SCOTTISH SCHOOLS SCIENCE

EQUIPMENT RESEARCH

CENTRE

Bulletin No. 58 September 1972.

Contents

Introduction

Ever since its inception, one of the main methods of bringing the activities of SSSERC to the notice of teachers has been the staging of exhibitions throughout Scotland. Since the autumn of 1966 when the first one was held in Ayr Science Centre, these have occurred at an average of one per month. Characteristically, any number from 40 to 80 exhibits are staged, and the time allowed for the teacher to see them has varied from an hour to several days. During the six years, some innovations have taken place; while most exhibitions are for teachers, we have held some for laboratory technicians and for students at Colleges of Education. While normally a professional member of staff and a technician have advised during the exhibition, we have set up exhibitions and left them unattended for a week for teachers to visit as and when they could.

Often when staging exhibitions the staff have been conscious of failure or partial failure to achieve a desired level of communication. Sometimes it happens that the idea which we feel to be a winner on all counts is scarcely glanced at by the perambulating teachers, and while the disappointed exhibitor may try to imitate Coleridge's Mariner by stopping one in three he will be fortunate if he succeeds. At other times, with general purpose equipment such as the oscilloscope or, more recently, the chart recorder and the three-way tap, we know that the one exhibit we have selected to illustrate its use does not do justice to the apparatus. To cover these situations we propose an extension of our services which has already been tried out in biology during the past year and which we hope will bring us into more personal contact with the teachers in a given area. This is to run demonstration lectures, round a central theme, of no more than 45 minutes duration and showing perhaps between 12-20 experiments or items of apparatus. It is hoped that this would stimulate informal discussion in the group which would be of benefit to all. While these lectures could be run in conjunction with an exhibition, there are advantages in considering them as separate entities. When the same equipment is used in demonstration and on exhibition there are practical difficulties in moving it from the lecture room and re-assembling it in the exhibition site. Also, holding a lecture in conjunction with an exhibition tends to concentrate the exhibition audience into one space of time, whereas one advantage of a three hour exhibition ought to be that the teacher can arrive and leave at whatever time he chooses. Where the economics of travelling force us to consider combining the two functions, it may be a solution to hold the demonstration in the evening, and the exhibition the following day. But in the main we see these demonstration lectures as fitting into the programme of groups of teachers, and we know that there are several of these throughout Scotland, who arrange a series of regular meetings during the school session. We already have one such commitment, to talk to physics teachers in Aberdeen on Friday, 16th March, 1973, on the subject of the chart recorder, and we invite inquiries and suggestions for possible themes and dates from other groups.

The proposed extension of our services does not mean that we intend to curtail our normal exhibition programme and as bookings for the present session are light, we are likewise inviting inquiries for possible exhibitions between now and July 1973.

Biology Notes

<u>Transpiration in plants</u> Three major cognitive objectives of this section of the syllabus (IV (3)(c)) are presumably:

1) An understanding that transpiration is caused by evaporation;
2) An understanding of the tension-cohesion explanation for the movement of the transpiration stream;
3) An understanding of the mechanism and significance of stomatal control of transpiration - usually arrived at from a comparative study of the effect of environmental factors on evaporation and transpiration.

To these may be added a fourth, perhaps less generally recognised objective; an understanding of stomatal control of water loss as a homeostatic mechanism. Unfortunately the achievement of these objectives experimentally is often hampered by difficulties with some of the equipment used - particularly with bubble potometers and atmometers. With these difficulties in mind we have attempted to simplify the investigations involved, so that they can be performed on a pupil scale wherever possible, and still hopefully provide worthwhile results. In doing so we have made use of a type of bubble atmometer/potometer, the construction and operation of which are described below.

The design uses a three-way tap, the action of which was described in Bulletin 48 but which will be repeated here. The taps are obtained from <u>Henley's Medical Supplies</u> and are made in plastic. As the name suggests the tap has three outlets and a lever handle which rotates through 180°. The outlets form a T; two of these, on one arm and on the leg of the T are flanged square at the ends and these flanges should be trimmed off if these ends are to be inserted in tubing. The third outlet is tubular and can be inserted direct into tubing. The tap has three operating positions, connecting any two of the three outlets, the remaining one being blocked off. The position in use is shown by the lever handle which points towards the blocked outlet. In the descriptions which follow we shall indicate the tap position with reference to the blocked outlet, although it will be appreciated that most of the time the essential function performed by the tap is the interconnection of the other two.

