SCOTTISH SCHOOLS SCIENCE

EQUIPMENT RESEARCH

CENTRE

Bulletin No. 21. March, 1968.

Contents

Introduction

At a recent meeting the Development Committee of SSSERC agreed that the testing of pulse electroscopes should be discontinued, as the Unilab D.C. amplifier now provided a satisfactory alternative for the measurements which pulse electroscopes were required to perform.

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A meeting has been held between SSSERC and certain members of the S.C.E.E.B. panel responsible for preparing the proposed new biology syllabus with a view to preparing a list of equipment suitable for teaching the syllabus. This will be made available in a future issue of the Bulletin. Meanwhile it is estimated that to equip a biology laboratory from scratch to teach the syllabus will cost approximately £850.

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As last year we shall exhibit a comprehensive range of apparatus which has been made up or developed by us in the Centre over the past year at the A.S.E. (Scottish Branch) in the Chemistry Department, Glasgow University from 9th - 11th April. We hope as many teachers as possible will come to see the exhibition and convey to us their opinions or complaints on apparatus, manufacturers, or even ourselves.

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The Centre will be closed on Good Friday, April 12th.

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Our testing of low voltage power supplies has been under way for over six months, and preliminary results are reported elsewhere in this Bulletin. Our explanation of the delay is that in one sense we are carrying out the function we were set up to do, viz. protect the teacher from being sold apparatus which in one form or another is unsatisfactory. To some extent this situation has arisen out of the conflicting requirements of the Nuffield and Scottish syllabuses. Item 59 of the Nuffield equipment list, Low Tension Variable Voltage Supply, requires a provision of 1 per school, and specifies it as a "general purpose item of demonstration equipment providing up to 25 volts both D.C. and A.C. at 8 amperes and an essential requirement for the course." In Scotland we have, rightly in our view, regarded the power supply as an item of pupil equipment and sought to supply them in greater numbers. We have thus based our reports on the assumption that pupils will use these power units.

Our main cause of complaint, however, has been the lack of precision in the Nuffield statement; if manufacturers have received a more detailed specification which we do not know about, their interpretations have been variously and vicariously made. Thus we do not know whether A.C. and D.C. outputs must be available simultaneously, or whether - and this perhaps applies only to our pupil based apparatus and is not intended as a criticism of Nuffield - safeguards must be built into the design so that they shall not be available simultaneously.

More important are the rating conditions. Manufacturers have apparently not been able to decide whether the 25V, 8A maximum was for a period of 80 minutes, 6 hours or continuously. Rightly or wrongly/

wrongly, we have taken the view that an apparatus which the manufacturers claim, either in the catalogues or on the unit itself, will provide "25V AT 8 AMPS." must do so continuously, and that furthermore if it follows good engineering practice there ought to be some built-in factor of safety which ensures that at the maximum load the unit is not on the point of breakdown.

Whether it is a school requirement that this continuous power is necessary is a moot point, and one which the Nuffield Physics Project advisers should in all fairness to the manufacturers have decided. In teacher rather than pupil hands the power unit is more likely to be called upon to supply a greater-than-school-double-period load, even if it may be only the illicit charging of a flat car battery.

When we commenced testing of power supplies on continuous load we found that only a minority were not being over-rated, usually because no allowance had been made for the effect of temperature rise on the rectifier. A few failed disastrously by burning out the rectifier or melting the varnish on the transformer winding. In these instances we wrote to the manufacturers concerned and received replies which could be classified into two groups; the first defending the power supply by saying it was not meant to operate continuously at full load (but failing to specify any intermittent load condition), the second asking for time to re-examine the power unit with a view to remedying the defects. While the latter has held up our testing programme and is the main reason for the delay, it may not be the best solution. We believe that few teachers want a power unit modified to run continuously, and that most would prefer to have an intermittent load specification stating the maximum load which could be drawn for up to one hour, provided that this were followed by a specified rest period. Although tests would have to be carried out to determine this, we believe that all the units we have examined would stand up to an hour's full load followed by the same rest period before being put on load again. This is preferable to changing rectifiers and/or transformers for more powerful ones, particularly as this will almost certainly increase the price.

