SCOTTISH SCHOOLS SCIENCE

EQUIPMENT RESEARCH

CENTRE

Bulletin No. 38. April, 1970.

Contents

Opinion

It is all of four years ago since I wrote in this section of the Bulletin of the need for a warning system which showed when the power had been left on in transistorised devices. The indicators in use then, e.g. red fluorescent paint which is uncovered by the On/Off switch are still being used today, but sadly there seem to be no others, and our equipment continues to run down its batteries in the midnight hours due to an overlooked switch. The recent appearance in this country of equipment used in the Harvard Physics Course prompts me to offer one remedy which may or may not be an economic proposition, depending on the cost of the battery it is intended to save. One of the Harvard items is called Blinky, and consists of a relaxation oscillator discharging through a neon bulb. The circuit could not be simpler; a resistor and capacitor in series with a neon across the capacitor. This will flash at a rate which depends on the time constant of the circuit when connected to a power supply. The disadvantage is that, as far as I know, neons have not been constructed which will strike at voltages of less than 100 or so. Are there low voltage neons? or would it be possible to construct a small 90V battery just to operate the oscillator? A flashing signal of this type might do much to reduce the unnecessary drain on batteries left switched on. In one pH meter designed specially for schools and which is selling in vast quantities, to quote the supplier, the battery costs £2.19s. At this rate is it not economic to consider an additional, specially constructed warning device?

The problems of battery operated equipment do not end here. One hazard to which schools are particularly vulnerable by virtue of their method of use of apparatus is the leaky cell or battery. We were recently advised of this by Jordanhill College of Education who had to write off a piece of apparatus because of corrosion inside the box from this source. A quick check of our own equipment showed bad corrosion on the Terry clip holders on a Worcester circuit board from supposedly leak-proof cells. The only remedy would appear to be a regular check by the technician or teacher at say two monthly intervals of all battery operated equipment.

Manufacturers could help of course by designing equipment so that the batteries are not contained within the instrument but are in a shelf or open compartment adjacent to it. At least one manufacturer has appreciated this, and both the W.P.A. items referred to in the Trade News section of this Bulletin have external batteries. They might also consider designing equipment to use locally available batteries of such standard types as the PP9, U2 etc. Too frequently one finds an agglomeration of batteries the only function of which appears to be the preservation of the manufacturer's monopoly. In the battery referred to above, one finds three Mallory cells of two different types and a PP3 inside a box and fitted to a multi-pin socket. The total battery cost, even at retail prices, could not amount to more than 15s. So one is paying over £2 to have the cells connected to a socket the uniqueness of which guarantees that one will continue to pay this every time the power unit has to be replaced. Is it too soon to expect the A.S.E. Apparatus Committee to carry out the same standardisation for batteries as they have recently done for fuses?

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The great metrication campaign is turning out to be a damp squib, largely through its own fault. The majority of readers of the/

the Bulletin will not know that there are zealous metricophiles who scan every line to see if Homer has once again nodded. When a bulletin goes to bed and until it comes back from the printers, I lose sleep o' nights wondering if I have dropped a clanger, used $\frac{1}{2}$ in. as a dimension when 10cm would have done. If I have, the day after posting our telephone is jammed with calls. Cries of "Think Metric" resound and vibrate in the wires. For weeks I tell myself that one day soon I am going to wake up and think metric from then on. It has become a more desirable and less attainable achievement than stopping smoking. On every side I am told, "the building industry has gone metric, the engineering industry is going metric, everyone is going metric." It has become the "in" thing, like skinheads and long scarves. Its advantages are extolled ad nauseam; no more memorising of unit tables, no more complicated arithmetic. When (notice, not if) we go into the Common Market, we must be metric for conformity.