Fig. 1 Atmometer/Potometer

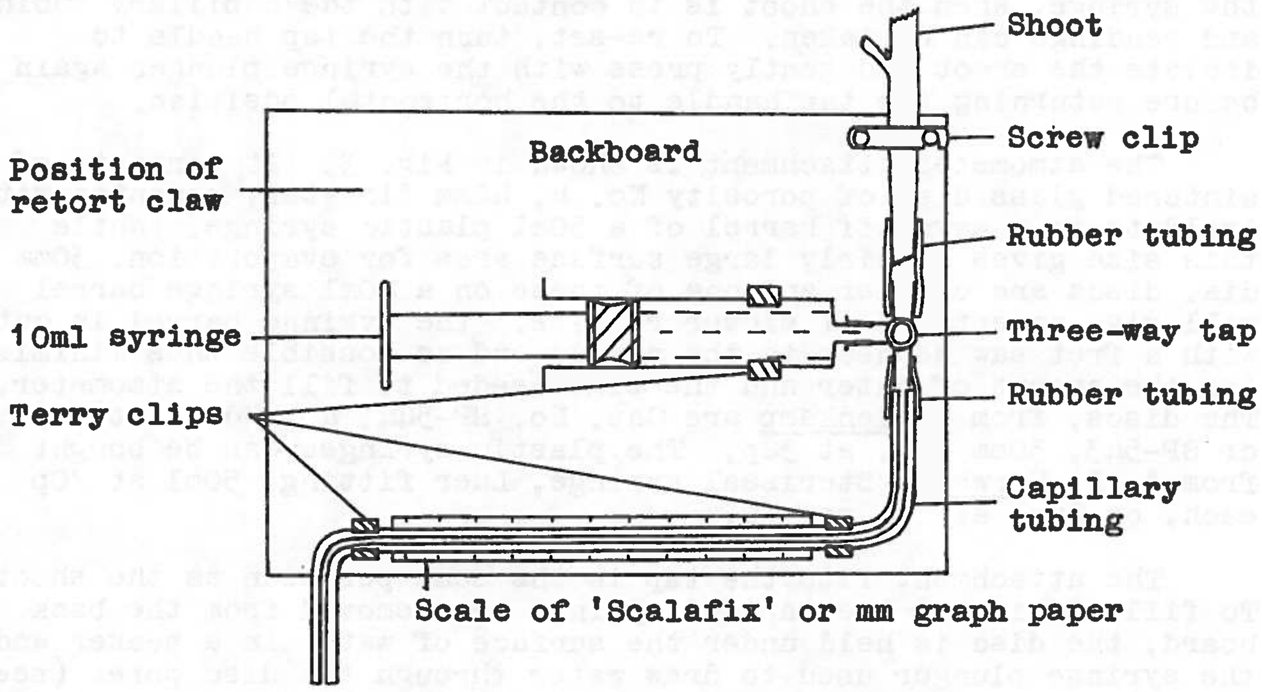
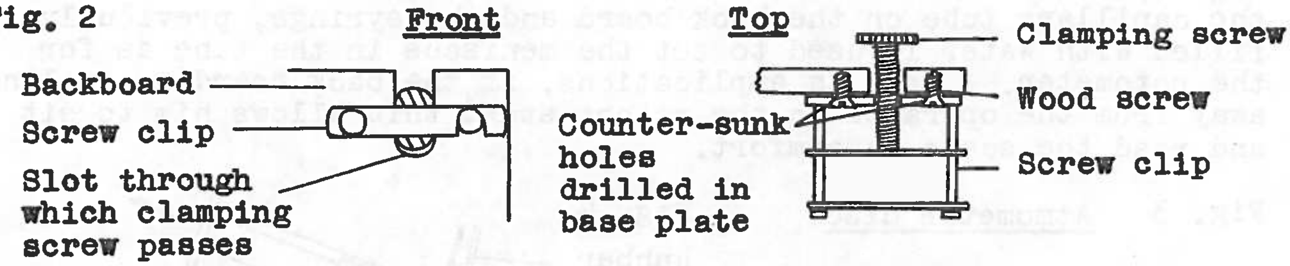


Fig. 2



The construction of the potometer should be evident from Fig. 1. The back board can be made from any suitable material, such as 6mm plywood. The main advantage of the three-way tap is that it allows the potometer to be dismantled, so that the tap and syringe are the only parts which need to be submerged when the shoot is connected.

Operation as a potometer is as follows. The syringe is disconnected from the tap, and the tap and rubber tubing connector disconnected from the capillary tubing. The syringe is then filled with water, and reattached to the tap which with the rubber tubing is submerged in a bowl of water. The syringe is then used to eject all the air from the tap and tubing. The shoot is cut under water, inserted into the appropriate piece of rubber tubing, and the tap handle then turned to isolate the shoot. This seals the cut end of the shoot from the air, so that the tap and shoot may then be removed from the bowl of water and re-connected to the capillary tubing. A screw clip attached to the back board as in Fig. 2 is used to support the shoot. The syringe, full of water, is clipped to the back board and inserted into the free end of the tap. Gentle pressure on the syringe plunger will then fill the capillary tubing with water; indeed the meniscus, or bubble, can be brought to any point on the scale by careful manipulation of the plunger. The apparatus is then fixed into a retort stand claw and the tap handle turned to isolate the syringe, when the shoot is in contact with the capillary tubing and readings can be taken. To re-set, turn the tap handle to isolate the shoot and gently press with the syringe plunger again before returning the tap handle to the horizontal position.

The atmometer attachment is shown in Fig. 3. It consists of a sintered glass disc of porosity No. 4, 40mm diameter, cemented with Araldite to a sawn-off barrel of a 50ml plastic syringe. While this size gives a fairly large surface area for evaporation, 30mm dia. discs are cheaper and one of these on a 20ml syringe barrel will give acceptable if slower results. The syringe barrel is cut with a fret saw as near to the nozzle end as possible thus minimising the amount of water and the time needed to fill the atmometer. The discs, from Gallenkamp are Cat. No. SF-544, 40mm dia. at 38p, or SF-543, 30mm dia. at 32p. The plastic syringes can be bought from A. R. Horwell, Steriseal syringe, Luer fitting, 50ml at 20p each, or 20ml at 60p per 10.

