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SCOTTISH SCHOOLS SCIENCE EQUIPMENT RESEARCH CENTRE

Bulletin No. 155

January 1987

Electronic Balances
Kynar Piezo Film

A D D R E S S   L I S T

SSSERC, 103 Broughton Street, Edinburgh EH1 3RZ; Tel. 031 556 2184 or 031 557 1037.

Adam Equipment Company, Third Avenue, Denbigh Industrial Estate, Bletchley Milton Keynes MK1 1EW; Tel. 0908 76231.

BDH Limited, Burnfield Avenue, Thornliebank, Glasgow G46 7TP; Tel. 041 637 2333.

Brash and Sons Limited, 37 Stamperland Crescent, Clarkston, Glasgow G76 8LH; Tel 041 638 2284.

Carlton Technology Limited, PO Box 21, Altrincham, Cheshire WA15 7LG; Tel. 061 980 8911.

Cherlyn Electronics Limited, 22 High Street, Histon, Cambridge CB4 4JD; Tel. 022023 4062

Creative Foam Corporation, 300 North Alloy Drive, Fenton, Michigan 48430, USA; Tel. 010 1 313 629 4149.

Farnell Instruments Limited, Sandbeck Way, Wetherby, West Yorkshire LS22 4DH; Tel. 0937 61961.

R.W. Greeff, 35 Nurseries Road, A8 Trading Estate, Baillieston, Glasgow G69 6UL; Tel. 041 773 2223.

Griffin and George Limited, Bishop Meadow Road, Loughborough, Leics. LE11 ORG; Tel. 041 248 5680 or 0509 233344.

Philip Harris Limited, Lynn Lane, Shenstone, Staffs. WS14 OEE; Tel. 03552 34983 (from Scotland) or 0543 480077 (direct).

IMS Scientific, Oakbank Industrial Estate, Garscube Road, Glasgow G20; Tel. 041 332 6088/9296.

International Electronics Limited, Ewood Bridge, Haslingden, Lancashire BB4 6LD; Tel. 0706 212211.

Mackay and Lynn Limited, 2 West Bryson Road, Edinburgh EH11 1EH; Tel. 031 337 9006.

McQuilkin Instruments Limited, 21 Polmadie Avenue, Glasgow G5 OBB; Tel. 041 429 7777.

(**continued** on page 36 and inside back cover. The inside back cover also carries a key matching makes of balance to supplier names).

SSSERC is an independent national advisory centre, solely controlled and largely financed by Scottish Regional and Islands Councils as Education Authorities.

OPINION

In pursuit of the end of the rainbow

As every science teacher knows, infinity is, approximately, at the far end of the laboratory. What dismays me is the sight of teachers, those perhaps with funny money in their pockets, forgetting this little homily and chasing after the end of the rainbow. "Can you recommend to me a good robot?" "What satellite receiver should I buy?" - these are questions I have been asked recently. One teacher showed me round his laboratory which had been equipped with eight microcomputers each linked to a different robot. There's new technology for you! But what saddened me is that 99% of the creative work which is associated with this equipment had already been done outwith that classroom by the engineers and technicians who had designed and built it. It is ironical that one major purpose of bringing technology into the syllabus is hardly going to be fulfilled by this means. The science has been wrung out of it.

What I would rather see is science education which is based on some of the fundamental laws, illustrated with applications which are modern where suitable. If important ideas can be illustrated only by using modern equipment, then this should be done. The pursuit of new technology as an end in itself is of little value; but where it can sensibly bring panache and excitement into the laboratory I for one don't mind indulging in the fun.

* * *

INTRODUCTION

ASE Scottish Region

Annual Meeting

This will be held in Culloden Academy, Inverness from the 13th to the 15th of April, 1987. The theme of the conference is to be "Education, Industry and Technology". The programme will include lectures and workshops to suit both primary and secondary sectors, covering both 'traditional' sciences and technological studies. We will be exhibiting, as usual, and look forward to meeting old friends and, we hope, making new ones.

