your funds are limited and you are at present unable to afford a commercial fast charger, you can still enjoy electric flight.

Your first flight of the day could be made using the pack which was trickle charged (1/10th rate) for 12 to 15 hours. Thereafter - and after the pack has cooled - you may fast charge by the set up shown at Figure 7. The pack is being charged through a 0.47 Ohm 25 Watt wire-wound resistor if seven cells are being charged, or through a 1.0 Ohm 25 Watt wire-wound resistor if six cells are being charged.

These resistors are available, at a cost of about £1.65 each, from Maplin Electronics, or similar companies which advertise in the electrical/electronic magazines,

The connecting leads should be of the 13 Amp household type, it is also wise to use an in-line 10 Amp fast blow fuse between the 12 Volt battery and the resistor for protection, in the event of a short circuit.

43. Construction Of Cheap DIY Charger. Looking again at Figure 7, the resistor will get HOT because it has a large amount of power to dissipate and should be bolted to a piece of aluminium measuring about 6 inches by 4 inches. Alternatively, a proprietary heat sink may be used which should have a good airflow around it.

The initial charge rate will probably be quite high, at about five Amps, because of the voltage differential between the 12V battery and the pack. This will very soon fall off as the battery pack voltage rises. The mean charge rate will be in the order of 3 Amps, so that charging a fully discharged 1700mAh pack may take some 40 minutes.

Note that great care should be taken to ensure that the terminals for measuring pack voltage can not be short circuited. These voltage measuring terminals could be standard red and black 4mm sockets which may be mounted in the aluminium plate already referred to. BUT, IF BRASS TUBES ARE USED, REMEMBER THAT THEY MUST BE INSULATED FROM EACH OTHER AND FROM THE HEAT SINK. The plate could be screwed to a base frame of 1.5 inches by 1/4 inch wood for ground clearance and the brass tubes could be glued into the wood.

Nicad cells have very low internal resistance - something in the order of 11 milliohms per cell. So that even with only seven cells, a short circuit will deliver a current of 90 Amps; sufficient to melt the tip of a steel screwdriver. The writer has a scar on his wrist to prove it!

44. Effects Of Tolerances To return to the matter of component tolerances. The resistors used will have a tolerance of + or - 10% and the Nicad's stated capacity is only a nominal figure whose tolerance might be + or - 5% for good cells and + or - 20% for others. You will therefore appreciate that it is simply not possible to give a definitive figure in minutes for the time taken to fast charge a given pack at any anticipated charge rate, assuming that you know the exact state of discharge of the said pack at the commencement of the charge.

As already stated a fully discharged typical pack of 7 x 1700mAh cells will be fully charged in about 40 minutes using a fully charged 12 Volt leisure battery through a 0.47 ohm WireWound 25 Watt resistor. But, because of component tolerances, expect some variation between different packs and different resistors and also with variations in the state of charge of the 12 Volt battery.

45. Be Cautious. It is for these reasons that you must, in the early stages until experience is gained with your own units, monitor very closely the voltage and temperature of the pack while fast charging with this low cost system.

Measure the voltage at the terminals shown at Figure 5 continuously and stop charging IMMEDIATELY when the voltage reading starts to drop. The actual drop will be only about 0.1 Volt, so use of a digital meter is almost essential for this job. The actual battery voltage might be in the region of 9.4V for 6 cells and 11.0V for 7 cells. Also, keep monitoring the temperature of the pack.

Note the expression 'MIGHT BE' in the last sentence referring to the maximum voltage reached. This is because packs will be found to differ widely in this respect and also why maximum voltage per se is not used as the determinant for cut-off. (It can, however, have uses viz EFUK issue No 34, page 38).

Although obviously not the best method, and somewhat inconvenient in use, you will achieve quite acceptable results using this cheap system until such time as you can afford a good commercial fast charger.

46. Procedure for Cheap Fast Charging. An illustrated example of how best to use this cheap method SAFELY will now be offered. The first time you try this method you must follow this recommended procedure PRECISELY.

Referring again to the set up at Figure 7. Firstly, attach to the flight pack a mercury filled, photographic processing or similar thermometer, wrapping two or three turns of paper around the thermometer bulb and secure it to the battery pack with a tight rubber band. This is to give good thermal contact between the cells and the thermometer bulb and to protect the latter from cooling draughts. Ensure that the rubber band is not perished. Have the pack out of direct sunlight and isolated from cold ground.

Next, connect the leads from the resistor and flight pack plug to the 12 Volt battery as shown in Figure 7. If you have a stop watch, start it when you plug in the flight pack to start the charge.

47. Do Not Over-Charge. Carefully monitor the pack voltage at the terminals shown in the diagram and also the temperature. You will observe voltage increases and temperature variations similar to those shown in columns A to D of Figure 8 as the charge continues.

You may, if you wish, wire in series between the 12V battery and the resistor, as shown in the diagram, a 5 Amp meter as used by glow motor flyers to monitor the glow plug current. These meters are not very accurate, but will give a good picture of what is going on. You will see that, in the example quoted, the charge was terminated after 38 minutes. With a subsequent capacity test proving that the pack was, indeed, fully charged.

Stop the charge by unplugging the flight pack IMMEDIATELY when you notice a small reduction in voltage, or if you observe a more than slight temperature increase. Remember that because of component tolerances your times may be different from those shown in the writer's example.

Note that after the charge was terminated, the temperature continued to rise for eight minutes. This is because the high temperature reached in the cores of the cells took time to percolate out to the skins.

48. Charging Cells of Smaller Capacity. Can You Charge Cells Of Smaller Capacity? Based on this example you might expect that this arrangement would charge a 1400mAh pack in about 38/1700 X 1400 = 31 minutes and a 1200mAh pack in 38/1700 X 1200 = 27 minutes. These figures are only approximate, but are much better than uninformed guesses.

Clearly these lower capacity packs are now being charged at a little more than 2C, but they will not be damaged at the charge rate given. So, if you are using such packs, follow the same procedure, but expect to have to terminate the charge after a shorter time.