The attachment fits the tap in the same position as the shoot. To fill it, it and the tap and syringe are removed from the back board, the disc is held under the surface of water in a beaker and the syringe plunger used to draw water through the disc pores (see Fig. 4). When the attachment is full of water it is reconnected to the capillary tube on the back board and the syringe, previously filled with water is used to set the meniscus in the tube as for the potometer. For both applications, if the back board is inclined away from the operator in the retort stand this allows him to sit and read the scale in comfort.

Fig. 3 Atmometer disc

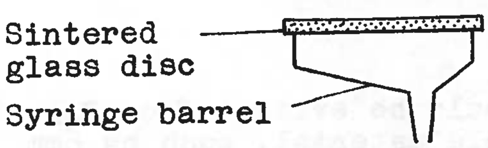
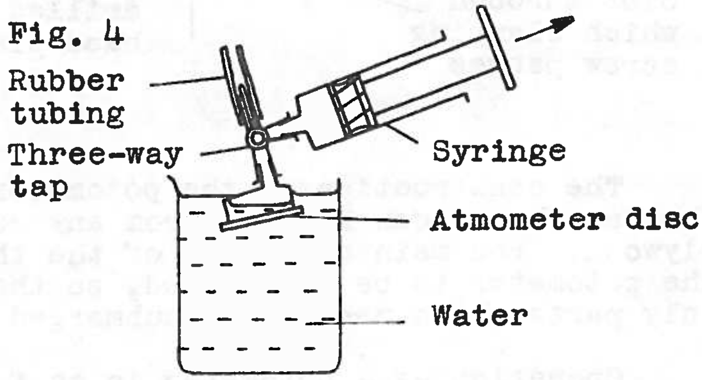


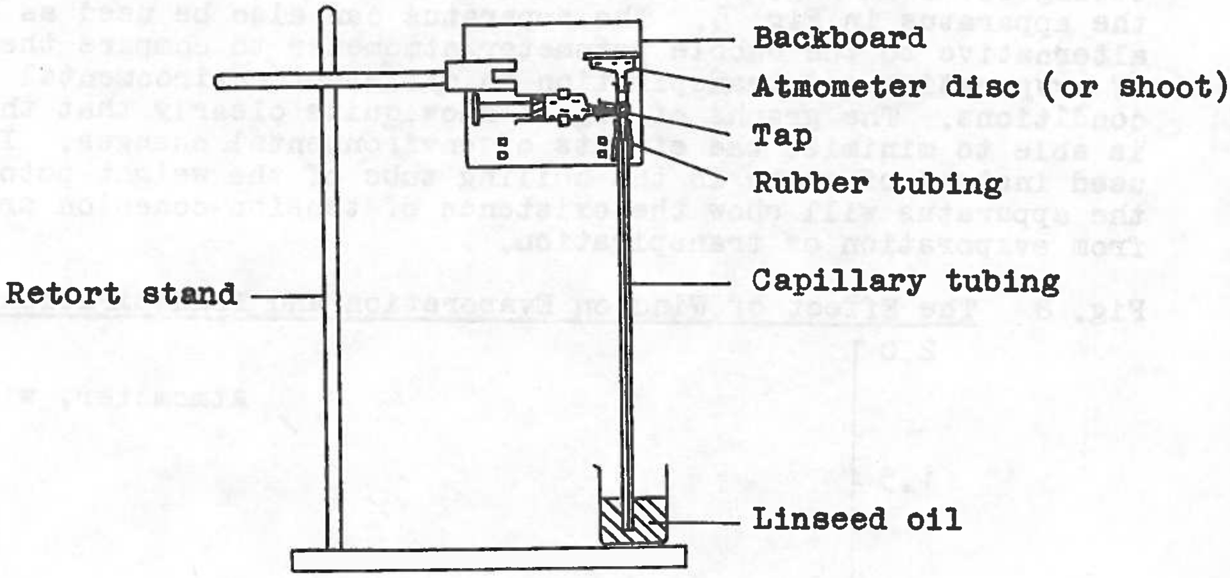
Fig. 4



The writer has used this apparatus for several years on a class scale, with pupils of 14 years and upwards. The great majority of pupils were able to set it up and obtain a sufficient number of readings to reach worthwhile conclusions, in a double period.

