SCOTTISH SCHOOLS SCIENCE

EQUIPMENT RESEARCH

CENTRE

Bulletin No 28. January, 1969.

Contents

Introduction

These Bulletins, like the work of the Centre, are about science equipment, and on occasions when we have strayed from the straight and narrow path to discuss more controversial educational topics, the flames of wrath have descended on our head. The discussions had of course an ulterior motive, one which we sincerely hope will pay off now. By stimulating in the recipients the expectancy of the occasional controversial issue, we hoped they would be conditioned to open eagerly each Bulletin as it reached them, and having opened, to swallow and inwardly digest its contents, however mundane they might be.

What we write now is not about apparatus, nor, we believe, is it controversial, nor dry and dreary. Mr. A.J. Mee, who is due to retire soon, has given outstanding service to science education. A number of people have felt that Scottish teachers would welcome the opportunity to make a national gesture of appreciation of his services and for this purpose a fund has been established to which donations can be made. It is not our purpose here to eulogise Mr. Mee; there are many better fitted to do so, and in any case those in whom this strikes a favourable response will already have personal knowledge of the help he has given them. We want here only to use the Bulletin as a means of giving publicity to this move. It is likely that any presentation made to Mr. Mee will be carried out at the regional meeting of the Association for Science Education at Galashiels, from 8 - 11th April. Although the Regional Committee of the A.S.E. are operating the machinery of this fund, they would wish to emphasise that they do so without any sectarian bias and that all who wish to contribute should feel free to do so, and of course to attend the presentation. Precise details regarding the occasion will be given in our next Bulletin: cheques, postal or money orders should be made payable to The A.J. Mee Presentation Fund, and sent to the address given below.

Dr. W.M. Todd, The Lindens, Victoria Terrace,
Crieff, Perthshire.

Opinion

In less than a year's time, on New Year's Day, 1970, Britain will go over to the Continental system of colour coding of mains driven apparatus. The live lead will then be coloured brown, the neutral light blue, and the earth lead striped green and yellow. We have eleven months to consider the implications of this change, and to consider in general the question of colour coding on terminals. At present there is confusion over whether red should be used for positive voltage or danger, and to a lesser extent whether black is negative, chassis potential, or merely safe. A quick look around the fronts of the power supplies gathered in our display laboratory would suggest that yellow is almost universal for low voltage AC outputs; must this disappear now that yellow is one of the colours on the new mains system? Obviously the use of green for earth should be kept, as the only firm link with the past.

One of the EHT units we report on elsewhere in this issue uses red for both ends of the high voltage supply and black for the centre tap, which seems to flout both conventions referred to above. In another we find that the centre tap is blue; will this in the future be mistaken for mains neutral? On yet another, blue is used for the negative end of the supply. One EHT unit runs to ten output terminals; would it be a help, or a confusion to have them present a kaleidoscope of colour to the user? On three terminal networks such as amplifiers, should we have a convention regarding input and output socket colours? Time seems all too short for the trade to rationalise these problems before the next Happy (?) New Year.

* * * * * * *

The biologist who decides to use mice as his medium for genetics experiments will certainly require more than the two per laboratory provision of rearing cages mentioned in our equipment list in Bulletin 23. This, however, may well prove to be the least of his worries. He will require a proper Animal Room to house and feed his charges and the establishment of a proper feeding and cleaning routine. Mammals, as distinct from all other animals, come under the Cruelty to Animals and the Protection of Animals Acts. No experiments are permitted which are injurious or deleterious to health, and the animals must be painlessly killed. The interpretation of these conditions may be very wide indeed. If mice are trained to run a maze, as I have seen in Science Fair demonstrations, using hunger as an incentive, this could well be interpreted as being deleterious to health. If pupils are allowed to take part in the daily care of the animals, they may become so attached to them that - and this has happened - they will not hear of them being killed. How is one to dispose of upwards of 100 mice whose mutant characteristics make them unacceptable to pet shops? To give them away to the pupils themselves may place the teacher in the same position as the rag-and-bone man who offered day-old chicks in exchange for woollens, a practice which was rightly stopped some time ago.