If you are using Speed 400 types of motor with the popular 600mAh AA cells, or even smaller, such as those used by free flight enthusiasts, then YOU MUST NOT USE THIS ORDER OF CURRENT.

Remember that you should not fast charge at more than 2C (this would be only 0.54 Amps for a 270mAR pack). Can our brief study of Ohm's law help us here? Let us see.

49. How To Calculate Required Resistance Value. A fully charged 12 Volt leisure battery might measure 13 Volts or slightly more when OFF LOAD. However, when connected and delivering some three to five Amps, its voltage will probably be about 12.4 Volts.

The discharged pack voltage will be about 8.5 Volts, but on connection will rise almost at once to about 10 Volts. Thus, the voltage difference across the resistor will be 12.4 - 10 = 2.4 V.

You will recall that from the formula for current, I = E/R we can therefore transpose to find the resistance, R = E/I. Now we need to determine I.

To charge 600mAR cells at 2C we need a current of 1.2 Amps. We have already learned that, using the cheap method of fast charging, the current steadily reduces as the voltage difference between 12 Volt battery and pack reduces. So, we shall assume a starting current of 1.6 Amps. For the required resistance we now have
R = 2.4 /1.6 = 1.5 ohms.

50. Selecting Resistor. Now, resistors are manufactured in what are called preferred values, so that in practice we select the preferred value closest to that required.

To digress for a moment, The value of 1.5 Ohms may also written as 1.5R or alternatively as 1R5, with the R taking the place of the decimal point. A 100 Ohm resistor might appear listed as 100R; a 1000 Ohm as 1000R or as 1K, the "K" indicating a thousand; a 1700 Ohm resistor would appear as lK7 (1.7K).

If we do not happen to have at hand a resistor of 1.5 ohms, what can be done? If we do have two resistors whose values are 2R2 and 4R7 (2.2R and 4.7R) both with power ratings of 7 Watts; could these be used?

Application of Ohm's law. When two resistors of different values are wired in parallel, the combined resistance value must be less than that of the lower of the two resistances. Remember from Figure 1 the reciprocal calculation.

So, 1/2.2 + 1/4.7 = 1/R or, = 0.4545 + 0.2127 = 1/R

Which equates to 1/R = 0.6672 = 1.4988

Which, I'm sure you will agree, is close to the 1.5 which we need!

51. Determining Resistor Wattage. The two resistors are 7 Watt types: will that power rating be adequate?

Let us look first at the 4R7 resistor. We know that the voltage differential between 12 Volt battery and pack is 2.4 Volts, so that the current will be 2.4 / 4.7 = 0.51A. Remember that power in watts is given by: current squared multiplied by resistance, so 0.51 x 0.51 x 4.7 = 1.22W.

Well within the rating of the 7 Watt resistor.

What about the 2R2 which we know will take more current?

2.4 / 2.2 = 1.091A and 1.091 x 1.091 x 2.2 = 2.62W.

Again, well within the 7 Watt rating. We know that the mean current will be less than that calculated, because of the reduction in voltage differential as the pack charges, so all is well.

Therefore, put the two resistors side by side, twist their leads together and solder them in place of the 0R47 resistor in Figure 5. We are now ready to fast charge our pack of seven 600mAh cells. (Incidentally, 7 Watt Wirewound resistors cost about 30P each.)

52. Resulting Fast Charge. See the results of the fast charge in columns F to I at Figure 8. Note that the temperature rise after termination of the charge was for a shorter time in this case because the mass of the cells is smaller.

The fact that both packs in this spreadsheet have been charged in 38 minutes is just a coincidence. Be especially careful in charging unvented cells, remembering that they are potentially bombs full of highly poisonous shrapnel. At the first sign of voltage reduction, terminate the charge. Likewise if the temperature suddenly and unexpectedly shows a rapid increase.

General Care Of Nicads

53. Do Not Fast Charge HOT Packs. Always allow packs to cool for at least 20 minutes after flying before fast charging, for longer if ambient temperatures are above 20^0C - (68^0 F)

If the pack has not been fully discharged then, obviously, it must not be fast charged for the same time as you have determined for a fully discharged pack. Gain some experience with your own units before attempting to fast charge, using the cheap method, and a partially discharged pack.

Whatever charging system you use, after some five or six fast charges, cycle your flight pack by running it down with the bulb to one Volt per cell (7 Volts for a seven cell pack) and trickle charge at one tenth of C (the mAh capacity) for at least 14 hours. Then repeat the exercise. This will equalise the charge point of the cells within the pack and help prevent the reverse charge effect mentioned earlier. Follow these rules and your packs will last a long time.

You will now appreciate the desirability of having more than one flight pack as soon as funds permit. Two or more packs may be taken to the field already trickle charged and then just given a top up fast charge for some 3 to 5 minutes - with monitoring - just before flying, so drastically reducing the time between successive flights.

54. Storage Of Packs. If you are not flying for a day or two, do not leave packs either fully or partly charged - discharge them down to one volt per cell for storage. Never store cells in a damp environment.

If they have not been used for several weeks, trickle charge them at 1/10 rate for 14 or 15 hours, discharge, and then charge and discharge them again before using them for flight.

THE BATTERY ELIMINATOR CIRCUIT (BEC)

(Last Revision 9/2/95)

55. Advantages Of BEC. Some commercial electric flight switches and throttles have BECs (Battery Eliminator Circuits) which derive a voltage of 5V from the flight pack and supply this to the receiver, thereby eliminating the need for a receiver battery pack. Clearly, this results in a substantial saving of weight.

If you have to run up a steep hill, or a long flight of steps, then carrying an extra stone in weight will significantly affect your performance. So it is with your model. The most important determinant of climb performance is NOT AERODYNAMICS, but power to weight ratio. Any additional weight, other than that providing more voltage, and/or amps, to the motor, will reduce the rate of climb. The effect on gliding performance is much less important in terms of overall performance. Obviously BECs are "Heaven sent". Or are they?