The 1986 meeting at Craigie College was generally agreed to be one of the better ones of recent years. We hope that even more folk than the many who trekked to Ayr will make the effort to travel north for the 1987 conference. From what we hear, Culloden Academy will be another excellent venue.

The dreaded A9 is now so improved you can leave the Central Belt after breakfast and be in Inverness in time for lunch. We would reassure any English readers thinking of attending - there is no truth in the rumour that north of the Great Glen you may fall off the edge.

Cost Index

Our cost index for science education consumables was established at 100 in May 1974. In November, 1986 the index stood at 370 as against 364.83 in May. This gives a percentage increase for the six month period of 1.4%. Readers will recall that we were unable to obtain all of the data for computation of the index in November, 1985. That means that we cannot give a year-on-year figure on this occasion. However in June 1987 we should be able to publish a figure for the 12 month period May 1986 to May 1987.

Ross & Lamont

In Bulletin 154 we gave an old and incorrect telephone number for this firm. The up-to-date number is:

041-771 1473

Heat resistant cable for soldering irons

If soldering irons are used by inexperienced persons, staff as well as pupils, there is a fair chance that the hot tip will come into contact with the lead and burn through the insulation. Till recently we would have advised that schools purchase low voltage irons only. However we have recently tested silicone cable and find that it is resistant to damage by heat from the hot bits of soldering irons. A 240 V iron fitted with silicone cable is therefore quite satisfactory for novice pupils. Such an iron would be our recommended buy because the cost of a low voltage supply unit does not have to be borne.

Silicone cable is available from Carlton Technology Limited, who charge 90 pence per metre. This firm also stocks Antex soldering irons which have been fitted with silicone cable. We recommend that schools refit any existing irons with this cable.

Science teachers are asked to inform their colleagues in Home Economics about silicone cable - it has a suitable current rating for their irons too!

* *

Sulphur dioxide canisters

Over the last dozen or so years we have had a continuing trickle of enquiries about these canisters. These have usually been on what to do about corroded valves. We pointed to this problem in our manual on hazardous chemicals [1]:

> "Sulphur dioxide 'cylinders' [or syphons] are susceptible to corrosion particularly of the valve and in the area where the brass is in contact with the aluminium cylinder".

We went on to point out that they should not be stored near sources of corrosive fumes such as acids. A suitable location is an open shelf in a general store. In humid conditions the canister should be so stored but in a clear plastic bag with some silica gel. Our experience had been that the major problems arose because of poor storage conditions in schools.

However late last year we had a request on an aspect, at least to us, novel. This came from a chemistry department in a College of Education. They had the distinction of being the first case, to our knowledge, where canisters were actually corroded on delivery. Understandably, they were somewhat miffed. Our advice was to pursue the supplier because it was probable that someone had improperly stored a batch of canisters. We also suggested that the correspondence be copied to ourselves and that the original bear a note that this had been done (a useful tip for other complainants).

We are glad to report a happy ending. The supplier promptly earned new Brownie points, admitted the error and sent replacements. It was claimed that moisture in the store was possibly to blame and stated that this was a reason for their policy of keeping at a minimum their stocks. The supplier also promised that his staff had been made aware of the complaint and that they would be more vigilant in future "and so should we all" (this writer said, in piety and poor grammar).

For the record, we would be interested to hear of any other incidents of delivery of ready-corroded canisters. BDH are usually the actual makers and fillers but many other firms act as agents and thus store and distribute the canisters. So please, if it has happened to you address yourself first to the actual supplier, (and send nosey old SSSERC a copy).

Reference

1. SSSERC, "Hazardous Chemicals - A manual for schools and colleges". Oliver and Boyd, first published 1979, ISBN 0 05 003204 6.

* * * * *

"The uncreative mind can spot wrong answers, but it takes a creative mind to spot wrong questions".