Nor/

Nor does the matter stop at the legal requirements of Acts of Parliament. The frequency of pet food advertisements on television bears witness to our wholly illogical love of mammalian pets. Consider the furore which is aroused every now and then by the keeping of battery hens, or the artificial feeding and/or injection of young calves to whiten veal. "Experiments with Animals" can become the rallying cry of the anti-vivisectionists and of a large part of the national press. While working wholly within the legal requirements of the Acts, a teacher may unwittingly draw to himself, his school and his profession, a great deal of unwelcome publicity and public odium.

* * * * * * *

In future years the Bristol meeting may be remembered by the minor irritations caused by lapses in our twentieth-century technology which more and more seems to ignore the human element. Lapses such as the bomb-like ticking of the heater in the bedroom, the inability of the plastic cups to insulate any fingers against scalding hot tea, or the steps down to the main building from the street, which at 1m were too wide to allow a single step on each and forced most pedestrians into a dot-and-carry-one gait.

In a more serious vein the meeting was notable for the number of new items of apparatus on the manufacturers' stands with again a preponderance of physics. Amongst the new pieces which the teacher should look out for in forthcoming months are a phase contrast unit built into the iris diaphragm on a new Swift microscope, a chart recorder which in conjunction with an Exelo syringe will graph gas volume with time, and a new balance from Griffin and George. Air tables appear to be catching on, and Philip Harris, M.L.I., and Ealing Scientific all showed versions. When large these tables are expensive, and with the smaller versions one wonders whether teachers and technicians will have the skill to manipulate their photography so that the initial tracks are not superimposed by reflections from the table edge. There would seem to be some point in attaching adhesive rather than repelling magnetic strip round the periphery of these small tables. A new approach to frictionless pucks was also shown in a member's exhibit and on the Griffin and George stand. Compressed air pucks are used, completely self contained and operated by a small DC motor mounted on the puck.

Of interest to chemists and physicists alike will be an X-ray diffraction apparatus now under development by Teltron for the Nuffield A level physics project. The detector is a G-M tube coupled to scaler or ratemeter, and is mounted in a spectroscope so that as the detector is rotated, the central diffracting specimen, which can be crystal or powder, rotates at half speed. A new film by Mullard: "Are There Electrons?" describes the Millikan experiment using plastic spheres weighing 2×10^{-12}g in place of oil. Although the rest of the apparatus is standard and probably already in many schools, with the spheres costing £25 for 5ml, the film may be the more prudent if less educationally desirable buy. The film also shows how to deduce quantization of charge from the figures for balancing voltage obtained in the experiment.

E.H.T. Power Supplies

Most of the E.H.T. Power Units built for educational use have been produced in response to a demand by the Nuffield Project, so that we should properly start by outlining the Nuffield requirements. These are:

1. A variable DC supply up to about 5kV.

2. The supply must have an on/off switch and an indicator lamp is desirable.

3. The case should be earthed but the output should be independent. This will enable either end to be earthed.

4. Power packs should have an independent 4mm earth socket on the front panel connected to the chassis and the third pin of the mains supply.

5. The output sockets should be the 4mm type advocated for all apparatus.

6. For safety purposes there should be a built-in resistor limiting the short-circuit output to 3mA.

7. The output should be smoothed. The ripple should not be more than 1%.

8. All instruments should be such that they can be operated from 50Hz, 200/240V AC mains.

9. A meter should be incorporated in the unit to give an indication of the voltage output.

10. An independent 6.3V AC output is a useful additional facility, but it must be independently wound.

One or two points on this specification are open to misinterpretation. The first of these is the use of the word independent. In (3) it means that the insulation to earth of either side of the output should be greater than 5kV. Does it also mean this in (10), referring to the heater winding? A heater winding with this degree of insulation is necessary if one is to operate electron beam tubes with an earthed final anode, as is customary for example with cathode ray tubes. As is pointed out later in this report, we found several short-comings in this respect.