So, cautiously, I put out a few feelers from my stagnant ditch to see what metsam the current is carrying past me. I read in my Scotsman of 24/2/70 that the building regulations lay down that "the hearth shall project a minimum of 152.4mm over a fireplace at each side." That's funny, I think, how does the German putzfrau calculate the rate for the job if it is based on acreage with numbers like these? I enquire against the day when this bulletin will have to go metric, not only in its thinking, but in its column centimetres. Foolscap will disappear to be replaced by something called A4 size. Immediately I see the advantages of metrication, viz:

Old style	Question:	Calculate the area of a foolscap page.
	Answer:	Area = 8" x 13" = 104 sq. in.
New style	Question:	Calculate the area of a size A4 page.
	Answer:	Area = 210 x 297 = 62370mm^2

I retreat in confusion. Give me back my octavos and foolscaps, my rods, poles and perches. I shall be more at home with the French, buying my wine by the litre and sitting before a hearth which does not, I hope, extend 152.4mm from the fireplace.

Physics Notes

Experiments on the Coulomb law of electrostatic force feature in the Certificate of Sixth Year Studies Physics course and Philip Harris have produced a modified beam balance for measuring the force in question. As the charges involved can be measured with comparative ease using a D.C. amplifier, it becomes possible to determine the absolute permittivity of free space, ε_0. The details of the method given below were sent to us by Jordanhill College of Education who acknowledge that it is a modification of a P.S.S.C. method.

One of the spheres used is supported on a bifilar suspension above the platform of an overhead projector. A similar sphere attached to a perspex rod is brought up to it; if similarly charged the spheres will repel and the deflection and separation of the spheres/

spheres can be measured on the projected image. We used two $\frac{1}{2}$in. dia. expanded polystyrene spheres. One was drilled centrally in the lathe. To do this without distorting the sphere, a metal disc of the same diameter is clamped in the lathe chuck behind the sphere. This stops the sphere from retreating before the drill and the chuck grips the sphere lightly but sufficiently to prevent it turning. One sphere is drilled right through, the other one partially.

The spheres are coated with Dag silver conducting paint, obtainable from Acheson Colloids. The paint solvent also dissolves polystyrene, so that the paint must be used very sparingly, and after every brush stroke the ball should be held (skewered on the hole already drilled) in a current of warm air to accelerate drying. Even blowing breath on it will help. When so coated the balls have a mass of around $\frac{1}{4}$g. One ball is threaded with a single nylon filament and the other is cemented on a length of 6mm dia. perspex rod. We made a wooden framework supporting two nylon collars on dowel rods to fit round the perimeter of the projector platform and the ends of the nylon filament were stuck with a small tag of Sellotape to each collar so that the suspended ball was centrally placed on the platform and about 1cm above it. The length of the equivalent simple pendulum should be between 40 and 60cm. This framework must not be disturbed relative to the projector when an experiment is in progress.

The perspex rod holding the second ball must be long enough to be clamped in a retort stand on the bench in front of the projector, so that the ball is level with the suspended one. This stand has to be moved so as to adjust the separation of the spheres within fine limits, and we tried threading the rod and screwing it through a fixture on the edge of the framework referred to above. There are difficulties with this method, however, since perspex rod is rarely absolutely straight, nor is it always possible to cement the ball on the rod so that the rod axis passes through the ball centre.

To get the optical magnification of the system we stuck a length of Scalafix tape on a strip of perspex supported at the level of the balls and arranged it to superimpose on a 50cm length of paper scale stuck on the wall. All measurements were then taken on this paper scale and reduced to actual distances by dividing by the magnification.

For the first experiment to verify force proportional to charge a 4cm length of wood was used as a spacer to determine a constant separation of the spheres. The spacer was held on the wall between inside edges of the sphere images. The vertical position of the suspended ball is noted on the wall scale, both balls are charged to 2kV from an EHT power supply when they diverge and the support carrying the fixed ball is then moved to get the separation referred to above. The deflection of the suspended sphere is then obtained from the wall scale. The measurements are repeated, increasing the potential of the fixed ball in 1kV steps to the limit of the power supply. Further readings can be obtained by then increasing the potential of the suspended sphere by 1kV steps. If one is unwilling to accept that Q is proportional to V, this can be established in a preliminary experiment for the spheres used, with the D.C. amplifier. As an example of the order of magnitudes obtained, we found a deflection of 13cm when both balls were charged to 6kV, the separation between the spheres being about 0.6cm. The length/

length of the pendulum was 45cm. For the small deflections obtained, $\tan\theta = \theta$, so that the deflecting force can be assumed proportional to the deflection.