Low Voltage Power Supplies

Under this heading we group any power supply designed to generate between 20 and 30 volts at currents of order 5-10 amperes, both alternating and direct. Broadly this corresponds to Item 59 of the Nuffield Physics Project list. The units we have examined are Advance Electronics PP14 and PP15; British Electrical Resistance Co. PSU1; Griffin and George GN59; Philip Harris P7997/20, P7997/20A and P7997/27; W.B. Nicolson K95/1300; Radford Electronics N59R and LAB59R (the Labpack); Unilab 022.314 and 022.316. Of these, the PSU1, GN59, P7997/27, N59R, LAB59R, and 022.316 had been approved by Nuffield in June 1966, the last publication we have on Nuffield approved apparatus. Most of the other units have come into production since that date. The results of tests on some of these units are summarised in the Bulletin Supplement; the remainder will follow in a later Bulletin.

All power units use a transformer to obtain the low voltage; the majority connect the mains earth lead to chassis although some keep the latter floating and provide an earth terminal. The mains switch/

switch may be single or double pole; there is some virtue in the practice of one manufacturer of using a single pole switch in conjunction with a neon indicator wired between live and earth, as it will reveal an incorrectly wired plug by lighting up before the unit is switched on.

The more expensive power supply uses a variable transformer for controlling the secondary output. This has the advantage that the output is continuously variable, and the disadvantage that there is no indication of even an approximate output voltage. Where provided the output control has a scale running 0 through to 100. Together with the high price, this makes the unit demonstration rather than pupil equipment.

For units using a standard transformer, the output voltage is controlled by tappings on the secondary which are usually selected by rotary switch, although one design brings all taps out to sockets on the front panel. Switching the secondary voltage creates certain difficulties which we feel may give trouble in the long term. If the rotary contact is of the make-before-break type then there must be a moment when the step voltage is being short-circuited, subjecting the transformer to mechanical as well as electrical stress. If the controls break before making (and both types are to be found in the power units we examined) then the load current is broken at every step, raising the possibility of arcing at the switch contacts. For this reason the wafer type switch which appears on some models has a higher rating for carrying current than switched current. Bringing all taps out to the front panel solves these difficulties, but raises the human problem of how to dissuade pupils from plugging lengths of wire into vacant sockets when the unit is working, and possibly shorting parts of the secondary.

All units have some means of overload protection in the output circuit, and the majority have fuses in the primary. Glass cartridge fuses come in a variety of sizes and the efforts of the A.S.E. Apparatus Committee to reach agreement on standardisation amongst manufacturers are to be welcomed. The functions of a protection device are two-fold, to protect both the power unit and its load, and there is no doubt that wire fuses are both the simplest and most economical method of doing this. It seems a pity therefore that the fashion amongst science teachers has tended towards the use of expensive cut-outs. Dare we say that if the spirit of alternative syllabus teaching pervades the laboratory, the nuisance value of having to replace their own fuse may make pupils more careful not to overload their equipment in the future? Cut-outs can be either magnetic or thermal. The former operates satisfactorily and with A.C. or unsmoothed D.C. give audible warning of maximum loading before they trip out. Thermal cut-outs are less satisfactory as they have high inertia and will tolerate a large overload for an appreciable time before operating. They are therefore useless in protecting low voltage lamp bulbs against excess voltage being switched on to them.

Most units connect the A.C. output terminals to the rectifier system, thereby making it possible to obtain A.C. and D.C. outputs simultaneously. Although it became obvious from our temperature tests that few if any of the units would survive this treatment, only one design makes this impossible by means of a A.C./D.C. selector switch, and a further one explicitly warns that A.C. and D.C. may not be drawn simultaneously. Although we think it highly unlikely that teachers will want to use simultaneous A.C. and D.C. - except in the design which brings all the transformer taps out there is the restriction that they must use the same voltage setting for both outputs - yet we think that a facility which is possible but not intended as a method of use should be warned against, preferably on the unit itself. In general we have not made tests on simultaneous loading/

loading on both A.C. and D.C.

Rectifiers are all bridge-connected, and the majority are selenium types with air-cooled fins. A number of units however are using silicon diodes either separately mounted on heat sinks, or encapsulated. It was under continuous D.C. load that power units overheated or failed. The first common fault was failure to allow for the effects of temperature rise on the rectifier. Selenium rectifiers require to be de-rated to 70% or less of their normal power output if the ambient temperature rises by 35 deg. C. In many cases we found higher ambient temperatures around rectifiers which when cold were working "flat out."