Anthony Jay, 1967.

In: "Management and Machiavelli; An Enquiry into the Politics of Corporate Life". Holt, Rinehart and Winston.

Practical investigations

We are seeing hopeful signs of a swing back to more open ended pupil practicals. We also look for greater emphasis on investigative activity, problem solving and projects. This is not the place to detail the variety of legitimate educational purposes of practical work. Undoubtedly there is a need for some holistic activities where the means justify the means, and to pot with the assessment of ends.

Some of the factors to watch when setting up both mini- and full scale projects were described by Ian Downie in SSSERC MeMo 4 [1]. The context there was within electronics but many of the principles are transferable to other subject areas. These include the need for initial training in required skills, prior exposure to techniques and knowledge in simpler contexts so building up to more complex tasks and problems in unfamiliar settings. That all sounds high falutin but a mini-project or problem can be very simple. It may be set for relatively junior forms.

Sizing Cells

For example we were sent recently an idea on measuring plant cells. The simple techniques on which we worked are applicable at S1 or S3. With a little imagination they can be used to set a simple problem. This should provide welcome relief from the, now too familiar, prescriptive, worksheet approach. The work would be a mini-project set at the end of work on microscopy and plant cells. The question - "The onion skin cells we have examined; how long are they and how wide?".

Tackled as an elementary exercise in quantitative microscopy the problem essentially involves measuring the field of view, counting cells along diameters and arithmetical division. A longitudinal row of cells is bound to lie along one diameter Similarly, on another must lie a transverse row (Fig.1.).

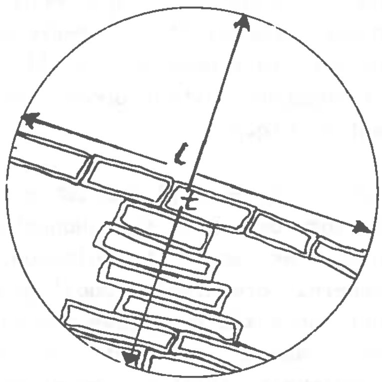

Fig.1.

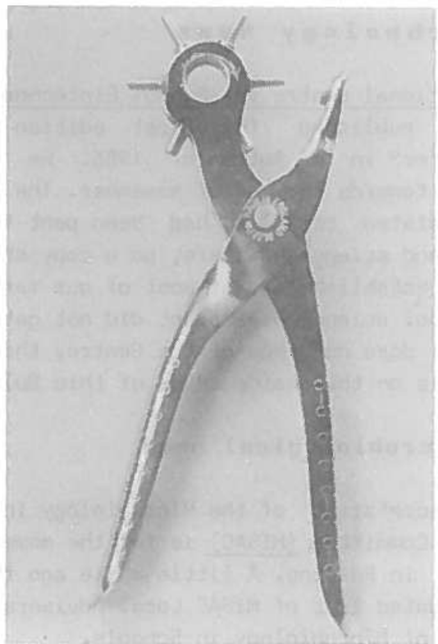

Fig.2.

At this stage pupils should already have been taught how to use a microscope and how to make a temporary mount. Rather than supply them with a worksheet or workcard with a detailed prescription for a method, why not 'hints and tips' cards and a range of simple equipment or tools? The amount of help provided can be varied according to the teacher's judgement of the degree of difficulty offered by the problem.

The solution at which we arrived needed nothing more than a clear plastic ruler with fine mm markings (in addition to specimen, slide, cover slip and microscope). Other answers might require looking up data in a book or, of all things, the use of a rotatory leather punch, cardboard and a bowl of water (Fig.2).

In Bulletin 156, we will publish a further short piece with more detail on our suggested solutions. In the interim we would be pleased to receive other answers, preferably pupil-generated. One small hint: use a x10 objective and x10 eyepiece. For the swots we set a supplementary problem - "Without further counting can you estimate how many onion cells altogether are in the field of view?".