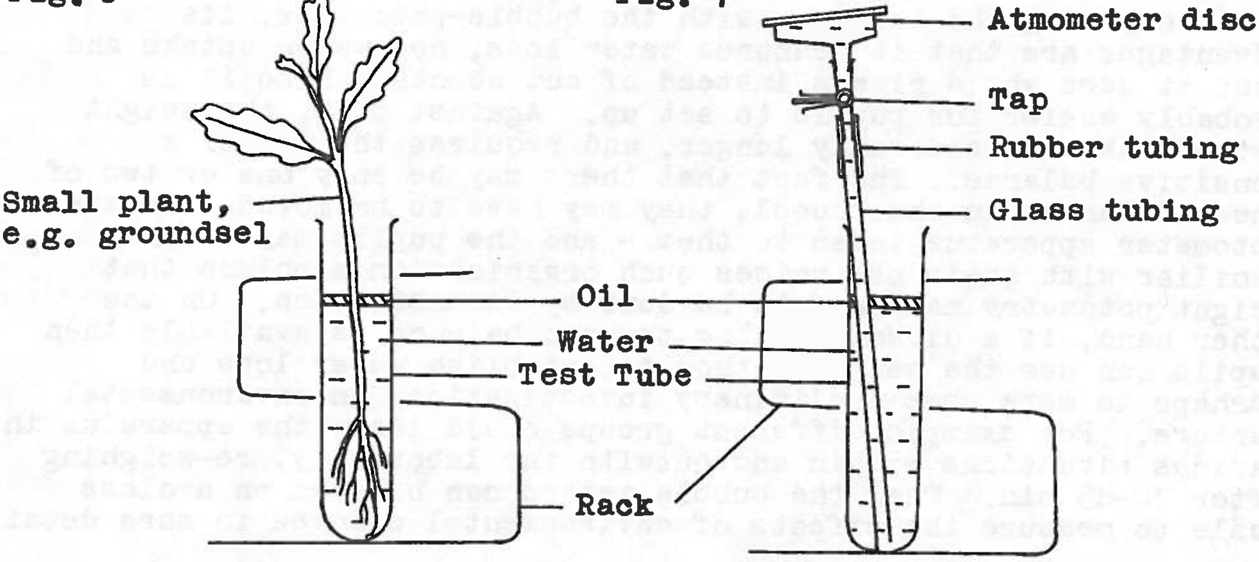
A suggested approach, incorporating the use of this apparatus, is then as follows. To demonstrate evaporation and tension-cohesion, the apparatus shown in Fig. 5 is set up. The main part of the apparatus is essentially the atmometer/potometer described, but with a straight 40cm length of capillary tubing. It is set up as already described, to the point of re-assembling the various parts on the back board. The capillary tubing, still full of air, is then dipped into the beaker of oil and filled with water by depressing the syringe plunger. The tap handle is turned to isolate the syringe and within minutes it can be seen that the oil is being steadily drawn up the tube. The experiment is suitable for carrying out on a class scale, though it could be set up as a demonstration with mercury, in addition to or instead of the suggested arrangement with oil.

Fig. 5



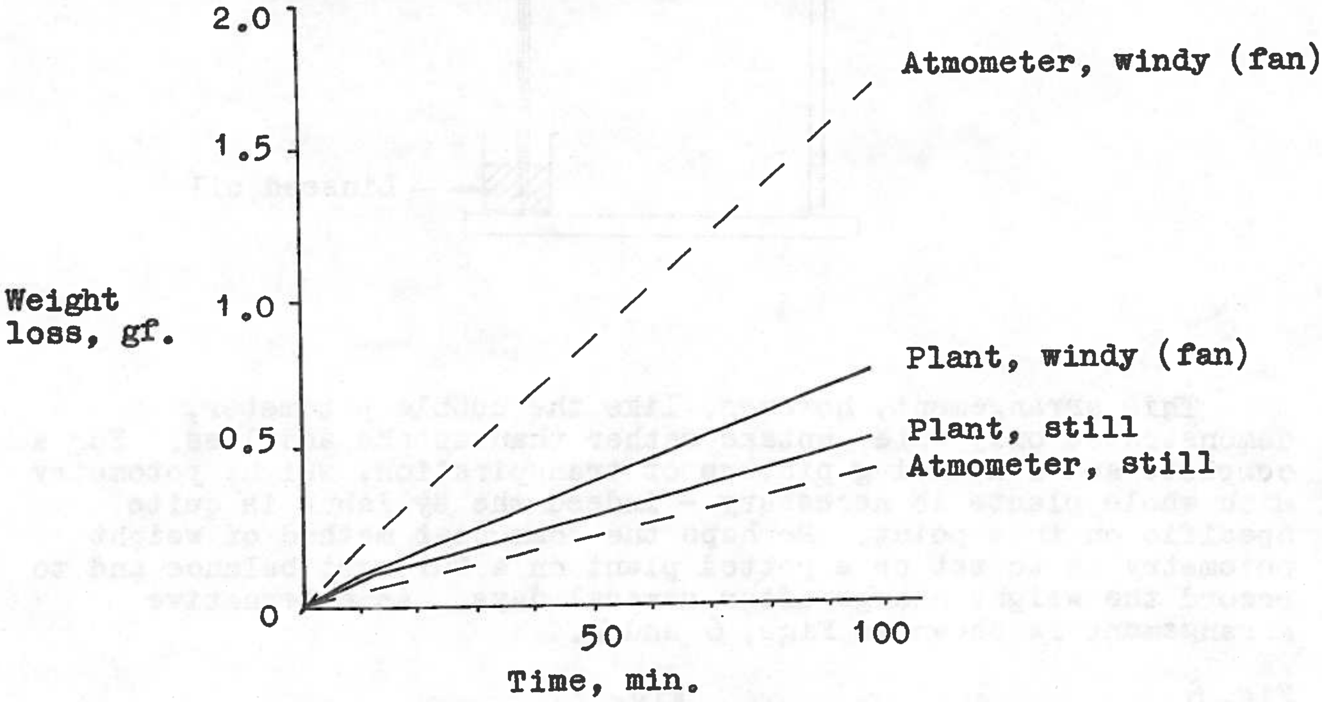
This arrangement, however, like the bubble potometer, demonstrates only water uptake rather than uptake and loss. For a complete and convincing picture of transpiration, weight potometry with whole plants is necessary - indeed the syllabus is quite specific on this point. Perhaps the commonest method of weight potometry is to set up a potted plant on a Butchart balance and to record the weight change after several days. An alternative arrangement is shown in Figs. 6 and 7.