56. Risks of BEC. Well, very few things in this world are entirely good or entirely bad. The main disadvantages are that, firstly, there is a voltage cut-off point at which the motor will be suddenly stopped in order to leave sufficient power in the flight pack to supply the receiver and servos for a reasonable length of gliding time.

This means that you may not be able to make it back to the landing area if you have not been cautious and find that you have to glide a long way back up wind.

Secondly, it is possible for a cell in the flight pack to go open circuit, in which case there is an immediate, total radio failure. This could also occur as a result of a failed battery connection.

To put this into proportion, many electric flyers have never experienced an open circuit power pack in many years of flying whereas a few have had two or three such failures in the same time scale. The degree of risk is such that insurance is in no way prejudiced if a BEC is used without any additional receiver battery backup.

57. Recommendation. We are here concerned with ensuring that your first electric model is successful and, in view of the undoubted weight saving advantage and the fact

that you will not have to worry about the state of your receiver battery pack, it is unreservedly recommended that you use a BEC in models with only two servos. If you later wish to know more about the details of this argument you may obtain further information from BEFA.

ELECTRIC FLIGHT SWITCHES & THROTTLES

(Last Revision 9/2/95)

58. For this first model you will need a flight switch or throttle with BEC capable of currents up to an absolute minimum of 25 Amps. Considering the future, it would be desirable, if possible, to buy one with a capacity of at least 30 Amps and preferably more. As already intimated, whichever unit is chosen should have a BEC system so that no receiver pack will be necessary.

A flight switch is really all that is needed for a glider and would also suffice for a sports model. However, for the latter, a throttle (speed controller) is much to be preferred. Irrespective of the type of model, but assuming it has enough power for a good rate of climb, a throttle may be used to give a significantly increased motor running time.

59. Safety Warning. Ensure that the propeller is clear of all obstructions including your hands when you plug in the flight pack and also when you switch on the receiver switch. This is because some flight switches and throttles will permit a momentary burst of current to the motor before settling down.

60. Never Run The Pack Right Down. In the event that you do not use a BEC and particularly if you use a switch, as opposed to a throttle, it will be possible to run the flight pack right down. For the reasons already stated this must NOT be done. Therefore, when you notice a distinct loss of power you should immediately switch off the motor.

PROVISION OF COOLING

(Lest Revision 9/2/95)

61. The motor you will be using is designed for short term use only and will benefit from supplying the brush region with some cooling air. Two simple V shaped openings in the nose are all that is required, as shown at Figure 9.

No provision for battery cooling in flight is necessary. If you fly a sports model with continuous full power for about five minutes, land immediately and then remove the flight pack, it will be quite warm to the touch. Throughout the next ten to fifteen minutes, however, the skin temperature will continue to rise, because a high temperature was reached in the cores of the cells. Similar to the effect in fast charging isn't it? But of longer duration, because more Amps were involved and therefore more heat generated in the cores. Cooling air in flight would not have affected this in any way, so why bother?

RADIO SUPPRESSION

(Lest Revision 13/2/95)

62. Suppression Capacitors. Expensive motors are supplied with adequate internal radio suppression components fitted, but the motor you will be using in your first model may not be - even if the manufacturer says that it is suppressed.

Some commercial kits are supplied complete with motors, these may have one capacitor soldered between the motor terminals. While helpful, this is not so efficient, under difficult reception conditions, as the so called delta configuration using three capacitors.

Therefore, three small capacitors should be soldered to the motor tags as shown at Figure 10, keeping the leads as short as possible. Ensure that the voltage rating of these capacitors is not less than 1.5 times the maximum number of cells that will ever be used in the model. A soldering iron intended for printed circuits is not man enough for the job of soldering to the motor case - a 70 Watt iron is much better. Also, ensure that the bare leads of the capacitors cannot short out on the motor case. Use sleeving if necessary.

63. Receiver & Aerial. Keep the receiver well away from the motor and route the aerial as far away from the servos as is reasonably practical. The best position for the aerial is out through the top of the fuselage, near the receiver, and thence to the top of the fin from where it should be fastened and the excess allowed to trail free. Never double it back so reducing its length.

Although not always practicable, the best radio installation is where the servos are mounted forward of the receiver and the aerial is routed as already stated.

64. Power Leads. All wire has resistance, the longer the lead the greater the resistance (resulting in loss of voltage to the motor and therefore loss of power) . Also, current passing through a wire causes an induction field.

At the sort of currents we use, this induction field may have radius of an inch or two around the wire and, since it may cause radio interference, it should be kept well away from the receiver and aerial. Something to also bear in mind for the future if you think of multi-engined or unconventional types.

Therefore, always keep the power wiring as short as possible, using wire with a core diameter of 2mm and solder the switch or throttle power output leads, negative to the motor negative tag and positive to the fuse, as shown at Figure 11. If you later build models powered by Speed 400 motors, then the internal leads stripped from domestic 13

Amp mains leads will be adequate for the currents used since they should be lower than 10 Amps.

Conclusion

It is to be hoped that you have now gained a little more understanding of the requirements that will enable you to successfully fly your first electric model.

Inevitably, reading of a volume such as this will lead to more questions than can be answered here. Therefore, for beginners, the golden rule is "ASK IF IN DOUBT".

As previously stated, BEFA has it's own technical help service, details of which can be found in 'Electric Flight U.K.'