Biotechnology News

The National Centre for School Biotechnology in Reading published the first edition of its "Newsletter" in the Autumn of 1986. We received our copy towards the end of November. The covering letter stated that it had been sent to all UK schools and science advisers, so a copy should be in the establishments of most of our readers. If your school science department did not get a copy and still does not know of the Centre, the address of NCSB is on the inside cover of this Bulletin.

More microbiological news

The secretariat of the Microbiology in Schools Advisory Committee (MISAC) is for the moment also residing in Reading. A little while ago they sent us an updated list of MISAC Local Advisers for the teaching of Microbiology in Schools.

Local advisers are willing to give general advice on microbiological practical and project work. If a topic lies outwith their own particular area of expertise they can often refer it on to expert colleagues. Local Advisers are usually members of UK microbiological societies with an interest in school based education and who have volunteered to support in this way the work of MISAC.

It is some years since we last published details of the MISAC Local Adviser service in Scotland. As of September 1986 the MISAC list included local advisers in Aberdeen, Ayr, Edinburgh and Glasgow. In Aberdeen there are two advisers, Mr M.S. Davidson and Dr G.W. Gooday, of the Macauley Institute and Marischal College respectively. The south west is served by Dr S.G. Deans at Auchincruive near Ayr. Edinburgh and the south east are covered by Dr.J.F.Lowe and Mr.R.M. McLarty, both of Edinburgh University School of Agriculture. In Glasgow are based Dr D.E.S. Stewart-Tull at the University of Glasgow and Dr L.P. Macham of Glasgow College of Technology. Full addresses are given on the inside cover of this bulletin issue.

Reference

1. SSSERC, 1986, "MeMo 4: Making a Start in Teaching Microelectronics". (See the section on "Methodology").

* * *

Electronic balances - a review

Abstract

This article outlines possible weighing requirements in Scottish school science courses and indicates strategies for meeting such needs. It includes tabulated summaries of information on a large number of models which have been tested at SSSERC or CLEAPSE School Science Service. A small number of other models which have not been tested are also included. Most of these are models similar to those tested or are members of a closely related series.

The availability of full test reports is indicated and the SSSERC test procedure summarised. Finally, three software packages for interfacing electronic balances to the BBC microcomputer are reviewed.

Choosing a balance

Simplifying the problem

Once the specifications of capacity and sensitivity have been chosen and the size of the available budget is known, a considerable narrowing down of choice results. The second step is to consider if extra features available on some models are desirable or an unnecessary nuisance. The next stage, we hope, would be an approach to the Centre for further information and the relevant test reports. It is worthwhile asking the local agent for either a demonstration, or better still a short loan, before making a final decision.

Electrical safety

A further reason for contacting us concerns electrical safety. Some of our evaluation samples had electrical safety faults. For example one model had the input fuse in the neutral side instead of in the live. Another sample had a mains on/off rocker switch which was easily levered out with the tester's thumb nail.

On receiving our draft test reports some manufacturers have rapidly responded and have corrected such faults. Others may do so in the near future.

Patterns of provision

We are often asked which weighing ranges and sensitivities are needed for particular courses. Clearly individual schools and departments will have their own thoughts on this. We summarise below the gist of ours:

Area	Capacity	Sensitivity
(i) S1 to S6	1 to 2 kg or slightly greater	10 mg
(ii) S6 Chemistry	100 to 200g	1 mg
(iii) General purpose	5000 g	1g
	500 g	0.1 g

General purpose balances (iii), can be widely used in preparation rooms as well as in laboratories. They are seen as the modern replacement for the Butchart or for the two-pan beam balance. Inexpensive load-cell balances will be more than adequate for such tasks, provided that they are fitted with a robust mechanical overload protection. They tend to be the most portable of all, many having the option of running on batteries as well as on mains.