The second main fault was to quote the same maximum current for either A.C. or D.C. load. If one remembers that rectifier losses have to be taken into account, it is obvious that the transformer current must be greater on D.C. than A.C. with the same load, and our tests show that a 30% increase is typical. This meant that a transformer correctly rated for a D.C. load, was being under-run on A.C. which is not a bad thing. Regrettably there were also instances where the transformer was working flat out on A.C. and being 30% overloaded on D.C.

Most units connect the rectifier output to the D.C. terminals with no reservoir capacitor to provide smoothing. With some units this is an optional extra. It should therefore be borne in mind that what is labelled as a D.C. output is usually unsmoothed, full-wave rectified A.C., and there must be experiments where this is unsatisfactory. One such is the use of oscilloscopes on D.C. connection as for example with the White rotary resistor. Another which tends to be forgotten is the behaviour of a moving coil meter. This will register the average value of current through it, which is 63.7% of peak amplitude, and is lower than the 70.7% peak which is the R.M.S. value, and which one would obtain from energy considerations. This error may be significant where absolute values are in question, e.g. in determining Joule's Equivalent.

Smoothing in low voltage units is of doubtful value unless the manufacturer is prepared to select his rectifiers carefully for low forward resistance, and back them up with really high value capacitors so that ripple is negligible even at high currents. Otherwise, a capacitor across the output leads to poorer regulation. Good regulation means that the output voltage remains nearly constant irrespective of load current; by raising the output voltage to peak value for zero current, a capacitor makes the output more dependent on load current, and incidentally makes it more difficult to set the voltage control to give the required output. In these cases a set of regulation curves would be a real help to teachers.

Our tests consisted of drawing regulation curves using 240V mains input for various A.C. and D.C. voltage settings up to the maximum current specified by the manufacturer. These curves are reproduced in the individual reports. We also attached copper constantan thermo-couples to the transformer core and rectifier cooling fins, bolted the covers back into place and ran the unit at full load, recording temperatures every ten minutes until a steady temperature was reached, usually after 2-4 hours. A.C. and D.C. conditions were applied separately for this test usually on different days to allow adequate cooling between tests. In cases where there was doubt about the rectifier rating we also measured its ambient temperature at a point approximately 1 cm beneath it. Where the output voltage control was calibrated, we also derived from the regulation curves the mean single step increment in voltage for various currents; tables showing these increments for A.C. and D.C. are given in the reports. Where thermal cut-outs were fitted, the unit was overloaded by varying amounts and the time taken for the cut-out to operate was measured; tables of these times are also given.

Chemistry Notes

Surprisingly accurate results for the gram molecular weights of the permanent gases can be obtained by the simple technique of injecting a measured volume of pure gas into a rigid container and determining its mass. The plastic containers in which Johnsons supply photographic developer solution are sufficiently rigid and light weight for use on this experiment, and the only other requirements are for a three place balance, a plastic syringe of 50 ml capacity, and a cylinder of gas. A satisfactory alternative for the plastic bottle is an empty Aerosol spray container, with the valve removed.

The bottle is fitted with a single hole stopper, glass and rubber tube, the last containing a glass bead to act as a pinch valve. When assembled the weight for the 250 ml capacity bottle will be about 50 g. After weighing the bottle, the syringe is loaded with 50 ml of the required gas from the cylinder which is then injected into the bottle. Up to four such injections can be done, and if need be the bottle can be weighed each time to check that the readings are reasonably constant, differing by no more than 1-2 mg. If more than 150 ml are injected, the syringe will not fully empty on the last "shot" due to the higher pressure in the bottle, and there is also a tendency for the base of the bottle to bulge outwards. The first error can be allowed for by subtracting the "empty" reading on the syringe, but there is no easy way of correcting for the second.

The table below shows our results for oxygen and methane. When we attempted this with home-prepared gases, the results were not so accurate, which we attribute to impurity in the gas. For schools with a top pan balance which reads to 1 mg, the Parazone bottle offers greater accuracy since it is larger and up to 400 ml of gas can be injected. Regrettably it is too big to fit into the weighing chamber of most balances.