* * * * *

FIG 1 (Revised 16/2/95)

APPLICATIONS OF OHM'S LAW

I = E/R	I = Current in Amps
E = IR	E = Volts (Electromotive Force)
R = E/I	R = Resistance in Ohms
$W = I^2R$ or W =VA	A = Amps
HP = W/746	W = Watts (Power)
	1 HP = 746 Watts
	Ah = AMP HOURS
	mV = Millivolts (thousandths of)
	mA = Milliamps
	m =1/1000 or 0.001

For resistors of 500R and 750R in parallel, your math book will explain reciprocal calculations: -

1/R = 1/500 + 1/750 = 3/1500 + 2/1500 = 5/1500 = 1/300 or 300 Ohms

To estimate length of motor run in minutes divide the Ah capacity of the cells by the Current, ie Amps, and multiply by 60. For example with a 1700mAh pack operating at 16A, the arithmetic is 1.7/16X60=6.375 minutes. Note, however, that the current in the air is less than the current on the ground, because the prop is unloaded by the forward speed such that the actual current will be only some 85 per cent of what it was on the ground.

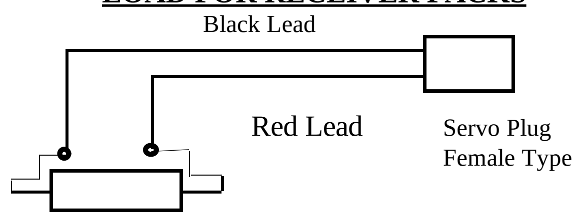
If the prop turns for, say, 5 minutes at full power in the air, you may estimate the current viz: 1.7/5X60=20.4Amps - and this is the true mean current in the air. With 7 cells at 20A the voltage will be about 7.5V so the power will be 7.5X20.4=150W. This would result in increased brush wear and a shorter life than desirable with a Speed 600 motor - 15A or 16A is better for long life.

At 16A 6 cells would give 6.4V and 16X6.4=102W while 7 cells would give 7.5V and 16X7.5=120W hence the 20% power increase mentioned in the script. In general, the motor and battery may be regarded as constituting half the A.U.W. of the model, so by using 7 cells instead of 6 we have added 2 ounces of weight to a 40 ounce model - an increase of 5% - but we now have 20% mare power which is a well worth while improvement to the power to weight ratio. Use 7 cells in preference to 6. The weight increase will have very little effect on the glide, while the rate of climb will be much improved.

If you wish to compare the power of your motor with an IC motor you must multiply the W input by motor efficiency, say 0.65, then divide by 746. Thus in the 7 cell example above:- 120X0.65/746=0.10HP and this is the power that will be delivered to the prop. Remember that the BHP delivered by the IC engine will NOT be the maximum stated by the manufacturer.

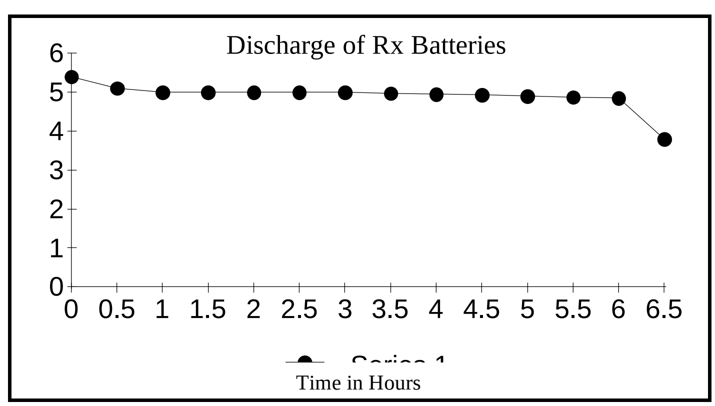
FIG 2 (Revised 9/2/95)

LOAD FOR RECEIVER PACKS



27ohm 7W WW RESISTOR WITH ENDS BENT AS SHOWN OVER WHICH TWO SHORT PIECES OF BRASS TUBING ARE SOLDERED TO PROVIDE MEASURING TERMINALS FOR VOLTAGE CHECKS. BATTERY TO BE TESTED OR RUN DOWN PLUGGED IN, BUT IF RUNNING DOWN DO NOT GO DOWN TO LESS THAN ONE VOLT PER CELL (4V FOR 4 CELL PACK). THE CURRENT WILL BE 185mA. HEAT SHRINK AROUND BODY OF RESISTOR AND REMEMBER THAT THE RESISTOR WILL BECOME FAIRLY HOT AFTER A FEW MINUTES. USE THIS LOAD IF YOU WISH TO CHECK THE Rx PACK BEFORE FLIGHT AND DO NOT FLY IF THE VOLTAGE UNDER LOAD IS LESS THAN 4.9V.

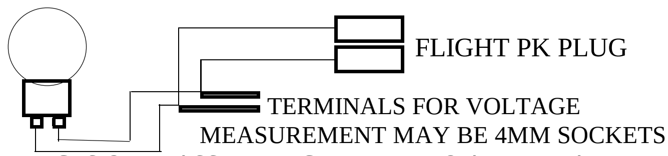
FIG 3 Revised 9/2/95



This graph shows a 500 mAh pack discharging at a rate typical of a small glider with 2 micro servos. It will be seen that once the voltage falls below 5V it would be dangerous to fly since the point on the curve could be near the edge of the cliff! The safe thing to do is to fly only if the voltage is in excess of 4.9V and this voltage must be measured under load as stated in the text.

FIG 4 (Revised 11/2/95)