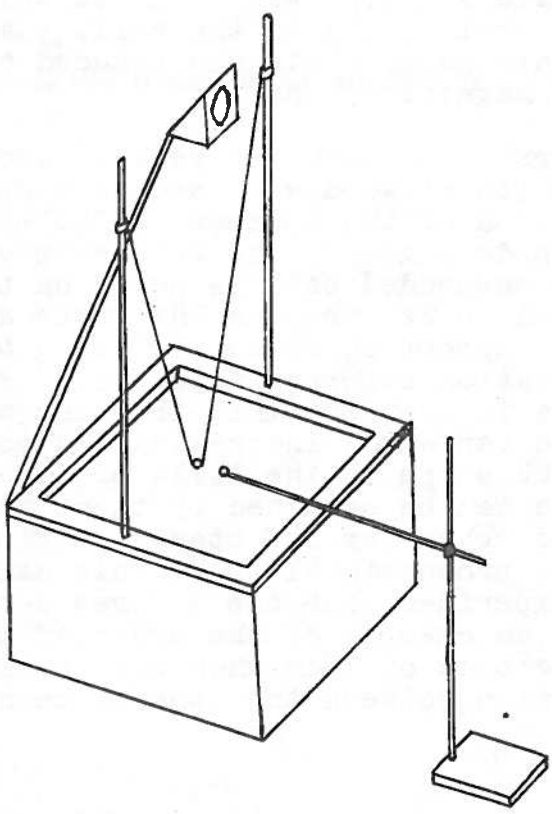
In the second experiment, to verify that the deflecting force is inversely proportional to d^2, both spheres were charged from an electrophorus, and then the deflections for various separations (between centres) measured. Finally from the same experiment, the value of ε_o may be found if both spheres are carefully lifted from the projector so that they retain their charge and discharged individually into the D.C. amplifier.

The amplifier (<u>Unilab</u>) is first adjusted to give a full scale meter deflection for an input of 1V. As we found from a preliminary measurement that the charge on a sphere was between $2\text{-}3 \times 10^{-9}$C, a standard 0.003μF capacitor was connected across the amplifier input. A bare 4mm plug was inserted in the input socket; when the charged sphere is touched on to this it effectively discharges itself into the capacitor and the resulting potential is registered on the output meter. The necessary formulae for calculating the absolute permittivity are:

$$F = \frac{q_1 q_2}{4\pi\varepsilon_o r^2} = \frac{mga}{L}, \text{ where}$$

q_1, q_2	=	charges on the spheres;
r	=	separation between sphere centres;
m	=	mass of the suspended ball;
a	=	deflection of suspended ball;
L	=	length of equivalent simple pendulum.

The estimated error was about 30%, half of which was contributed by the squared term. This could be improved by using a larger L allowing a greater separation for the same deflection.



Chemistry Notes

We mentioned in Bulletin 36 that there was perturbation in some quarters at the inclusion of dangerous chemicals in lists for teaching chemistry syllabuses which we issued a few months ago. This question is now under review by a Standing Committee on Safety set up by the S.E.D., and although it is early days to make promises, we hope that one result will be the publication of a manual on hazardous chemicals. It is therefore somewhat as an interim measure that we give details below of the type of hazard associated with the chemicals listed by us.

Allyl bromide - Irritant vapour, harmful to respiratory system and eyes.

Ammonium fluoroborate - Harmful dust, also if swallowed.

Ammonium trioxovanadate - Poison. Harmful dust, may cause conjunctivitis.

Ammonium oxalate - Poison.

Anthracene - Suspected carcinogen.

Aniline - Poison, absorbed by skin, suspected carcinogen.

Antimony sulphide - Poison, harmful to skin. (Stibene which is formed by action of acidic reducing agents on materials containing antimony is an extremely poisonous gas.)

Arsenic - Poison.

Arsenic trioxide - Poison.

Asbestos - Carcinogen, avoid inhalation of dust.

Barium salts - All bariun salts except barium sulphate are poisonous and can be absorbed by skin.

Barium metal - Inflammable in contact with water.