Condition (7) requires that the ripple content should not exceed 1%, but does not specify the load condition under which this is to be measured. With HT and other smoothed supplies, it is customary to measure ripple voltage at the maximum load, but in this case we do not have any load condition specified. What we have therefore done is to measure the ripple content at zero external load and maximum voltage output, which usually means that the current drawn from the unit is that required to operate the meter. In addition we have gone on to specify the external load current which brings the ripple content up to the 1% level.

It/

It is not realistic, however desirable it might be, to consider the performance of the power unit on its own; it must be related to possible uses to be made of it. Apart from experiments with a capacitative load - i.e. charging of insulated conductors to high potential - where the only consideration is the maximum potential delivered, the experiments which require a high voltage supply are those of conduction through gases and vacuum. A power supply which has an open circuit voltage of 5kV and a short circuit current of 3mA has an internal impedance of 1.7MΩ, and the existence of this must be borne in mind during any application of the unit. Thus when examining the discharge phenomena through a gas at varying pressures, the voltage available will always be the minimum required to maintain the discharge. As the observations here are usually qualitative only, this places no restriction on the unit.

With hot cathode electron tubes the situation is somewhat different. The <u>Teltron</u> range of tubes operate at potentials between 2 and 5kV, drawing currents of 1-2mA. For example, the Perrin tube, TEL524, specifies a typical operation at 4kV and 1.8mA. This would not be achieved with the Nuffield type power unit; instead one would get at maximum setting 2.9kV and 1.3mA. With the TEL525 which is used to determine the ratio e/m, the suggested operating current of 1mA would give a maximum P.D. of 3.3kV. While the limitations on the power unit do not invalidate experiments with Teltron tubes, they do restrict their range of use, and this may be a serious limitation where quantitative measurements are to be made. It is, of course, a moot point whether the tubes should have (if they could have) been designed to meet the specification of the power unit or vice versa.

The power supplies we tested were Advance Electronics PP12; Griffin and George N10-380; Philip Harris P7998/01; Linstead Electronics S2; W.B. Nicolson K95/1065; Radford Electronics "Hipak" and Unilab 022.131. Reports on some of these models appear in the Supplement to this Bulletin, and others will be given at a later date. All except the S2 rectify the supply at mains frequency usually in some form of voltage doubler circuit. The S2 uses a valve oscillator working at approximately 20kHz feeding a Cockcroft and Walton staircase rectifier system.

Various forms of voltage control are employed. On the S2 a potentiometer controls oscillator amplitude. The remainder control the input to the E.H.T. transformer either by potentiometer, variable transformer, or stepped switching across a voltage divider which may be either inductive or resistive, in conjunction with a potentiometer to act as a fine control. This requires the use of a separate transformer to provide the 6.3V AC output. All the units use the S.T.C. K8 series of high voltage rectifier, which are rated for 5mA maximum DC. Outputs are resistance capacitance smoothed, and there is adequate series resistance between the output terminals and capacitors to limit the short circuit current to a safe value. The output voltmeter is used as the current path for discharging the circuit on switching off, and in the Hipak which has no meter, fixed resistors are used to perform this function.

In/

In units where the smoothing and reservoir capacitors are large, say 0.5µF, discharge through a 100µA meter takes a considerable time, and we have measured the time constant (= time for the output to fall to 37% of its initial value) of the decay of the output. It is our opinion that the maximum allowable time constant on a power unit should be 4s or less. Otherwise there is delay in waiting for the voltage to collapse before handling output connections, and/or the risk of unnecessary shock which although harmless can seem quite unpleasant to numbers of people, teachers and pupils alike.

Measurements on the output voltage were made using a Marconi 125A E.H.T. voltmeter, which has an input resistance to DC of $3x 10^9$Ω. Units supplying only this meter were assumed to be on open circuit. A chain of 2MΩ resistors, suspended from a high voltage insulated terminal at the live end, were used in series with a milliammeter to load down the power unit and so obtain the regulation curve. The validity of this technique depends on their being no leakages to earth from points along the resistor chain, and can only be confirmed by claiming that the system gave consistent results. At the same time the accuracy of the output voltmeter was checked. Ripple content on the supply was measured by connecting the output through a 2µF capacitor to an oscilloscope, and measuring peak-to-peak value. This was then converted to an equivalent R.M.S. value at the fundamental frequency of the supply. These measurements were taken on open circuit, and again to determine the output current at which the fundamental ripple content reached 1%. The oscilloscope waveform showed that one or two power units had high frequency oscillation, probably due to corona discharge somewhere within the unit, associated with the output; this was ignored in estimating ripple content.