CAR HEADLIGHT BULB LOAD FOR FLT PACKS

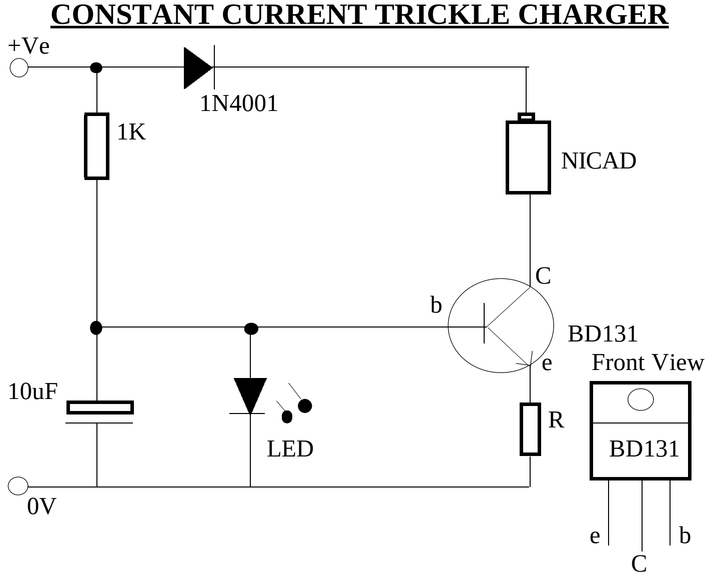


OR 2 PIECES OF BRASS TUBING FIXED INTO A PLY PLATE WITH THE BULB

THE CAR HEADLIGHT BULB IS A SUITABLE LOAD FOR DISCHARGING FLIGHT PACKS. USE ONE BULB FOR UP TO 10 CELLS, TWO BULBS IN SERIES FOR 12 TO 20 CELLS AND THREE IN SERIES FOR MORE THAN 20 CELLS. THE CURRENT WILL BE ABOUT 2.7A TO 3.5A DEPENDING ON THE VOLTAGE. DO NOT RUN DOWN TO LESS THAN ONE VOLT PER CELL.

FIG 5

CONSTANT CURRENT TRICKLE CHARGER



B0TH RESISTORS ARE 0.6W 1% TYPE.

THE LED IS A STANDARD 5mm RED. THE CATHODE IS DENOTED BY THE SHORT LEAD AND THE FLAT ON THE BODY.

THE APPLIED VOLTAGE MUST BE AT LEAST 1.7 X THE MAXIMUM NUMBER OF CELLS TO BE CHARGED.

THE CAPACITOR MUST HAVE A HIGHER VOLTAGE RATING THAN THE APPLIED VOLTAGE.

USING A 12V BATTERY AS THE POWER SOURCE THE CHARGER WILL CHARGE FROM ONE TO SEVEN CELLS AND WILL ALMOST FULLY CHARGE AN EIGHT CELL PACK IF THE 12V BATTERY IS FULLY CHARGED. IF MORE THAN 7 CELLS ARE TO BE CHARGED THEN IT IS PREFERABLE TO USE A MAINS POWER SUPPLY DESIGNED TO PROVIDE A VOLTAGE OF BETWEEN 1.7 AND 2 TIMES THE MAXIMUM NUMBER OF CELLS TO BE CHARGED; AND NOT LESS THAN 250mA PER UNIT ASSUMING IT IS DESIRED TO CHARGE SEVERAL PACKS SIMULTANEOUSLY. IN THIS CASE THE TRANSFORMER USED MUST HAVE A MINIMUM RATED OUTPUT EQUAL TO THE TOTAL CURRENT REQUIRED DIVIDED BY 0.62. IF THE APPLIED VOLTAGE IS GREATER THAN ABOUT 18V THEN THE 1K RESISTOR SHOULD BE INCREASED IN VALUE TO RESTRICT THE CURRENT APPLIED TO THE LED TO BETWEEN 10 AND 15 mA.

THE RESISTOR "R" SETS THE CHARGE CURRENT AND ITS APPROXIMATE VALUE WILL BE 1.39 (1.39 BECAUSE THE VOLTAGE ACROSS R WILL BE ABOUT 1.39V WHEN THE CIRCUIT IS IN OPERATION, DEPENDING ON THE CHARACTERISTICS OF THE BD131 AND LED) DIVIDED BY THE REQUIRED CURRENT IN AMPS. FOR EXAMPLE, THE CHARGE CURRENT IS TO BE 170MA SO, 1.39 / 0.170 = 8.17 OR 8 OHMS. THE PREFERRED VALUE OF 8R2 WOULD BE JUST RIGHT. ONE COULD OF COURSE USE TWO 16 OHM RESISTORS IN PARALLEL TO GIVE 8 OHMS. IF AN EXACT CHARGE CURRENT IS REQUIRED THEN OBTAIN A 22 TURN CERMET 1K PRESET, MAPLIN REF UH23A. WIRE IT UP AS SHOWN BELOW, SET IT TO EXACTLY 8 OHMS AND CONNECT IT TEMPORARILY INTO THE CIRCUIT. CONNECT THE POWER SUPPLY, THE LED SHOULD NOT GLOW; THEN CONNECT A LARGE CAPACITY, DISCHARGED NICAD PACK AT WHICH TIME THE LED SHOULD LIGHT UP AND MEASURE THE VOLTAGE ACROSS THE PRESET AFTER SOME 10 MINUTES. DIVIDE THAT VOLTAGE BY 8 (THE RESISTANCE TO WHICH YOU SET THE POTENTIOMETER) AND THE ANSWER IS THE CURRENT BEING PROVIDED. DO NOT USE YOUR METER TO MEASURE THE CURRENT BECAUSE IT WILL TELL LIES. IF THE CURRENT IS NOT WHAT IS REQUIRED, DISCONNECT THE NICAD, THEN THE POWER SUPPLY, WAIT 20 SECONDS AND THEN SET THE PRESET TO A SLIGHTLY DIFFERENT VALUE. THEN REPEAT THE EXPERIMENT AND SO ON UNTIL YOU HAVE THE CURRENT YOU WANT. THEN OBTAIN A 1% RESISTOR OF THE VALUE MEASURED ON THE PRESET AND SOLDER THAT ONE INTO THE CIRCUIT.

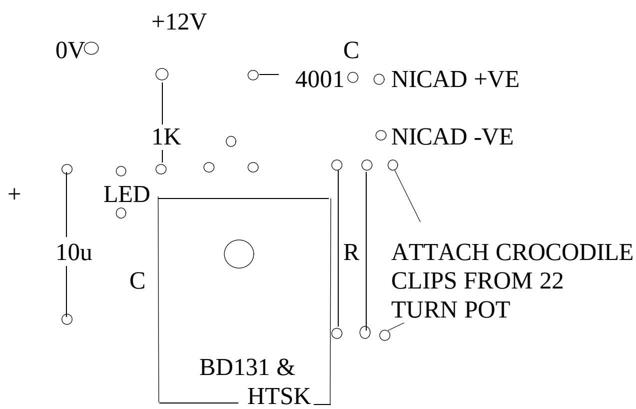
THE TRANSISTOR MUST BE MOUNTED ON A HEATSINK AND THE MAPLIN VANED HEATSINK REF JX2lX SHOULD BE ALL RIGHT FOR PACKS OF UP TO ABOUT 14 CELLS.