Benzene - Poison, absorbed by skin.

Benzoyl peroxide - Explosive when dry.

Bromobenzene - Poison, absorbed by skin.

1-Bromobutane - Harmful vapour.

2-Bromobutane - Harmful vapour.

2-bromo-2-methyl propane - Harmful vapour.

Bromine - Liquid bromine burns skin and eyes, vapour irritates eyes and respiratory system.

Carbon disulphide - Extremely harmful vapour, highly inflammable, low flash point.

Carbon tetrachloride - Poison, harmful vapour, irritates eyes.

Chloroacetic acid - Extremely corrosive, causes severe burns.

Chloroform - Poison, harmful vapour.

Chlorosulphonic acid - Corrosive, irritant vapour. Decomposes with explosive violence when mixed with water.

o-Cresol - Poison, suspected carcinogen, absorbed by skin.

Crude oil - Suspected carcinogen.

Dichloroacetic acid - Corrosive, causes burns.

Dimethyldichlorosilane - Harmful vapour.

Dichloromethane - Poison, harmful vapour.

Diethylamine - Highly inflammable, low flash point.

Diethyl ether - Highly inflammable, low flash point.

Ethylamine - Highly inflammable, irritant vapour.

Fluorene - Suspected carcinogen.

Fluorenone - Suspected carcinogen.

Formaldehyde - Poison, irritant vapour.

Hydrobromic acid - Poison, vapour irritates respiratory system and eyes.

Hydrochloric acid - Poison, vapour irritates respiratory system and eyes.

Hydrofluoric acid - Poison, extremely harmful and corrosive vapour, skin burns may cause no pain until after several hours.

Hydrogen peroxide - Corrosive, causes burns.

Iodine trichloride - Corrosive, harmful vapour, irritant to eyes and skin.

Lead acetate - Poison, avoid breathing dust.

Lithium - Corrosive, inflammable in contact with water.

Mercury - Poison, harmful vapour, absorbed by skin.

Mercury (II) chloride - Poison, harmful dust, absorbed by skin.

Mercury (I) nitrate - Poison, harmful dust, absorbed by skin.

Mercury (II) nitrate - Poison, harmful dust, absorbed by skin.

Mercury (II) oxide - Poison, harmful dust, absorbed by skin.

Mercury (II) thiocyanate - Poison, harmful dust, absorbed by skin.

Methane gas - Inflammable, store cylinders in a cool place.

Methylamine - Irritant vapour, highly inflammable.

n-methyl aniline - Harmful vapour, absorbed by skin.

Naphtha - Highly inflammable, low flash point.

Nickel fluoride - Poison.

1-octene - Inflammable.

Oxalic acid - Poison, harmful dust.

Phenol - Poison, corrosive, harmful vapour, absorbed by skin.

Phosphorus, yellow - Spontaneously combustible.

Phosphorus trichloride - Irritant vapour, causes burns, liquid decomposes violently in contact with water.

Potassium - Corrosive, inflammable in contact with water.

Pyridine - Harmful vapour, highly inflammable.

Quinol - Suspected carcinogen.

Silicon tetrachloride - Harmful vapour, corrosive, reacts violently with water.

Sodium - Corrosive, inflammable in contact with water.

Styrene - Harmful vapour.

Thallium (I) chloride - Poison, harmful dust, absorbed by skin.

Thionyl chloride - Irritant vapour, corrosive.

Trichloroacetic acid - Corrosive.

Biology Notes

It is many issues ago since we commented in a bulletin on the lack of foresight evinced by some local authorities which would not or could not provide a separate electrical supply to biology laboratories to enable them to keep essential services running when the supply to the school in general was cut off, e.g. at weekends. We know that this problem still exists, and for some months past have sought a means of providing aeration to aquaria without relying on a mains power supply. As a result, we devised a simple diaphragm pump which operated successfully from a 12V D.C. motor. It was our intention to construct a self-controlled unit which would aerate the aquarium with a mains-operated pump at times when mains power was available, but which would automatically switch over to the low voltage pump driven from a car battery when the mains power was cut off. When the mains pump was operating, the battery would be recharged from the mains.