The low-voltage AC output was measured; the summary gives the output voltages at the maximum specified current.

All except the Hipak have an output voltmeter. This we consider to be essential on a high impedance unit such as this, where output voltage is very dependent on the current being drawn. In addition to indicating the output state to an individual however, the power unit must be used for demonstration work, and for this purpose a large clear-scaled meter is essential. While it will seldom be necessary for a class to distinguish between say 1.8 and 2.0kV, the meter must be readable to within ± 500V by a seated class. We therefore specify the radius of the meter scale arc, which is taken to occupy a 90° sector. Even then it should be recognised that readability may depend as much on the size of numbers and clarity of marking of the scale, on the pointer shape, e.g. knife edge or spade head, as on the scale size. A large scale too finely subdivided may be more confusing to pupils than a smaller one marked in 500V divisions.

These observations are based on the results of tests made with 125 pupils seated in a classroom who were asked (1) whether they could distinguish the numbers on the dials of the output meter, and (2) to write down the value indicated by the pointer. The need for clear figures was emphasised by the fact that three times as many pupils read the dial incorrectly when they could not distinguish the numbers/

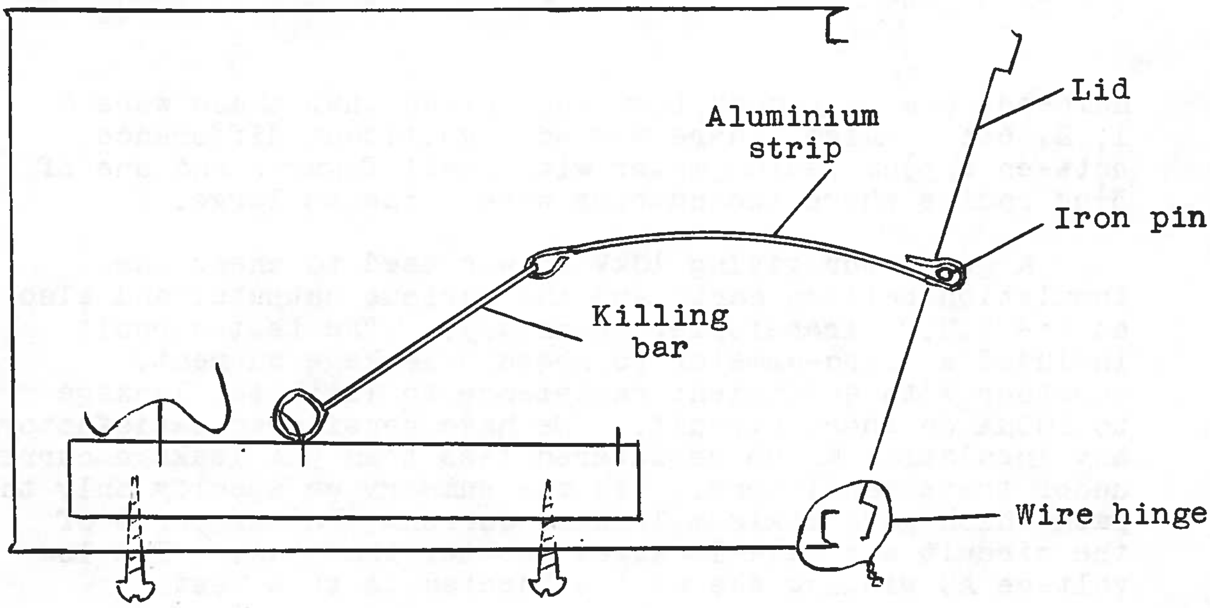
numbers, even although they were given that these were 0, 1, 2, etc. Also, there was no significant difference between a $5\frac{1}{2}$cm radius meter with small figures and one of $3\frac{1}{2}$cm radius where the numbers were twice as large.