Fig. 6 Fig. 7



This has the advantage over the potted plant method that if a top-pan balance with 10mg sensitivity and 200g capacity is available, significant weight changes can be recorded within a double period. Using the wire mesh test-tube rack as described in Bulletins 48 and 50, the total weight of the apparatus should be about 150-170gf. The arrangement with the atmometer disc emphasises the similarities and differences between transpiration and evaporation. The glass tubing shown in Fig. 7 is filled in the same way as described for the apparatus in Fig. 5. The apparatus can also be used as an alternative to the bubble potometer/atmometer to compare the rates of evaporation and transpiration in different environmental conditions. The graphs of Fig. 8 show quite clearly that the plant is able to minimise the effects of environmental changes. If oil is used instead of water in the boiling tube of the weight potometer, the apparatus will show the existence of tension-cohesion arising from evaporation or transpiration.

Fig. 8 <u>The Effect of Wind on Evaporation and Transpiration</u>



Comparing the weight- with the bubble-potometer, its advantages are that it measures water loss, not water uptake and that it uses whole plants instead of cut shoots. Also it is probably easier for pupils to set up. Against this, the weight method takes considerably longer, and requires the use of a sensitive balance. The fact that there may be only one or two of these balances in the school, they may have to be moved - or the potometer apparatus taken to them - and the pupils may be unfamiliar with their use raises such organisation problems that weight potometry may have to be done by demonstration. On the other hand, if a direct reading top-pan balance is available then pupils can use the weight method to establish water loss and perhaps to make some preliminary investigations on environmental factors. For example different groups could leave the apparatus in various situations within and outwith the laboratory, re-weighing after 30-45 min. Then the bubble method can be used on a class scale to measure the effects of environmental changes in more detail.

In summary, three possible experimental approaches to the achievement of the objectives stated at the beginning have been suggested.

1) Use of a slightly modified form of the bubble atmometer/potometer described, to show tension-cohesion (Fig. 5). Use of small-scale weight potometry and atmometry to establish water loss from whole plants and from non-living porous surfaces (Figs. 6 and 7). Use of the bubble atmometer/potometer (Fig. 1) to investigate the effect of environmental factors, and hence to establish the role of the stomata.
2) Use of the modified bubble atmometer/potometer as before, to show tension-cohesion. Use of the weight atmometer/potometer both to show water loss and to investigate the effect of environmental factors - thus replacing the bubble atmometer/potometer.
3) Use of the weight atmometer/potometer in all three stages of the investigation.

While approaches 2) and 3) have certain advantages to offer - notably by rationalising and simplifying experimental procedure for the pupils - in most school situations approach 1) will probably be the most effective because of the time factor.

In The Workshop

We have sold many hundreds of the small Nife cell, measuring 55 x 25 x 90mm high, usually in batteries of 19 cells owing to the way these have been assembled. Most teachers would break this battery down into smaller units and reassemble the cells in a smaller battery box. A disadvantage of making this arrangement permanent by interconnecting the cells with metal strips is that it makes them difficult to remove from the box for charging, and if kept in the box for that purpose the electrolyte tends to spray over cell tops and the wood of the box itself, causing corrosion and an unsightly mess. Hence we have designed a battery box which has spring contacts to the cell terminals so that cells can be slid into position and removed for charging. Charging the cells still presents difficulties; either a bank of double croc. clips leads has to be made up for connecting each cell to its neighbours, or one of the battery boxes we suggest could be kept solely for charging purposes, limiting the corrosion to this box only.

The design is for a box with open sides, so that if all the cells are pushed in from one side they connect in series, and if from the other side they connect in parallel. In the series arrangement each cell operates a break switch as it is inserted so that the box needs only one pair of output terminals irrespective of how many cells are used. Moreover, if the full capacity of the box is not required, cells can be omitted from any position in the box in the parallel connection, and also in the series connection except for the first one which must be placed in the slot where there is no break switch. If we put a break switch across every cell then the output would be shorted when the parallel connection was being used. Because each cell has to have a special connecting strip fitted to its anode it is impossible to insert cells in the box the wrong way round and so get a wrong polarity. There are only two actions which could produce a fault; if cells were inserted from both series and parallel sides of the box together, then the series cells, being at a higher voltage would partially discharge themselves through the parallel ones. Secondly if a cell on the series side of the box is not pushed fully into position until it comes to a stop it is possible that it could be shorted, although this can be avoided by careful bending of the phosphor bronze strip which forms the switch contact. The design details given are for a battery of three cells, but any number could be accommodated by making the box longer and adding one more switch and two more contacts for each additional cell. Also the dimensions given are for the Nife cell within the polythene container in which they were originally supplied; if the cells are to be used without these containers then the baseboard slots should each be reduced in width from 31 to 27mm, the slots on the box top need to be correspondingly closer together, and the whole box is reduced in size as a result.