Some have argued that a sensitivity of 10 mg is sufficient for CSYS Chemistry and that even the expense of a balance with sensitivity of 1 mg is unjustified. However in using a 10 mg balance for gravimetric and volumetric determinations the errors are, in our opinion, unacceptably large. A number of chemistry teachers share our view that for SYS, one balance with a 0.1 mg sensitivity could be more a requirement than a luxury.

The purchasing decisions of any particular school, in providing this weighing capability, will be influenced by the type of balances already held.

Possible strategies include:

(a) using three different types of balance as outlined above.

(b) combining in one balance both 10 and 1 mg sensitivities, yet having a capacity of 1 to 2 kilograms. Recently arrived on the market, at reasonable prices, are dual range and floating range balances which will do just that. A comparison shows this route to be cost-effective. For example, a dual range instrument (1500/150g capacities by 0.01/0.001 sensitivities) selling for £833 can replace the two separate balances of types (i) and (ii) in option (a) above. Those separate models would have a combined cost of about £1500. Against that saving has to be set the obvious disadvantage of only one weighing station instead of two. Two balances can be used in two different sites and in the event of a breakdown you will not lose all weighing capability.

(c) using an existing mechanical analytical balance for CSYS Chemistry and for precise weighing of other small quantities such as of growth substances for the biology department. If this is feasible then only types (i) and (iii) will be needed.

The slower operation of a mechanical balance presents little problem in CSYS work, unless an output for logging is wanted. If carefully used and regularly serviced these old mechanical models should provide many more years service.

Three further points are worth considering:

(i) the portability of balances weighing to 1 mg and;

(ii) software packages available for particular makes of balance;

(iii) the advantages of having the same make throughout the school - easier understanding of controls, larger discount for purchase of greater numbers and only one software package needed.

Some of the new models with 1 mg sensitivity are essentially top pan balances supplied with a somewhat rudimentary draughtshield of low profile, which is not permanently attached. (See key 'Ds' in the "Comments" column of the Tables). These balances,like other top pans, can be treated as portable. Other models are really descendants of the analytical type, with an integral glass draught shield and sliding doors, (See key 'Gds'). This latter type are transportable rather than truly portable and are better left in one site.

Software packages are not really interchangeable between different makes or even between different models from the same manufacturer. We have found significant differences in the quality of different packages. The availability of a useful software package will certainly help in choosing between two otherwise comparable balances.

Technical background
Principles of operation

These days, electronic balances may essentially differ only in the actual sensing mechanism. The electronics of processing the resulting signal and displaying it as a weight may be basically much the same from model to model. Balances are excellent examples of modern 'software engineering' techniques. Here the same microprocessors are programmed in different ways to carry out different functions, the hardware staying much the same.

Force Compensation types

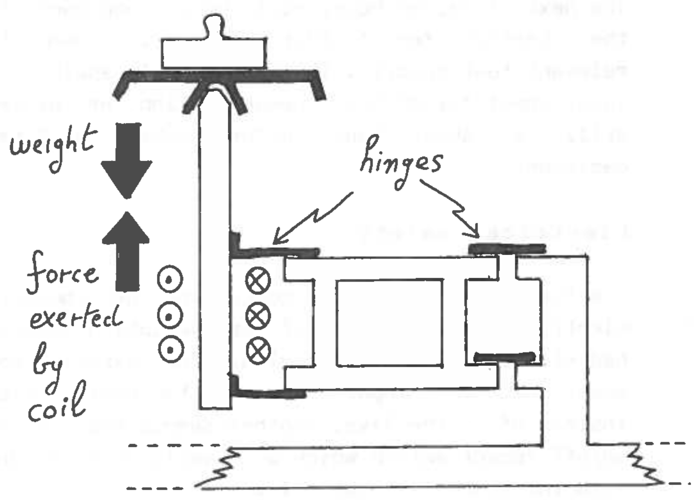

Fig.1 - Force compensation mechanism (schematic)

When the pan is loaded the mechanism, which is suspended on delicate metal 'hinges', undergoes slight displacement from its datum reference position. A feedback circuit supplies sufficient current to an electromagnetic coil to return the whole mechanism to that reference point.(Fig.1) This current is measured and processed so that it reads in grams. Clearly such a read-out is affected by local variations in the magnitude of gravitational acceleration. Calibration with a standard mass is thus needed upon installation and at yearly intervals thereafter.