Gas	Increase in Mass per 50 ml, mg.			G.M.W.
Oxygen	64	65	63	30.7
Methane	32	32	31	15.4

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At the request of our Development Committee we have carried out a series of organic preparations to determine the minimum grouping of apparatus necessary for carrying out these experiments, and to obtain comparative costs. The first part of this account gives details of the experiments performed, which we believe to be more than adequate for Section 20 of the alternative chemistry syllabus, and the second part is a summary of manufacturers' apparatus which is adequate for the experiments. In the main our principle was to attempt the preparations with standard laboratory equipment, e.g. boiling tubes mounted with Terry clips on a vertical asbestos board, and only where results were unsatisfactory or yield was poor did we have recourse to semi-micro equipment.

Two text-books were used:

Ref. (1): Advanced Level Practical Chemistry, by J.W. Davis, published by John Murray, 18s.6d.

Ref. (2): Organic Chemistry through Experiment, by Waddington and Finlay/

Finlay, published by Mills and Boon, 16s.6d.

The symbols P and D are used to distinguish pupil and demonstration experiments, and where we refer to the "wet asbestos" method it should be borne in mind that the builder's material Rocksil is a satisfactory alternative to asbestos which has been found to have carcinogenic properties.

1. Ethylene, P. or D. Prepared by heating excess conc. sulphuric acid with ethanol. This was tried in boiling tubes but would be hazardous for pupils. Results were satisfactory using the wet asbestos method as detailed in Ref. (1), p.19, using ethanol and aluminium oxide powder.

2. Nitrobenzene, P. By method given in Ref. (1), p.198. A mechanical stirrer is advisable. Distillation was attempted using boiling tubes and an air condenser with very poor results. With full scale distillation apparatus the results are satisfactory except for the effects on rubber stoppers so that ground glass equipment is advisable.

3. Glycerol, P. The saponification of mutton fat was attempted in a test-tube, with unconvincing results.

4. Paraffin cracking, P. By wet asbestos method of Ref. (1), p.194, with porous pot chips. Results were satisfactory.

5. Ethanol, P. Prepared by fermentation of yeast and cane sugar. Distillation was first attempted in boiling tubes with unsatisfactory results, due to very low yield. Using full scale distillation apparatus the results were satisfactory and although small scale apparatus would be quicker it would yield only a few ml of ethanol.

6. Ethyl benzoate, P. Prepared by warming ethanol, benzoic acid and sulphuric acid in a test tube, Ref. (2), p.128. For the extraction, ground glass apparatus is essential, although this may be an unsuitable pupil experiment because of the time involved. The procedure is to reflux for two hours, followed by distillation to remove excess ethanol. Ethyl benzoate is then extracted with ether, followed by distillation of the solution to remove ether, and final distillation of the product.

7. Acetaldehyde, P. Prepared by dropping sodium dichromate in ethanol solution onto warm dilute sulphuric acid as in Ref. (1), p.208, or Ref. (2), p.34. Using a boiling tube with bent delivery tube into a cold receiver, results were satisfactory.

   Just as suitable and more easily set up, is the wet asbestos method with copper turnings and ethyl alcohol, described in Ref. (2), p.36. This also avoids the need to purchase a ground glass dropping funnel, which can be expensive.

8. Aniline, D. Ref. (1), p.216. The method is to reflux a mixture of nitrobenzene, hydrochloric acid and tin for 30 minutes, followed by addition of sodium hydroxide and distillation, extraction with carbon tetrachloride and final distillation of the product. Results were satisfactory using full scale distillation apparatus, although for a school demonstration ground glass apparatus is almost essential.

9. Phenydiazonium chloride, D. or P. Prepared from aniline, hydrochloric acid and sodium nitrate, Ref. (1), p.217. The dye Sudan G was then prepared from this by addition of resorcinol and/

and sodium hydroxide. The preparation is satisfactory when carried out in full-scale apparatus.

10. Hydrolysis of ethyl acetate, D. By refluxing ethyl acetate and sodium hydroxide, followed by distillation of ethyl alcohol, Ref. (2), p.53. This was satisfactory using full-scale apparatus, although small scale apparatus would be more suitable.