This solution failed because we could not obtain a cheap D.C. motor which would run indefinitely. For a motor to run over a major part of a weekend, which we can assume to be 60 hours, it is necessary to find one which on the load presented by the pump consumes not more than, and preferably much less than 1A current. This occurs because the commoner types of car battery have typically a capacity of 60-80 ampere-hours. This means a small motor similar to the Mabuchi type, and we have found that these will drive the pump with a current consumption of 200-500mA which is well within the required limit. Unfortunately, such simple motors wear out quickly, either on the brushes or the copper of the commutator or the motor bearing itself which is usually a steel shaft press fitted into nylon. So far we have found none that operated for over 500 hours which would mean a new motor every two months or so, and this is not a viable solution.

We considered the construction of an inverter circuit which would convert 12V D.C. from a battery into 240V A.C. which would then be used on a mains pump, taking over when the commercial mains supply failed. This also is unworkable because even the smaller commercial pumps have a current consumption of 100-200mA, and a calculation shows that even being optimistic and assuming a high efficiency of conversion of the supply, a battery with a capacity of 300+ Ahr would be required.

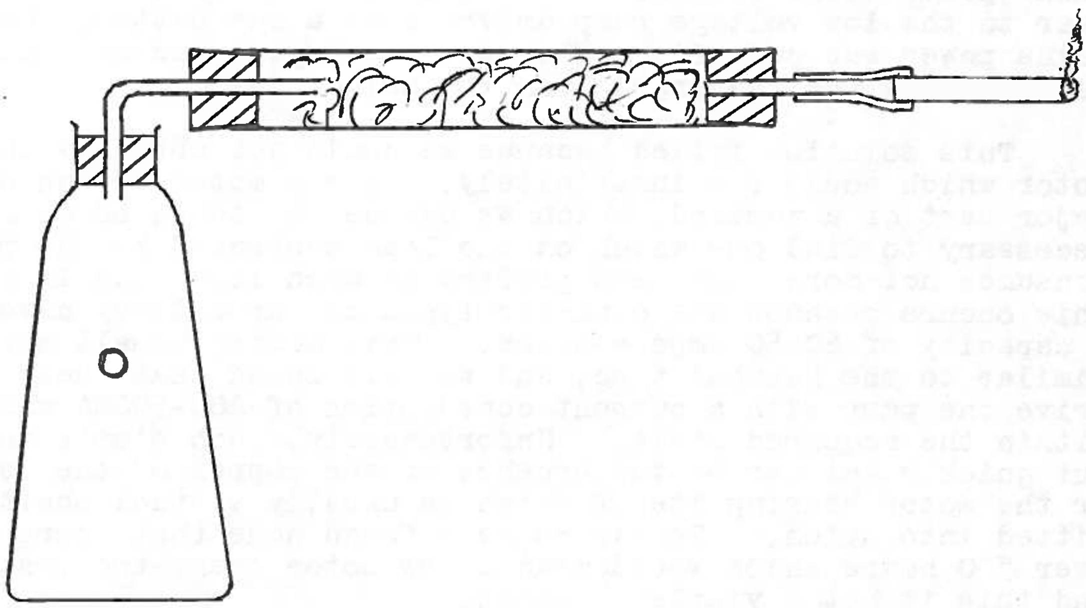
The design given in the Workshop section of this bulletin relies on the mains water supply for its operation. It may already be known to, and used by, many biology teachers. It is interesting to note that its invention was necessitated many years ago when schools did not have money to spend on aeration pumps, even where the school did have electrical power. It is not the best solution to the problem if only because the local Water Board may object to the continual drain even at the slow dripping rate that we specify. There is also always a risk, however slight, that a mishap will occur and the teacher will meet a flood when he opens the door of his laboratory on Monday morning. Thus we would like to hear from manufacturers or teachers of a 12V D.C. motor which can run if need be continuously something over 1000 hours.