(22 Turn Pot on next page diagram)

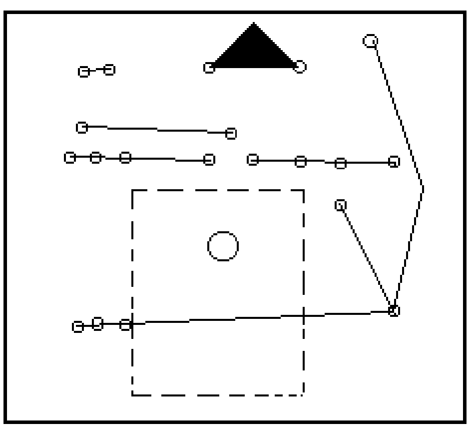
22 Turn Pot

FIG 6
LAYOUT & CONSTRUCTION OF TRICKLE CHARGER

Component Side

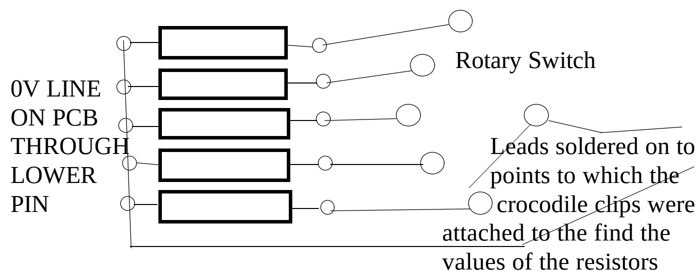


Copper Side



THIS SIMPLE PRINTED CIRCUIT MAY BE MADE BY USING THE COPPER SIDE DIAGRAM AS A PAPER PATTERN TO MARK WITH A COMPASS POINT THE 1mm HOLES TO BE DRILLED THROUGH THE PCB. THEN DRILL THE HOLES. CLEAN THE COPPER WITH A DAMP BRILLO PAD AND WASH AND DRY - DO NOT TOUCH WITH FINGERS. PAINT TRACKS AS INDICATED, 3mm WIDE, WITH CELLULOSE DOPE OR ENAMEL PAINT. WHEN DRY PLACE IN ETCHING FLUID UNTIL COPPER IS REMOVED. CLEAN OFF PAINT WITH APPROPRIATE THINNERS AND STEEL WOOL. INSERT COMPONENTS FROM THE COMPONENT SIDE (EXCEPT FOR PINS) NOTING POLARITY OF DIODE, LED AND CAPACITOR AND AFTER BENDING OVER AND CLIPPING LEADS, SOLDER IN PLACE. USE THE 2145 PINS FOR ALL OFF BOARD CONNECTIONS: +12V; 0V; CERMET OR SWITCH; NICAD. SETTING UP INSTRUCTIONS ARE AT FIGURE 5. IF THE ROTARY SWITCH IS TO BE USED TO SELECT DIFFERING VALUES OF R THEN USE THE FOLLOWING ARRANGEMENT.

CHOSEN RESISTORS SOLDERED ONTO PIECE OF PCB ONE END OF EACH JOINED, THE OTHER ENDS WITH WIRE LEADS TO SWITCH TAGS.



IF YOU ARE UNCERTAIN ABOUT ANYTHING OR NEED ANY HELP PLEASE DO NOT HESITATE TO CONTACT THE FREE BEFA TECHNICAL LIAISON SERVICE, BUT PLEASE ENCLOSE A STAMPED AND ADDRESSED ENVELOPE WITH YOUR QUERY.

IMPORTANT SAFETY NOTE

THE ETCHING FLUID IS VERY CORROSIVE, WEAR PROTECTIVE GLOVES AND GOGGLES WHEN USING AND IF DISPOSING DOWN DRAIN USE LARGE QUANTITIES OF CLEAN WATER FOR DILUTION. KEEP WELL AWAY FROM CHILDREN, FISH, ANIMALS AND PLANTS. THE COMPONENTS MAY BE OBTAINED FROM MAPLIN:

Ref	
QFO3D BD131 Transistor	QL73Q 1N4001 Diode
RW75S Knob BK12	JX21X Vaned Heatsink
WL27E 5mm Red LED	FH42V Rotary Switch SW12
FB22Y 10uF 25V Capacitor	FL24B Pin 2145
PCB	1K 0.6W 1% Resistor
UH23A 1K Cermet Preset	

FIG 7 (Revised 15/2/95)
CHEAP FAST CHARGING

IF THIS METHOD IS USED IT IS VITAL FOR SAFETY REASONS TO CONTINUOUSLY MONITOR PACK VOLTAGE AND TEMPERATURE. SEE FIGURE 6,

BUT IF THE PACK BECOMES EXCESSIVELY HOT BEFORE THE VOLTAGE REACHES 10.5V FOR 7 CELLS OR 9.0V FOR 6 CELLS THEN TERMINATE THE CHARGE IMMEDIATELY. ON FAST CHARGING CELL TEMPERATURE SHOULD NEVER, BUT NEVER, EXCEED 38 DEGREES CENTIGRADE. NORMALLY A TEMPERATURE INCREASE OF 5 TO 7 DEGREES CENTIGRADE IS SUFFICIENT.