As a result of these experiments we conclude that only Nos. 2, 6 and 8 require the use of ground glass jointed apparatus, the other experiments being possible using standard laboratory apparatus with rubber joints. If small scale equipment is to be purchased it should therefore be of the ground glass type, and the following would appear to be the essential items:

1. Distillation Flask This is normally pear-shaped, of 50 ml capacity. Exceptions are the Fison flask, which is round, and the Gallenkamp which has 30 ml capacity.

2. Stillhead This fits the flask and has both side arm and top entry. Usually these are both standard joints, but on the Gallenkamp and Eureka models, the top entry is narrower and is suitable only for thermometer insertion.

3. Condenser Usually this is a Leibig condenser fitting either the side arm of the stillhead or directly to the flask for refluxing. Gallenkamp and Eureka use a cold finger condenser and jacket. The jacket side arm fits the flask directly, or can be connected through the stillhead if a thermometer is to be used. The jacket delivery fits the flask directly for refluxing.

4. Thermometer Pocket This is a tube closed at its lower end, its top being a standard joint fitting. A thermometer can be inserted in the tube, being held by a rubber stopper. A disadvantage is that the thermometer cannot be brought into contact with the liquid or vapour. In all the preparations carried out this pocket will serve adequately as a stopper, which is consequently unnecessary. The Gallenkamp and Eureka models have no thermometer pocket; the thermometer fits the smaller entry on the stillhead using rubber tubing. There is the advantage that the thermometer can be brought into contact with the reactants, and the disadvantage of possible contamination of vapour from the rubber fitting. Because of the different design, a stopper is a necessary item in the Gallenkamp and Eureka versions. Harris supply a throughway thermometer adapter, so that this set also requires a stopper.

5. Receiver Adapter This is a long tube with a standard joint fitting at the inlet end and is designed to deliver a distillate to a test-tube or some similar receiver. The need for this item is doubtful, and in many cases the delivery end of the condenser can be set to deliver directly to the receiver. This may not be so satisfactory where the receiver requires to be kept cold, e.g. experiment 6. Fisons do not make a long receiver adapter in the B14 size, although this is provided in the B19 size. The additional expense of standardising on the B19 range is considered not to be justified. Instead, in the B14 size Fisons make a short receiver bend with standard joint at each end, and it is this which has been listed. Gallenkamp and Eureka do not supply a receiver adapter but provide a graduated 5 ml receiver with side arm instead, and it is this which has been listed.

6. Stopper As indicated in item 4, stoppers are not thought to be necessary except for the Gallenkamp and Eureka versions where there is no thermometer pocket, and with the Harris, which has a thermometer adapter.

In the columns which follow, the first entry is the catalogue or reference number where this is known; the first price given is each in singles quantity and the second price is each in dozens quantities, where applicable. If the total cost is asterisked thus (*), it means that the price is that of the complete set of items where these can be bought as a kit; beneath this cost is given the catalogue number of the kit, thus: *ES16A. This cost may be greater than the sum of the individual components due to their being supplied in a special storage box.

	Item	Quickfit	Christison	Fisons	Gallenkamp
1.	Flask	FP50/1 9s. 9d. 8s. 8d.	K/14FP50 7s. 10d. 7s. 1d.	FRSB/5/1 6s. 2d. 5s. 8d.	FJ195 7s. 4d. 6s. 2d.
2.	Stillhead	SH4/11 15s. 6d. 13s. 11d.	K/14SH 12s. 5d. 11s. 2d.	SH/111 13s. 4d. 12s. 4d.	DT555 9s. 3d. 8s. 4d.
3.	Condenser	C1/11 21s. 6d. 19s. 4d.	K/14LC 17s. 2d. 15s. 5d.	CL/15/11 17s. 4d. 16s. 0d.	CU450 20s. 0d. 18s. 4d.
4.	Pocket	SH4A 10s. 0d. 9s. 0d.	K/14TP 8s. 0d. 7s. 2d.	TP/1 7s. 10d. 7s. 3d.	TF420 6s. 2d. 4s. 11d.
5.	Adapter	RA1/11 10s. 3d. 9s. 3d.	K/14RAP 7s. 7d. 6s. 10d.	RAB/11 10s. 6d. 9s. 9d.	-
6.	Stopper	-	-	-	SU520 4s. 3d. 2s. 10d.
	Fitting size	B14/23	B14	B14	B14/15
	Total cost	70s. 10d. 63s. 8d.	56s. 1d. 50s. 5d.	58s. 5d. 54s. 0d.	49s. 0d* 45s. 0d. *DT750