Load-cell type

A load-cell is a specially shaped piece of metal which is distorted by a load placed on the pan. The amount of distortion is sensed by strain gauges attached to the cell. These strain gauges form part of a bridge circuit. Changes in the out of balance current from this circuit are processed to read out directly in grams. Again this type of mechanism is essentially a force meter and calibration is required.

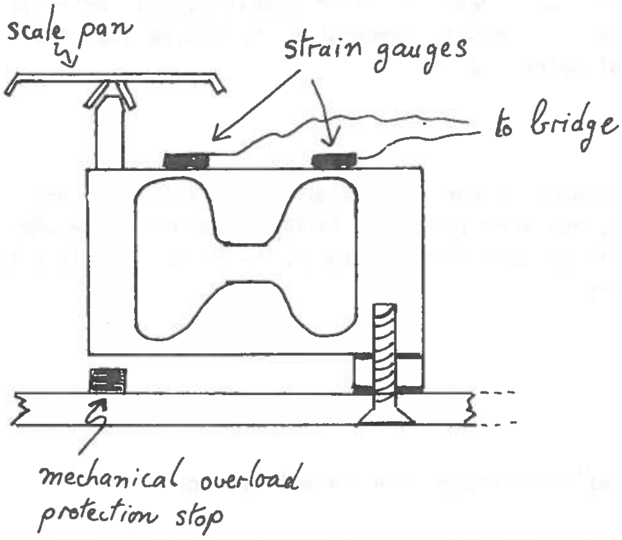

Fig.2 - Load cell mechanism, schematic

Load-cell balances are simpler and therefore much cheaper than force compensation types. It might be said that they have been developed from kitchen scales. With some of the cheaper models calibration is carried out in the factory, but is either impossible or very difficult for the user to repeat. Up-market models may have all the features of force compensation types including calibration, computer outputs or internal software controlling operational features such as, for example, choice of integration time.

Three other differences from force compensation models are:

- their greater portability because of their small size and possible battery operation, making them suitable for field work. Unfortunately this portability makes them more likely to be stolen.

- load cell types can only be designed to operate over a smaller capacity/sensitivity ratio than is possible for force compensation balances. They are usually designed for weighing to 1 g or 0.1 g sensitivity with maximum capacities of 800 and 6000g respectively.

- load cell balances usually exhibit shorter periods of drift when powered up from cold. (Manufacturers of force compensation balances usually recommend they be switched on some 20 minutes or so before use).

Summary tables

In the summary tables which follow (Tables 1-5) models are classified according to sensitivity and as to whether they are single, dual or 'floating' range. Prices are those for one balance and are as quoted at going to press. In recent months prices have been volatile, often reflecting currency movements. There have been several changes, usually increases, in prices of imported models. The prices given in the tables are thus only guideline figures. Readers are urged to check before buying.

A number of models, acceptable in other respects, attracted criticism in our tests on the grounds of electrical safety. Many have been modified to meet our requirements. Other manufacturers are also expected to comply. Therefore all except two of the models tested have been included in the tables. Our findings on safety re-inforce our advice that intending purchasers should contact the Centre.

KEY AND NOTES FOR TABLES 1-5

In any one table all balances have the same maximum sensitivity. Models are arranged in order of increasing capacity. The following key is used:

M mains powered **BE** mains battery eliminator **B** battery

R serial data output,(RS232 or RS423) fitted as standard. If an optional extra this column shows the price.