In The Workshop

The sketch on page 8 shows how an experiment may be set up to bring/

bring home to pupils (and teachers?) the quantities of tarry contaminants entering the lungs during cigarette smoking. The apparatus (the design of which comes from Liberton Secondary School, Edinburgh), consists of a 10cm length or thereby of glass tubing packed with cotton wool. The cigarette is inserted in a short length of rubber tubing fitted at one end. Aspiration is done by alternately pressing and releasing the plastic bottle. During the release phase, the hole in the side of the bottle is covered by the thumb; this makes the machine inhale. Pressing the bottle with the hole open expels air and smoke from the system.

We have found this type of aspiration better than continuous suction from a filter pump when the cigarette tends to burn too quickly. It is also more realistic, as the cigarette is smoked in puffs. The cotton wool requires to be packed fairly tightly.



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The principle of the aquarium aerator to be described is that the pressure of the water supply is used to force air into the aquarium with or without a diffuser. When the air reservoir is nearly full of water this siphons out, at the same time admitting more air so that the cycle is repeated. During the time that the reservoir is emptying of water, and while pressure is building up inside it, no aeration is taking place, but in our own version this occupies only 20% of the cycle time.

A wide-mouthed reagent jar, 2½ litres capacity is used as the reservoir. To fit this a No. 41 stopper is required, bought either solid from Griffin and George, or with a single hole from Gallenkamp. As the sketch on page 10 shows, four holes in all will be required through the stopper; those which will carry the air inlet and the siphon tube should be spaced apart to prevent the liklihood of air bubbles entering the funnel on the end of the siphon tube and creating an air lock. This of course can also be avoided by bending the end of the air inlet tube in a direction away from the funnel. Although the sketch shows all four tubes in line, this is done for clarity and is not necessary nor even desirable when boring the stopper. The main requirement in the reservoir, which need not be the jar specified above, is that of depth. Due to changes in diffuser pressure, or temperature, the water/

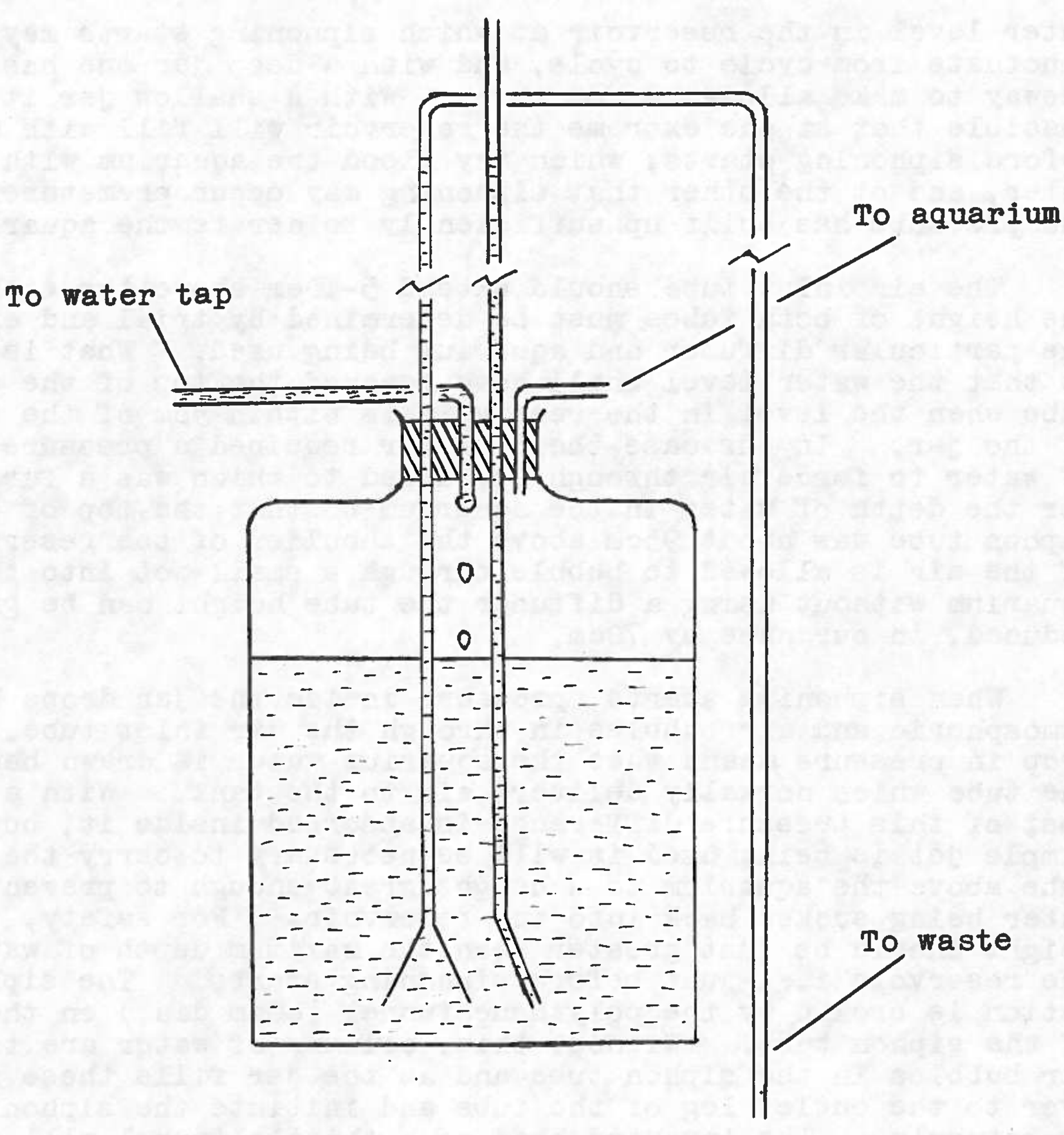
water level in the reservoir at which siphoning starts may fluctuate from cycle to cycle, and with a deep jar one has enough leeway to make allowance for this. With a shallow jar it is possible that at one extreme the reservoir will fill with water before siphoning starts, which may flood the aquarium with tap water, and at the other that siphoning may occur prematurely before the pressure has built up sufficiently to aerate the aquarium at all.