	Item	Harris	Eureka	Exelo
1.	Flask	C2284/J 9s. 9d.	- 9s. 0d.	F80/2 8s. 1d.
2.	Stillhead	C2284/E 16s. 9d.	- 13s. 6d.	J60/2 16s. 2d.
3.	Condenser	C2284/H 21s. 0d.	- 22s. 6d.	C10/2 18s. 8d.
4.	Pocket	C2284/A 8s. 0d.	- 11s. 0d.	J41/2 8s. 9d.
5.	Adapter	C2284/C 9s. 0d.	- -	J71/2 8s. 4d.
6.	Stopper	C2284/F 5s. 6d.	- 4s. 6d.	-
	Fitting size	B14	B14	B14
	Total cost	70s. 0d.	63s. 0d*	65s. 6d* *ES16A

In The Workshop

The model mass spectrograph is an attempt to illustrate qualitatively that in passing through a magnetic field, and provided that they have the same velocity, heavier ions are deflected less than lighter ions. Believing that it was necessary to emphasise that mass rather than size was the important criterion, we have chosen to illustrate the principle using two sets of spheres more or less the same size, but with very different masses. Thus the heavy "ions" vary in mass between 26 and 28.5g; the light ions between 5.3 and 6.1g.

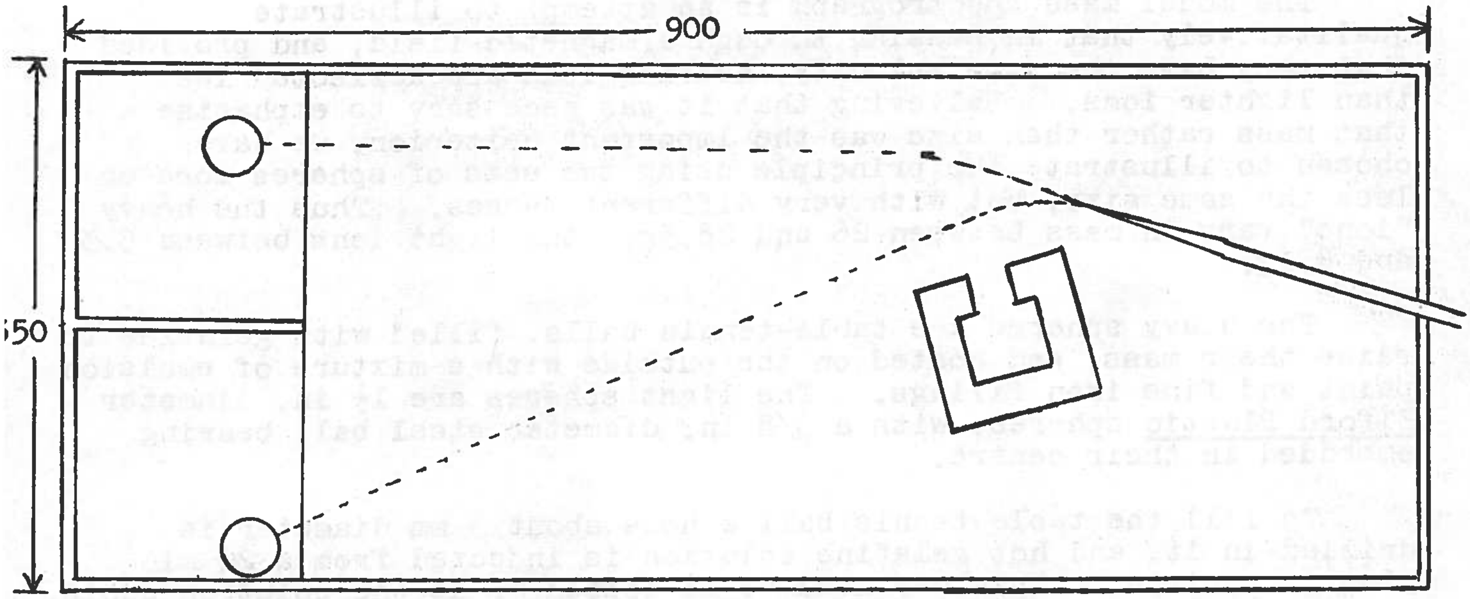
The heavy spheres are table-tennis balls, filled with gelatine to raise their mass, and coated on the outside with a mixture of emulsion paint and fine iron filings. The light spheres are 1½ in. diameter Elford Plastic spheres, with a 3/8 in. diameter steel ball bearing embedded in their centre.