BCD binary coded decimal output.(Fitted on many of the Oertling balances it feeds to the Beeb's user port).

CL current loop fitted as standard.

Z zero tracking **(Z)** zero tracking fitted, but can be switched off by user.

Acal automatic calibration. **Pcal** calibration by adjusting preset.

Ical integrated automatic calibration. An internal standard mass is positioned by a servo motor.

Ptco. part counting facility. **Cap.In.** capacity used indicator (analogue).

L weighing principle based on load-cell and strain guage technology. [Unless so marked, the principle is that of force compensation].

Ds Supplied with cheaper, but adequate draught shields. These are often simply plastic boxes or cylindrical shields - some open, some lidded and all easily removeable. Full type (see Gds below.) often available as an extra, a typical price - £100.

Gds has fixed, full glass shield with sliding doors.

SR nearly all dual range balances automatically change to the smaller sensitivity as they are loaded beyond the capacity of the lower range, eg. when the Ohaus G400D is loaded above 40g the sensitivity falls from 0.001 to 0.01g. Only in some instruments is the higher sensitivity automatically restored when the load is reduced.

Notes:

All balances fitted with floating range or polyrange will autorange down as well as upwards.

An exception has been made to our rule not to include something as a possible buy without an evaluation. Two models new on the market which have yet to be tested have been listed. These Ainsworth AC models seem to be excellent value and the agent has promised they will shortly be sent for testing.

Further technical guidance and explanation of terms is afforded by the annotated test procedure summary on pages 14 to 16.

TABLE 1 BALANCES WEIGHING TO 0.001g

(a) Single range

Manufacturer/ model	**Price**	**Range & recovery of sensitivity**	**Mains /batt?**	**Comput. output.**	**Lead**	**Software**	**Comments**
Mettler PM100	£803	100g	M	R & CL	£25	none	(Z), Acal; Cap.in.
Sartorius H120	£788	120g	M	£132	----£88----		(Z), Ical; Ds
Ohaus G120	£850	120g	M	R	----£52----		Acal; Ds
Mettler PE160	£945	160g	M	-----£95----		none	Z, Acal; Ds
Oertling NB33	£846	300g	M	£63	----£34----		(Z), Ical; Gds

(b) Dual range or floating range balances weighing to 0.001g
(The capacity of the less sensitive range, 0.01g, is shown first in column 3).

Salter FX-320	£895	300/60g SR	BE	-----£75----		none	(Z), Acal; Ptco; Ds
Precisa 300MC	£895	300g + floating 80g	M	R	----£25----		Cap.In; Acal
Mettler PE360	£845	300g + floating 60g	M	-----£95----		none	Z, Acal; Ds
Ainsworth AS-300D	£600	300/30g	M	R	--none avail.-		(Z), Acal.
Ohaus G400D	£850	400/40g not SR	M	R	----£52----		Acal; Ptco; Ds
Mettler PM460	£945	410g + floating 60g	M	R & CL	£25	none	(Z), Acal; Ptco; Cap.in; Ds.
Ainsworth AC400D	£864	400/40g SR	M	R	--none avail.-		(Z), Acal; Ptco; Ds
Sartorius L420P+	£1013	"Polyrange" 0 - 80 X 0.001g 80 - 160 X 0.002g 160 - 424 X 0.005g	BE	R	----£88----		(Z), Acal; Ptco; Ds
Oertling RB153	£833	1500/150g SR	M	BCD	----£34----		(Z), Pcal; Ds.