The air inlet tube should extend 5-10cm above the siphon tube; the height of both tubes must be determined by trial and error for the particular diffuser and aquarium being used. What is required is that the water level shall have reached the top of the siphon tube when the level in the reservoir is within 5cm of the shoulders of the jar. In our case the diffuser required a pressure of 70cm of water to force air through it, added to which was a further 30cm for the depth of water in the aquarium so that the top of the siphon tube was about 95cm above the shoulder of the reservoir jar. If the air is allowed to bubble through a small jet into the aquarium without using a diffuser the tube height can be greatly reduced, in our case by 70cm.

When siphoning starts, pressure inside the jar drops below atmospheric and air bubbles in through the air inlet tube. The drop in pressure means that the aquarium water is drawn back inside the tube which normally delivers air to the tank. With a diffuser, most of this pressure difference is absorbed inside it, but if a simple jet is being used it will be necessary to carry the delivery tube above the aquarium to a height great enough to prevent the tank water being sucked back into the reservoir. For safety, this height should be just greater than the maximum depth of water in the reservoir i.e. just before siphoning starts. The siphon action is broken by the polythene funnel (40mm dia.) on the end of the siphon tube. Without this, columns of water are trapped by air bubbles in the siphon tube and as the jar fills these are pushed over to the outlet leg of the tube and initiate the siphoning action prematurely. The inverted head of a thistle funnel will carry out the same function.

The water tap, aided if necessary by a screw clip on the delivery tubing, is adjusted to give a drip rate of 5-10 drops per second. At this slow flow rate any pressure fluctuations in the water supply may act on the tap washer to stop the flow permanently so that it is desirable to use a tap which is fed at a reasonably constant pressure, e.g. from a cistern within the building rather than from the mains, the pressure of which may vary greatly between day and night conditions. If the flow rate into the reservoir is increased to reduce the risk of stoppage then the siphoning action of emptying the reservoir will take a correspondingly greater fraction of the cycle time, and one may reach a condition when the water is flowing in at the same rate as it siphons out, so that the action goes on continuously without ever admitting more air to repeat the cycle. It is not possible to increase the siphoning rate by widening the siphon tube, since with a tube of bore greater than 4-5mm, which was the size we used, the water will not siphon over naturally but trickles down the side of the tube. Lest it be thought from the foregoing that the design is unduly difficult and restricted, it should be pointed out that our aeration time is 80% of the cycle (typically 10 minutes dead time and 40 minutes aeration) and that it is probable for most aquaria that aeration is required for only 50% of the time so that there is ample room to adjust the water inflow rate to avoid the difficulties mentioned above.