To fill the table tennis ball a hole about 3 mm diameter is drilled in it, and hot gelatine solution is injected from a 20 ml plastic syringe. This may need to be topped up as the solution cools. When the solution had set the balls were coated with a slurry of black emulsion paint and very fine iron filings, sold as iron pin dust by May and Baker. The slurry was made as thick as was consistent with its remaining brushable and only one coat was applied. There is no particular virtue in using black paint except to distinguish the heavy from the light spheres which are left self coloured. The light spheres are more difficult to make as they require to be drilled on the lathe to ensure that the inserted bearing is centrally placed. The ball is held in the lathe chuck backed by a wooden stopper of slightly smaller size so that when the chuck is closed it grips both ball and stopper, slightly compressing the ball. The stopper prevents the ball being pushed further into the chuck by the drill action. The stops must be set so that the drill passes slightly more than 3/16 in. beyond the centre of the ball, the slight addition being to allow for the fact that the drill face is tapered and the ball bearing will not therefore be seated home to the very tip of the hole. After inserting the ball, the hole is plugged with the turnings expelled from the ball and sealed over with a thin layer of Araldite. More balls than will be finally required should be made, and the collection tested for any obvious bias by rolling on a level surface before selecting the best half dozen.

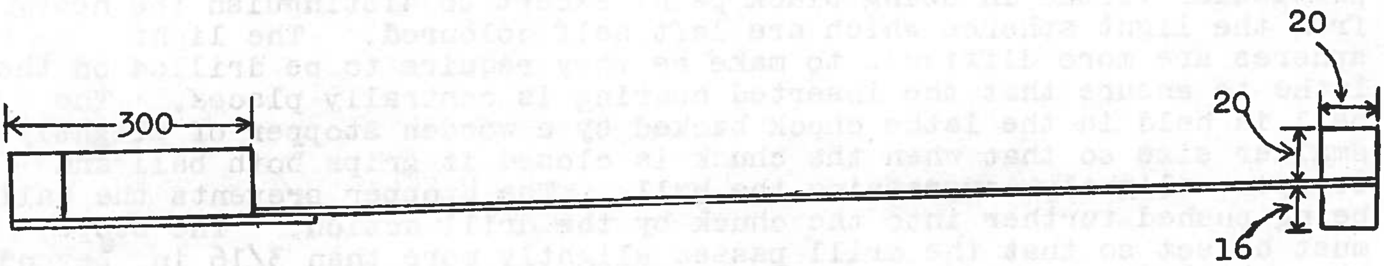
The tray in which these balls are projected measures 90 x 35 cm, with 7 mm plywood base, and sides of 20 mm square softwood. As shown in the elevation sketch the tray is slightly sloped and this together with a stepped base at one end which forms a shallow trough will prevent spend spheres from ricocheting back into the firing area where they will adhere to the magnet.

The launching ramp is a bent up V of aluminium sheet, tapered to a point and mounted on an aluminium bracket so that it is inclined at about 15° to the floor of the tray. As shown on the plan sketch, which has been drawn to scale, the ramp is also inclined at 12° to the longitudinal axis of the tray. The placing of the magnet, which is an Eclipse Major, and the launching point of the ramp must both be determined by trial and error as they are quite critical. To maintain the constant velocity condition all spheres should be launched from the same point. In use it may be found that occasionally a light sphere is repelled by the magnet because of previous induction, and the balls must then be rolled through a demagnetising coil fed with alternating current.