A generator giving 10kV DC was used to check the insulation between earth and the various outputs, and also at the E.H.T. transformer secondary. The test-circuit included a micro-ammeter to measure leakage current, together with sufficient resistance to limit the leakage to 100µA on short circuit. We have considered satisfactory any insulation which registered less than 5µA leakage current under these conditions. In the summary we specify only the path which gave maximum leakage current; other parts of the circuit may have leakages greater than 5µA. The low voltage AC winding was also subjected to this test.

On several units it was found that insufficient attention had been paid to the insulation of the low voltage AC. Normal PVC covered leads were used, which were sometimes run in contact with the metal chassis, or with similar leads which were at earth potential. The PVC on this cable is rated to 2.1kV DC and should not be stressed by careless wiring beyond this potential. These points have been brought to the notice of the manufacturers and are mentioned in the individual reports.

In The Workshop

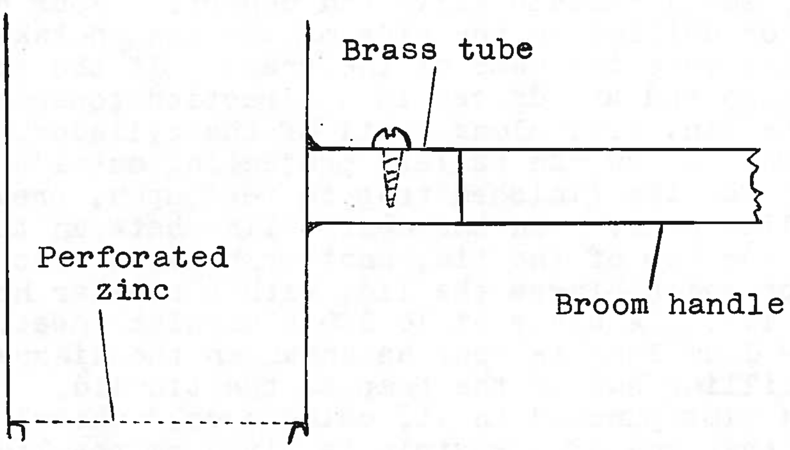
The traditional spring mousetrap, in conjunction with a 2 lb syrup tin, or other metal tin of similar size, can be used to trap small mammals alive and unhurt. Four holes are punched or drilled in the side of the tin to take wood screws passing into the base of the trap. If the screws are long enough and are driven in a direction towards the centre of the tin, i.e. along radii of the cylinder, then 5 - 6mm of each screw can be left projecting outside the tin to form feet for the finished trap to rest upon, preventing it from rolling over. On the centre line between the pairs of holes at the top of the tin, another hole is made to take the wire loop which hinges the lid, with a similar hole being made in the lid. A strip of 16 SWG aluminium sheet, 10mm wide and 8 - 10cm long is bent as shown on the diagram to attach the killing bar of the trap to the tin lid. The latter has a slot punched in it, using a cold chisel or similar and that end of the strip is fixed to the lid with an iron pin (a wire nail is suitable). The aluminium strip - and brass, mild steel or other metal will do equally well - must be long enough to allow the lid to lie flat when the trap is set in the normal way. When sprung the killing bar pulls the lid shut and is then held in a nearly vertical position, thus keeping the animal unhurt. A few respiration holes may be punched round the top side of the tin should this be thought necessary.



* * * * * * *

Another use for a 2 lb syrup tin is in the construction of a mud scoop for dredging from ponds etc. The base of the tin is first cut off with a tin-opener and filed smooth. A 50mm length of brass tube, 25mm outside diameter, is cut off and one end is filed to fit the rounded contour of the side of the tin which is then soldered to it. Both surfaces should be cleaned and tinned before soldering together, and a blow-torch used in making the joint.

A disc of perforated zinc is cut to fit inside the tin and soldered to the inside of the lip at the lid end. A broom handle is fitted inside the brass tube, secured by a wood screw from the side.