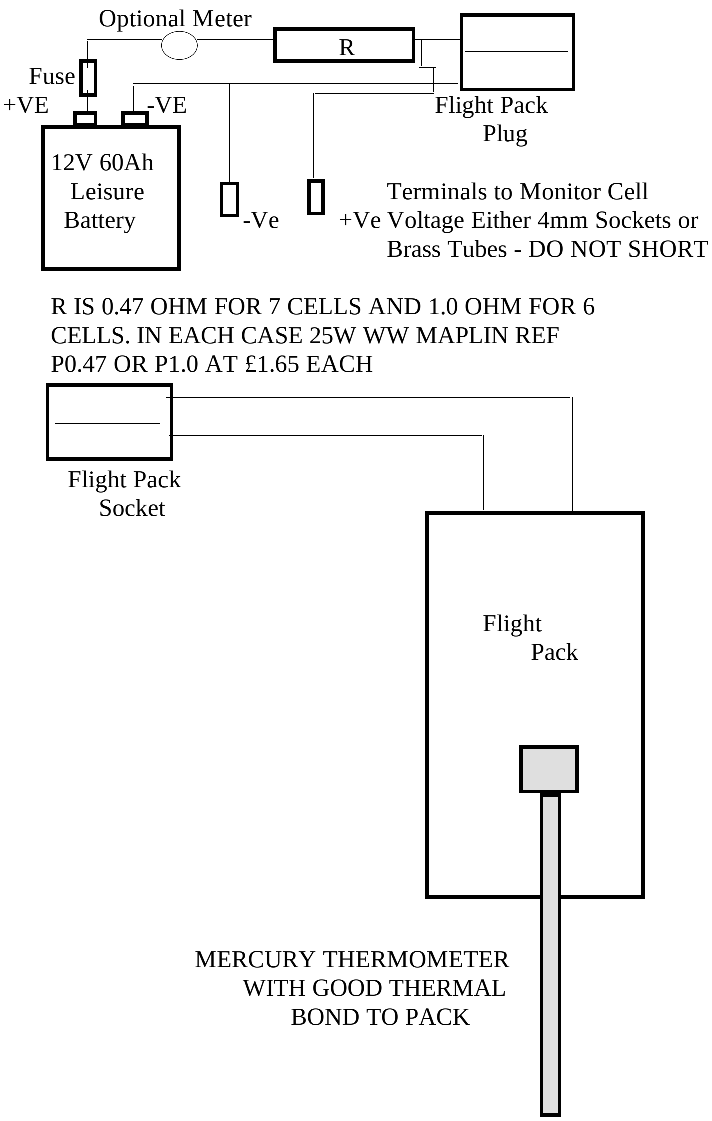


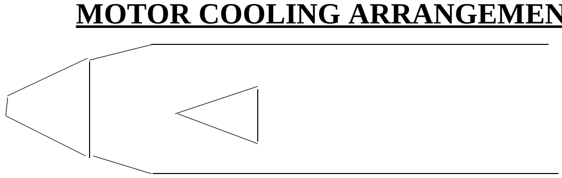
FIG 8 (Revised 14/2/95)

CHEAP FAST CHARGING THROUGH A RESISTOR

(This is on the next page)

FIG 9 (9/2/95)

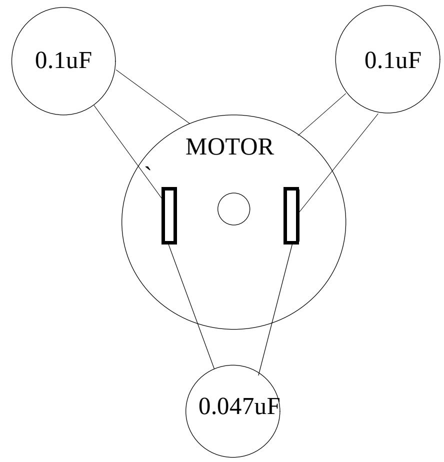
MOTOR COOLING ARRANGEMENT



TRIANGULAR HOLES 15MM X 10MM ON EITHER SIDE OF NOSE, ONE JUST BELOW THE CENTRE LINE OF MOTOR WITH BASE ABOUT 0.5 INCH AHEAD OF BRUSH AREA AND THE OTHER JUST ABOVE CENTRE LINE OF MOTOR WITH APEX ABOUT 0.25 INCH BEHIND BRUSH AREA.

FIG 10 (Revised 9/2/95)

CORRECT MOTOR SUPPRESSION FOR 35 MHZ RADIOS

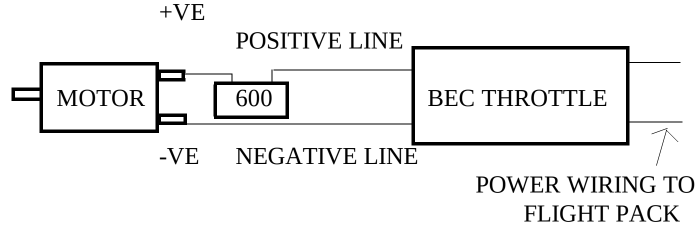


THIS SO-CALLED DELTA CONFIGURATION USING 3 SMALL DISC CAPACITORS IS SUPERIOR TO USING ONLY ONE OR TWO CAPACITORS: THEY SHOULD BE SOLDERED IN AS SHOWN THE 0.1UF HAVING ONE LEAD EACH SOLDERED TO THE METAL CASE OF THE MOTOR. THE VOLTAGE RATING OF THE CAPACITORS SHOULD NOT BE LESS THAN 1.5 X THE MAXIMUM NUMBER OF CELLS TO BE USED.

KEEP ALL LEADS AS SHORT AS POSSIBLE AND DRESS COMPONENTS TO CONFORM TO CROSS-SECTIONAL DIMENSIONS OF MOTOR.