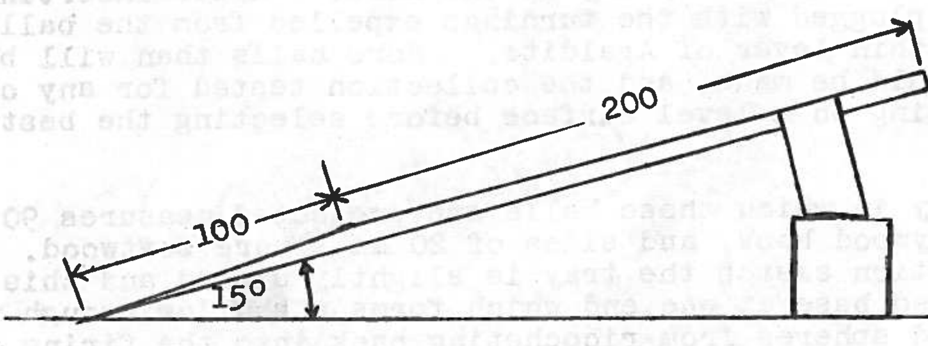
All dimensions in mm.



Mass Spectrograph model; plan view.

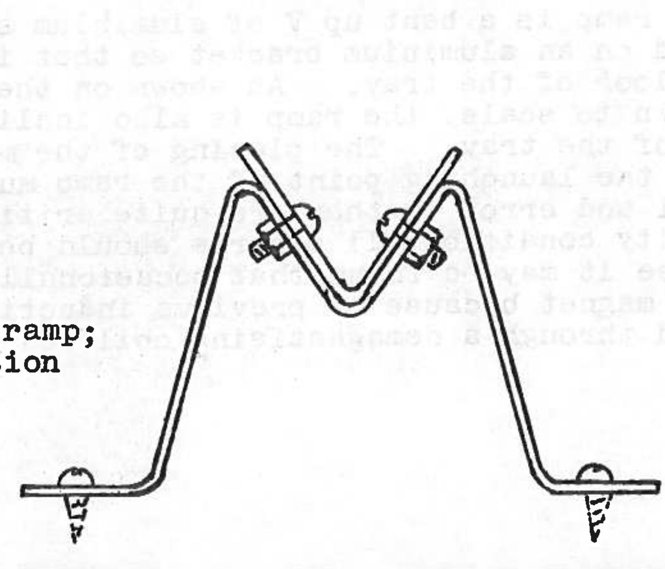


Tray elevation; mid-section.



Launching ramp; side elevation.

Launching ramp;
end elevation



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

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

A. Christieson Ltd., Albany Road, Gateshead East Industrial Estate, Gateshead, 8.

Efford Plastics Ltd., Broomfield Works, [illegible] Corner, [illegible], Yorkshire.

Eureka Scientific Co. Ltd., 192/6 [illegible] Lane, Ilford, Essex.

[illegible] and Sons Ltd., [illegible] House, Westgate Road, Broadstairs, Kent.

Fisons Scientific Apparatus Ltd., Bishop Meadow Road, Loughborough, Leics.

A. Gallenkamp and Co. Ltd., Technico House, Christopher Street, London, E.C.2.

Philip Harris Ltd., 63 [illegible] Drive, Dalgety Bay, Fife.

Johnsons of Hendon Ltd., Hendon, London, N.W.4.

May and Baker Ltd., Dagenham, Essex.

Mitchell and Cooper Ltd., [illegible].

[illegible] Ltd., [illegible] Lane, [illegible], Lancs.

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

Advance Electronics Ltd., Roebuck Road, Hainult, Ilford.

A. Christison Ltd., Albany Road, Gateshead East Industrial Estate,
Gateshead, 8.

Elford Plastics Ltd., Brookfield Works, Wood Street, Elland,
Yorkshire.

Eureka Scientific Co. Ltd., 192/8 Ilford Lane, Ilford, Essex.

(Exelo) W.G. Flaig and Sons Ltd., Exelo Works, Margate Road,
Broadstairs, Kent.

Fisons Scientific Apparatus Ltd., Bishop Meadow Road, Loughborough,
Leics.

A. Gallenkamp and Co. Ltd., Technico House, Christopher Street,
London, E.C.2.

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

Johnsons of Hendon Ltd., Hendon, London, N.W.4.

May and Baker Ltd., Dagenham, Essex.

Quickfit and Quartz Ltd., Stone, Staffordshire.

Rainbow Radio Ltd., Mincing Lane, Blackburn, Lancs.