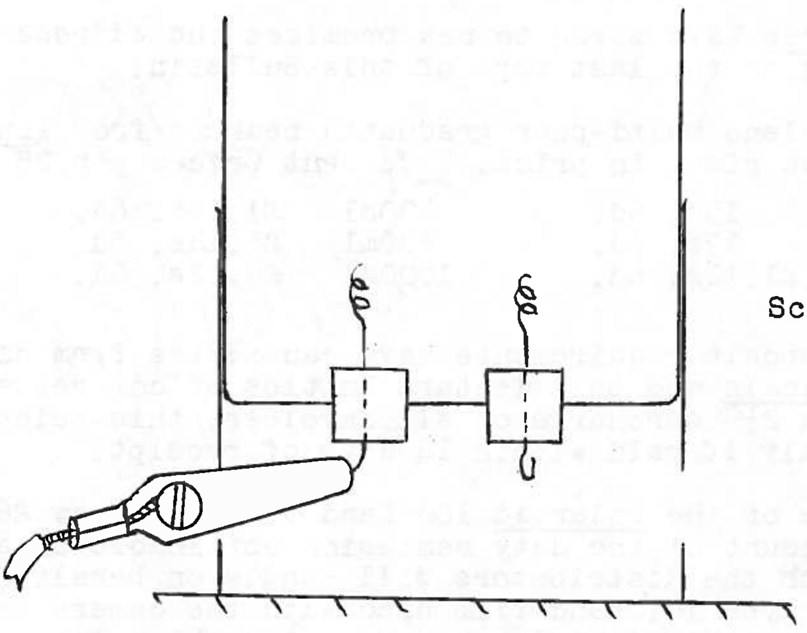


* * * * * * *

An electrolysis cell for pupil use, which has the advantage of using all except a 10mm length of the platinum wire electrode, and has no seals or crimped joints on the platinum, can be made from a detergent or other plastic bottle. The type required - e.g. Fairy Liquid - must have a height of at least 10cm and be of uniform cross-section for this height from the base up. At a height of 5cm cut right round the bottle to remove the base. Punch out two holes, suitably spaced to take the electrodes, in the base, using a No. 5 cork borer (10mm dia. hole). Cut a solid No. 10 rubber stopper in half and pierce each half along its/

its axis with a knitting needle. Platinum wire can then be pushed along to project outside the stopper to a distance of 5 - 7mm. This part of the wire is bent into a U shape to form an attachment for crocodile clips, and the stoppers are fitted into the base. The active electrode wire can be spiralled or bent into any desired shape.

To form a resting base for the cell, another 5cm length of the bottle is cut off to form an open tube. Two larger, diametrically opposed holes are punched in the sides with a No. 7 cork borer - 12mm dia. - and the tube is then push-fitted over the base. Standard crocodile clips can be pushed through these side holes and then clipped on to the projecting platinum wire, provided that the holes for the electrodes are not more than 20mm from the edge of the container. This also has the advantage that the side hole supports the crocodile clip in position and reduces the risk of breaking the projecting platinum wire by repeated bending. Pulling on the connecting lead tends rather to rotate the complete cell. As described the capacity of the cell is about 100ml.



Scale: full size

Trade News

The field plotting paper, and silver conducting paint, items 22 and 23 of the equipment list for the post-Higher Physics syllabus which was published in Bulletin 19 are no longer to be handled by <u>Servomex Controls</u>. The conducting paint called Dag dispersion 915, is available at the price given, from <u>Acheson Colloids</u>. The paper in 50ft x 29in rolls can be bought from <u>Wiggins Teape</u>, but we have written to the main educational suppliers to see if they will distribute this item in smaller quantities more convenient to the individual school.

A new catalogue and price list from Jay-Jay carries full details of their range of educational instruments. Of interest to teachers of Engineering should be their motor test set, with which is supplied free a 100 page manual detailing the experiments which can be performed with the set. The motor test set, FH1, costs £110, less 20% educational discount.