FIG 11 (Revised 9/2/95)

MOTOR/FUSE/THROTTLE POWER WIRING



ALWAYS KEEP POWER LEADS AS SHORT AS POSSIBLE AND USE WIRE WITH A METAL CORE OF NOT LESS THAN 2MM DIAMETER EXCEPT FOR SPEED 400 MOTORS WHERE THE INTERNAL LEADS OF 13A MAINS LEAD MAY BE USED. FUSE

FIG 8 (Revised 14/2/95)

CHEAP FAST CHARGING THROUGH A RESISTOR

	A	B	C	D	E	F	G	H	I
1	7 x 1700mAh & 0.47R Resistor					7 x 600mAh & 1.5R Resistor			
2	MINS	AMPS	VOLTS	TEMP		MINS	AMPS	VOLTS	TEMP
3	START	5.60	8.45	13.5		START	1.60	7.70	12.0
4	1	4.60	9.80	13.2		1	1.24	10.30	11.8
5	2	4.20	9.90	13.2		2	1.17	10.50	11.7
6	3	4.15	9.95	13.1		3	1.16	10.50	11.7
7	4	4.13	10.00	13.1		4	1.15	10.50	11.7
8	5	4.08	10.02	13.1		5	1.14	10.50	11.7
9	6	4.03	10.05	13.1		6	1.13	10.55	11.7
10	7	3.96	10.07	13.0		7	1.12	10.55	11.8
11	8	3.90	10.10	13.0		8	1.12	10.55	11.8
12	9	3.83	10.10	13.0		9	1.11	10.55	12.0
13	10	3.75	10.13	13.0		10	1.1	10.60	12.2
14	11	3.69	10.15	13.0		11	1.1	10.60	12.2
15	12	3.62	10.17	13.0		12	1.1	10.60	12.2
16	13	3.57	10.18	13.1		13	1.09	10.65	12.3
17	14	3.52	10.20	13.1		14	1.08	10.68	12.3
18	15	3.49	10.22	13.1		15	1.08	10.70	12.4
19	16	3.42	10.23	13.1		16	1.08	10.70	12.5
20	17	3.39	10.25	13.1		17	1.07	10.72	12.6
21	18	3.34	10.30	13.2		18	1.07	10.72	12.8
22	19	3.28	10.33	13.2		19	1.06	10.72	13.0
23	20	3.23	10.38	13.3		20	1.05	10.73	13.1
24	21	3.17	10.42	13.3		21	1.04	10.74	13.2
25	22	3.09	10.48	13.4		22	1.03	10.75	13.4
26	23	2.98	10.50	13.4		23	1.04	10.78	13.7
27	24	2.85	10.60	13.5		24	1.04	10.80	13.9
28	25	2.65	10.70	13.6		25	1.03	10.81	14.1
29	26	2.41	10.80	13.8		26	1.01	10.82	14.4
30	27	2.18	11.00	13.9		27	1.02	10.83	14.7
31	28	1.98	11.15	14.1		28	1.03	10.84	14.9
32	29	1.84	11.25	14.4		29	1.03	10.85	15.2
33	30	1.74	11.40	14.9		30	1.02	10.86	15.5
34	31	1.68	11.42	15.3		31	1.02	10.87	15.9
35	32	1.64	11.45	15.7		32	1.01	10.88	16.4
36	33	1.63	11.48	16.3		33	1.00	10.89	16.9
37	34	1.63	11.49	17.0		34	1.00	10.90	17.5
38	35	1.65	11.49	17.8		35	1.00	10.90	17.9
39	36	1.67	11.45	18.8		36	0.99	10.92	18.7
40	37	1.70	11.40	19.9		37	0.98	10.95	19.4
41	38	1.79	11.30	21.0		38	0.98	10.85	20.2
42	39	Terminated		21.9		39	Terminated		20.7
43	40			23.0		40			21.1
44	41			23.5		41			21.6
45	42			24.1		42			21.8
46	43			24.6		43			21.8
47	44			25.1					
48	45			25.4					
49	46			25.6					
50	47			25.6					

FIG 11 (Revised 9/2/95) Continued:
MOTOR/FUSE/THROTTLE POWER WIRING
SHOWN IS MFR600 FROM MAPLIN REF CP64U COSTING £5.95 AND THIS IS STRONGLY RECOMMENDED IN PREFERENCE TO ANY OTHER FUSE DESPITE ITS COST. TWO CAN BE USED IN PARALLEL FOR CURRENTS IN EXCESS OF 15A AND TWO WOULD BE NEEDED TO COVER ALL THE POSSIBLE POWER VARIATIONS IN A SPEED 600 SYSTEM. THE LEADS SHOULD BE TWISTED TOGETHER AND THE BODIES SLIGHTLY FANNED OUT FOR COOLING. IF USING A 30A CAR FUSE IT IS PREFERABLE TO SOLDER IT IN RATHER THAN TO USE A HOLDER WHICH WILL IMPOSE UNWANTED RESISTANCE AND THEREFORE REDUCE POWER.

Details of Front Cover Model

My model, shown on the index page, is an electrified version of the 94” span Precedent T240. The 18 x 10” propeller is turned by a Graupner Ultra 2000 motor with a Kruse 2:1 belt drive reducer. Power is supplied by 28 x Sanyo N1700SCRC cells.

No attempt was made to minimise weight during construction. Flaps are fitted and the model is covered in Solartex for durability. The all up weight is 16.75 pounds. This gives a wing loading of around 30 ounces per square foot. Flight times range from seven to fourteen minutes.

If operating costs and initial outlay are considered over a three year period, the electric version will have cost only about two-thirds the total cost of the equivalent .60 glow-powered model. This assumes that the latter will be using 5% nitro and synthetic oil.

Of course, the electric version remains absolutely clean and is exceptionally quiet, a factor which is assuming ever-increasing importance as a result of noise nuisance complaints.

BEFA Would Like to Thank Ken Myers, of Walled Lake, Michigan, USA.

Ken Myers is the President of the Electric Flyers Only, Inc. and editor of the *Ampeer*, an electric newsletter. He put our original document into Adobe Acrobat .pdf format for us, so that we could share it with you. For this, we thank him.

You can visit Ken’s EFO WEBsite at:
http://ourworld.compuserve.com/homepages/i_fly_epower
or you can e-mail him at:
102575.3410@compuserve.com