A tall wooden stand was used to mount the siphon and air inlet tubes, using Terry clips; those that used to support the Boyle's Law sliding tube apparatus will serve admirably. All flexible connections were made with red rubber delivery tubing.



Trade News

Rolls of chart paper for use on the Heathkit (Daystrom) EU-20VE recorder may be obtained from Sensitised Coatings Ltd. at 18s.6d. per roll.

Walden Precision Apparatus are selling a D.C. amplifier and electrometer, Model EN50, which has current ranges of 10^{-11}, 10^{-10}, 10^{-9} and 10^{-8}A and charge ranges of 10^{-9}, 10^{-8} and 10^{-7}C. The amplifier costs £24. Accessories include an ionisation chamber.

From the same firm comes a combined potentiometer and Wheatstone bridge apparatus, Model KN15, costing £15.10s. On potentiometer operation the range is 2V x 0.1mV; on bridge operation 2kΩ x 0.1Ω. A feature of the instrument is the simplicity of the layout and the use of a single spring loaded switch which is held in one position for bridge and in a second position for potentiometer working.

Forth Instruments undertake to provide a weekly repair service for any Avo model of multi-range meter.

Unilab have produced a microamplifier with a 0-1mA D.C. output. The basic cost is £22.10s., but the amplifier must be used with one or other of their plug-in modules, e.g. 0.1mV - 1V D.C. (£4); 0.1μA - 1mA D.C. (£1) or 0.1mV - 1V A.C. (£6.10s.). A module which will give an output for display on a C.R.O. screen is under development.

Bulletin Supplement

Below is a summary of tests carried out on a further selection of E.H.T. power supplies. Reports on these models may be borrowed by writing to the Director. The classifications used are: A - most suitable for school use; B - satisfactory for school use; C - unsatisfactory.

Model No.	95-14	N14R	S2
Supplier	Morris Laboratory Instruments	Radford Electronics	Linstead Electronics
Price	£39.15s.0d.	£37.10s.0d.	£30
Output Control Coarse	Variable Transformer	Variable Transformer	Electronic
Fine	None	None	None
Open Circuit Output, kV	6.15	6.0	6.2
Short-Circuit Current, mA	2.9	2.1	0
Low Voltage AC Output	6.2V at 2A 13V at 4A	5.7-0-5.7V at 3A	6.1V at 3A
Output Meter	0 - 6V x200V	None	0 - 6kV x200V
Meter Scale Radius, cm	3.5	-	3.5
Meter Error	4%	-	2.5%
RMS Ripple, V.	30V	36V	30V
Current for 1% Ripple, mA.	Not achieved	Not achieved	Not achieved
Insulation Test	1.5µA max.	7µA	45µA
Decay Time Constant	18.6	14.5	<2
Assessment	B	B	B

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

Acheson Colloids Co., Prince Rock, Plymouth.

Avo International, Avocet House, Dover, Kent.

Daystrom Ltd., Gloucester.

Forth Instruments Ltd., Engine Road, Loanhead, Midlothian.

A. Gallenkamp and Co. Ltd., Portrack Lane, Stockton-on-Tees.

Griffin and George Ltd., Braeview Place, Nerston, East Kilbride.

Philip Harris Ltd., St. Colme Drive, Dalgety Bay, Fife.

Linstead Electronics Ltd., Roslyn Road, Near Braemar Road, London, N. 15.

Morris Laboratory Instruments Ltd., 96-98 High Street, Putney, London, S.W. 15.

Radford Electronics Ltd., Ashton Vale Road, Bristol, 3.

Sensitised Coatings Ltd., 108 Church Street, Croydon, CRO 1RE.

Unilab Science Teaching Equipment (Blackburn) Ltd., Clarendon Road, Blackburn, BB1 9TA.

Walden Precision Apparatus Ltd., Shire Hill, Saffron Walden, Essex.