The clamping of spectrum tubes, together with their power supply arrangements, always seemed to be a messy preliminary to spectroscopic work. Teachers who feel the same way will welcome the combined power supply unit and tube holder, which is part of Nuffield Year V Physics, from Griffin and George, Cat. No. N15-740/760, costing £18. Neon and hydrogen tubes at £2.2s. and £2 respectively, are also available.

An additional soil testing electrode for the pH meter by Philip Harris which we mentioned in Bulletin 24 can be purchased for £8.10s. If this is obtained in preference to the standard electrode, the cost of the meter is £33 instead of £32.10s., while if both electrodes are bought with the meter the total cost will be £40.

Radiospares have moved to new premises the address of which is given on the last page of this Bulletin.

Polypropylene multi-pour graduated beakers from Arnold R. Horwell have risen in price. Current prices per 25 are:

50ml	15s. 6d.	400ml	£1.18s. 6d.
100ml	19s. 3d.	800ml	£3.14s. 3d.
250ml	£1.12s. 6d.	1000ml	£4. 2s. 6d.

Import deposit requirements have caused the firm of Cambrian Chemicals who sell lecture bottles of compressed gases to add a 2½% surcharge on all invoices, this being recoverable only if paid within 14 days of receipt.

The price of the Polaroid 180 Land Camera is now £60. This takes account of the duty remission obtainable on a DFA3 form which the distributors will handle on behalf of a school. The type 107 land film used with the camera now costs £1.3s. but this includes purchase tax which is recoverable by the local education authority; details of this were given in Bulletin 14. The type 57 land film which was one of the two suggestions in the same Bulletin for taking radiographs, now costs £5.2s.5d. per pack, again inclusive of purchase tax.

Bulletin Supplement

Below is a summary of tests carried out on E.H.T. power supplies. For reasons of space only some models are included; the remainder will be summarised in a future Bulletin. Reports on these models can 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.	PP12	N10-380	P7998/01
Supplier	Advance Electronics	Griffin and George	Philip Harris
Price	£29	£38.5s.	£42
Output Control Coarse	Switched resistors	Variable transformer	Potentiometer
Fine	Potentiometer	None	Potentiometer
Open-circuit output, kV.	5.5	5.5	6.6
Short-circuit current, mA.	2.95	2.8	3.0
Low-voltage AC output	None	12.6V and 6.0V at 3A	12.0V at 3A and 5.95V at 4A
Output Meter	0-5kV x500V	0-5kV* x500V	0-6kV x200V
Meter scale radius, cm.	3.5	3.5	5.5
Meter error	4%	2.5%	6.5%
R.M.S. ripple, V.	10	5	14
Current for 1% ripple, mA.	2.0	>2.5	2.5
Insulation test	6μA, transformer to E	6.5μA, EHT output to E	19μA, transformer and L.T. AC to E
Decay time constant, s.	<1	9.6	5.4
Assessment	B	B	B

* Scale to 5kV occupies only 60° arc.

S.S.S.E.R.C., 103 Broughton Street, Edinburgh, 1.
Tel 031-556 2184.

Acheson Colloids Ltd., P.O. Box 12, Prince Rock, Plymouth, Devon.

Advance Electronics Ltd., Roebuck Road, Hainault, Ilford, Essex.

Cambrian Chemicals Ltd., 73 Cherry Orchard Road, Croydon, CR9 6AG.

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

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

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

(Jay-Jay) Educational Measurements Ltd., Brook Avenue, Warsash, Southampton, SO3 6HP.

Linstead Electronics Ltd., 35 Newington Green, London, N.16.

W.B. Nicolson Ltd., Thornliebank Industrial Estate, Glasgow.

Polaroid (U.K.) Ltd., Rosanne House, Welwyn Garden City, Herts.

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

Radiospares Ltd., P.O. Box 427, 13-17 Epworth Street, London, E.C.2.

Servomex Controls Ltd., Crowborough, Sussex.

Teltron Ltd., 32/36 Telford Way, London, W.3.

Unilab Science Teaching Equipment, Clarendon Road, Blackburn, Lancs.

Wiggins Teape (Mill Sales) Ltd., Industrial Paper Division, Gateway House, 1 Watling Street, London, E.C.4.