To make the connecting lug for each cell, strips of 16 S.W.G. copper sheet, measuring 10 x 50mm, are used. 6mm from one end of the strip a 4.8mm (No. 12 drill) hole is drilled for bolting to the positive terminal of the cell. The strip is then bent as shown in Fig. 1, the actual shape being less important than the overall height, which should be 20mm. Variations in this height will mean that some cells may not make contact when inserted in the battery box. The base for the box is made from softwood, measuring 130 x 130 x 20mm. For every additional cell required in the box, the base length should be increased by 38mm and an additional slot added. These slots, into which the Nife cells slide, are cut 31mm wide and 9mm deep. The box ends are made from 6mm plywood, using two pieces 130 x 127mm high. In one of these, two holes are drilled to receive the output terminals which would normally be 4mm sockets. The ends can be screwed, or glued and nailed to the baseboard. Fig. 2 shows this part of the construction.

The box top is also of softwood, 130 x 130 x 13mm. Slots 14mm wide and 8mm deep to take one set of contacts are cut from the top as shown in Fig. 3. These slots can be taken out by sawcuts at either side, then chiselling and filing, or completely on a circular saw bench by repeated parallel cuts. A sub-top part which carries the second contact to each cell is cut to the same profile as the top. The sub-top has the same dimensions as the top except that it is only 64mm wide; once the top has been fitted with the necessary contacts the sub-top is fixed to it as shown in Fig. 4 with the through bolts holding it in position.

Fig. 5 shows the drilling details for the top, viewed from above. Holes A, B, C, and D are No. 27 twist drill for 4 BA clearance. The two unlabelled holes are for wire connection to the output terminals and can be any convenient size. The sub-top should be clamped to the top in the position shown in Fig. 4 and holes B and C drilled through it. These holes carry the connections to the negative terminal of each cell. The connections take the form of a bent strip of copper, made from 22 S.W.G. sheet measuring 10 x 40mm; a 4 BA clearance hole is drilled at one end, a 30mm 4 BA round head bolt is inserted and the strip bent over the bolt head as shown in Fig. 6. This means that a screwdriver cannot be used to tighten the bolt in position, so that the bending of the strip can be postponed until the switches have been fitted. The same strips, fitted in the same way but using shorter bolts 19mm long, are used as the connection to the positive terminals on the parallel side of the box in holes D. These are shown in Fig. 6.

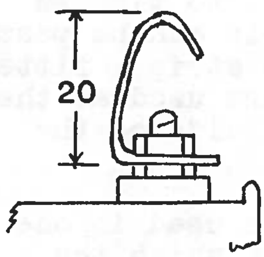
On the series side of the box, the same strip is used in one of the slots, that in which there is no switch and in which the first cell of the series connection must be fitted. The remaining slots all require a switch, made from two metal strips, which is normally closed but which is opened by the action of pushing a cell into position. The moveable part of the switch is a strip of phosphor bronze 38 S.W.G. thick measuring 10 x 35mm. It is drilled, bent and fitted into the slot by a 19mm 4BA bolt through holes A, as shown in Fig. 6. The other half of the switch is a flat piece of 22 S.W.G. copper, 10 x 15mm, which is drilled and secured against the upper surface of the sub-top by the B bolts. With the sub-top in position, and this is held by B and C bolts, the phosphor bronze strip is in positive contact with the flat piece of copper.

Connections to place the cells in series or in parallel are made by 10mm strips of 22 S.W.G. sheet copper with 4 BA clearance holes drilled at the correct spacing, the strips being bolted on the top of the box itself. These connecting strips are shown in dotted outline in Fig. 5. The connections which go to the 4mm output terminals are made with PVC covered wire, soldered to solder tags which are bolted to the appropriate connector strips. A similar flexible lead is used to join the two sets of positive terminals on the outside edges of the box, simply because there would be a risk of shorting against the negative terminals if a bent copper strip was used.

We would not claim that the switches are capable of carrying heavy currents, though they should be well scoured with emery paper before assembling, but they ought to be good enough for most of the school experiments requiring batteries.

When a cell is slid into position, the special terminal fitted to it bears against the phosphor bronze and breaks the switch contact. It is desirable also that this contact should be broken before contact is made to the other cell terminal. If this happens then the cell is short-circuited momentarily until the cell has been pushed fully home, although as mentioned earlier there is a risk of a continuing short if the cell is not fully inserted. Hence it is better to bend the phosphor bronze strip so that the switch action gets under way as soon as a cell is pushed in, i.e. a sharp downward bend should be given to the strip where it comes off its securing bolt. The shape is shown in Fig. 7, which also shows how the special terminal acts as a stop so that when the cell is slid fully in it is automatically in contact with the connector strips. On the parallel side of the box the action is similar save that there are no switches.

Fig. 1 Nife cell terminal



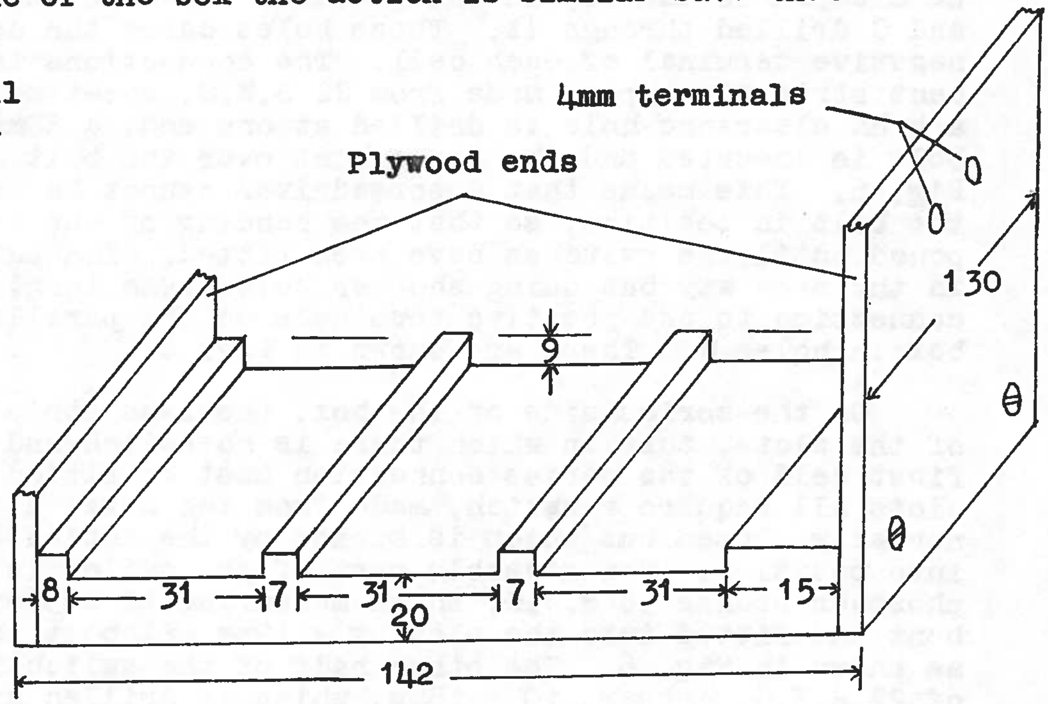
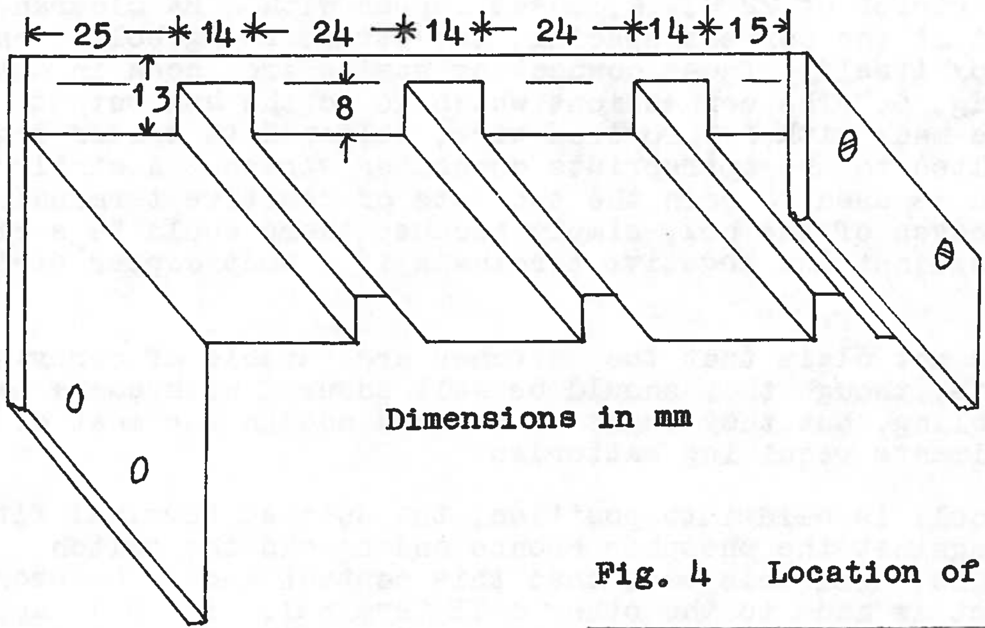


Fig. 2 Baseboard

Fig. 3 Top



Dimensions in mm

Fig. 4 Location of sub-top

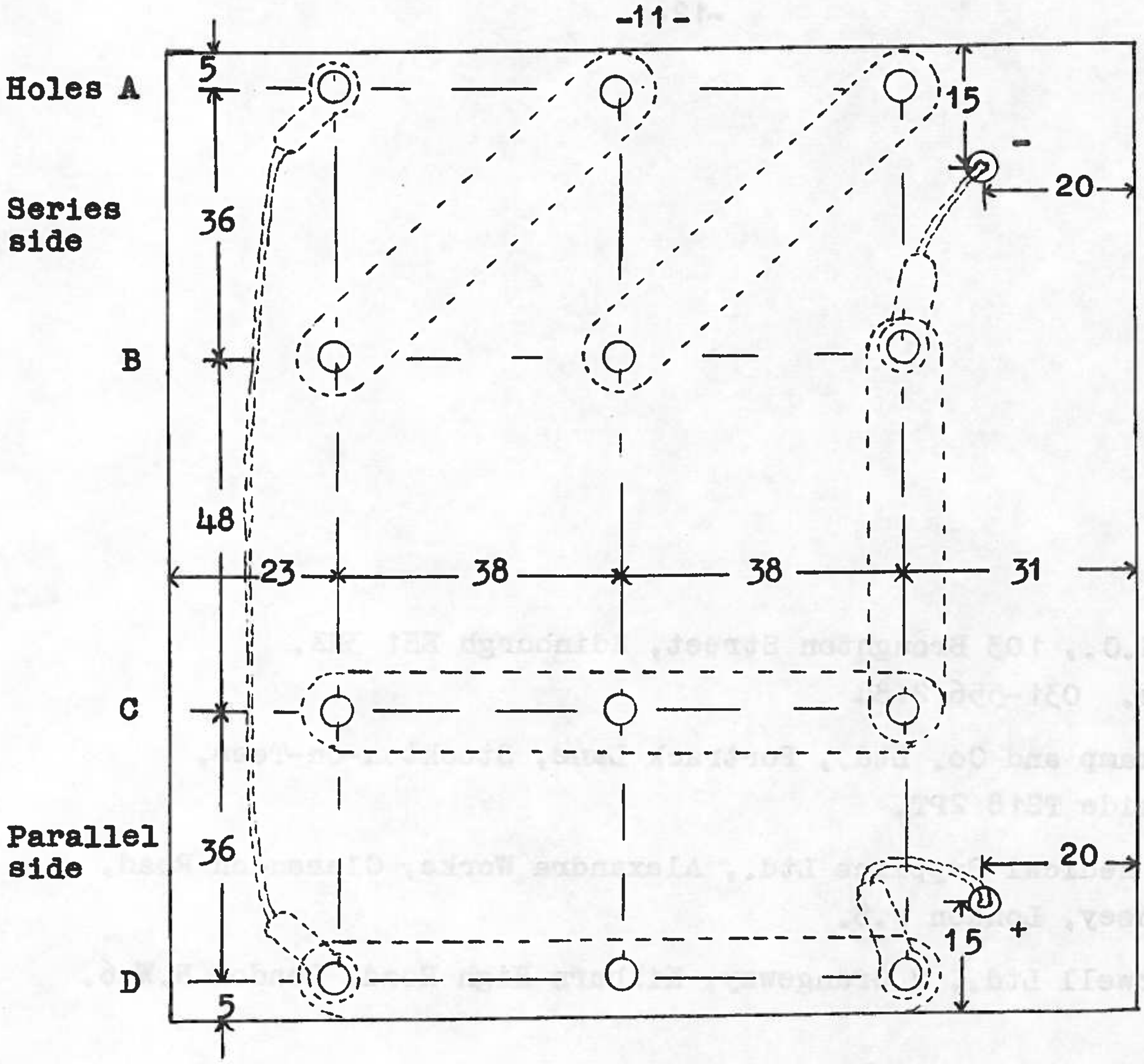


Fig. 5 Top: drilling details and electrical connections

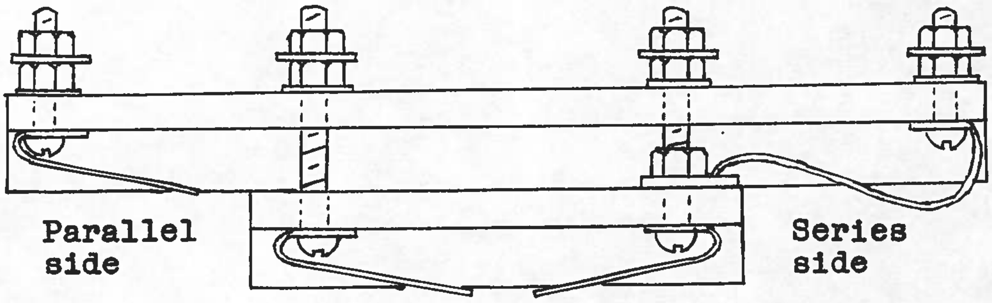
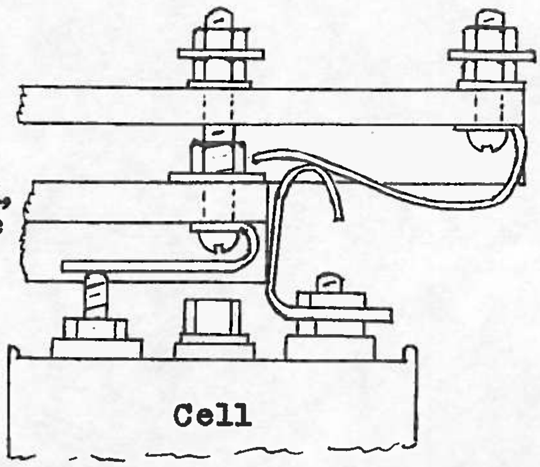


Fig. 6 Section through top and sub-top showing cell contacts and switch

Fig. 7 Nife cell in position, series side



All dimensions in mm

S.S.S.E.R.C., 103 Broughton Street, Edinburgh EH1 3RZ.
Tele. 031-556 2184

A Gallenkamp and Co. Ltd., Portrack Lane, Stockton-on-Tees, Teeside TS18 2PT.

Henley's Medical Supplies Ltd., Alexandra Works, Clarendon Road, Hornsey, London N.8.

A. R. Horwell Ltd., 2 Grangeway, Kilburn High Road, London N.W.6.