* *

TABLE 2 BALANCES WEIGHING TO 0.01g

(a) Single range

Manufacturer/ model	Price	Range & recovery of sensitivity	Mains /batt?	Comput. output.	Lead	Software	Comments
Whatman 100	£395	100g	B	------none------			Loadcell, Pcal
Bosch PE631	£958	200g	M	£113	---£35----		Z, Acal.
Cobos C-300	£563	300g	M	----£116----		none	Pcal.
Mettler PE300	£675	300g	M	-----£95----		none	Z, Acal; Cap.in.
Precisa 600C	£747	600g	M	£82	----£25----		Z, Acal
Ohaus G400	£745	400g	M	R	----£52----		Acal; Ptco.
Ohaus G1200	£808	1200g	M	R	----£52----		Acal; Ptco.
Oertling OB152	£616	1500g	M	R & BCD	----£34----		(Z), Pcal
Precisa 1600CE	£695	1600g	M	R	----£25----		Z,Acal; Cap.in.
Mettler PE1600	£945	1600g	M	-----£95----		none	Z, Acal.
Mettler PM2000	£1069	2100g	M	R & CL	£25	none	(Z),Acal; Ptco; Cap.in,

(b) Dual range or floating range balances weighing to 0.01g
(The capacity of the less sensitive range, 0.1g, is shown first in column 3)

Manufacturer/ model	Price	Range & recovery of sensitivity	Mains /batt?	Comput. output.	Lead	Software	Comments
Ohaus G1500D	£689	1500/150g **not SR**	M	R	----£52----		Acal, Ptco.
Sartorius L2200P	£805	"polyrange" 0 - 400 X 0.01g 400 - 800 X 0.02g 800 - 2200 X 0.05g	BE	£132	----£88----		(Z), Acal.
Ainsworth AC 3KD	£675	3000/300g SR	M	R	none	none	(Z), Acal; Ptco
Gravitron HD05/5	£711	3000/300g Range changed manually	M	----£150----		none	Pcal.
Salter FX-3200	£895	3200/600g SR	BE	----£75----		none	(Z), Acal; Ptco.

cont.

TABLE 2 (b) continued

Manufacturer/ model	Price	Range & recovery of sensitivity	Mains /batt?	Comput. output.	Lead	Software	Comments
Mettler PE3600	£895	3600 + floating 600g	M	----£95----		none	Z, Acal.
Ohaus G4000D	£807	4000/400g not SR	M	R	---£52		Acal; Ptco.
Mettler PM4600	£945	4100g+ floating 600g	M	R & CL	£25	none	(Z),Acal; Ptco;Cap.in.
Sartorius U4600P	£1007	"polyrange" 0 - 600 X 0.01g 600 - 1200 X 0.02g 1200 - 4600 X 0.05g	M	£132	----£88---		(Z), Acal; built-in software for check weighing. Control pad can be disabled
Oertling RC52	£786	5000/500g	M	BCD	----£34---		(Z), Pcal.
Sartorius U5000D (similar to older 1413)	£1265	5050/500 not SR	BE	R	----£88--- as for U4600P.		Acal,(Z), Control pad

* *

TABLE 3 BALANCES WEIGHING TO 0.1g

Manufacturer/ model	Price	Range	Mains /batt?	Comput. output.	Lead	Software	Comments
Cherlyn B1000	£149	100g (& 1000 to 1g)	M				Is a sensor without a read-out of its own. Only used with BBC micro. Z, Acal.
Whatman 2000	£435	200g (& 2000 to 1g)	B/BE	---none available--			L, Pcal.
Ravencourt Bonso 838	£165	500g	B	---none available---			L, Difficult to recalibrate.
Salter EW300B	£299	300g	BE	----£110----		none	L, Z; Pcal.
Murikami LF-600	£319	600g	M	not fitted see 600R below			L,(Z),Pcal; Ptco.
Murikami LF-600(R)	£386	600g	M	R	included	none	L,(Z),Pcal; Ptco.
Ohaus C501	£315	500g	B/BE	R	---£29----		L,Pcal;Ptco. A std. brass mass supplied.
Sartorius 1002MP9	£251	500g	B/BE	---none available----			L, Pcal; Ptco.
Whatman 800	£425	800g	B/BE	---none available----			L, Pcal.
Mettler PE3000	£595	3000g	M	-----£95----		none	Z, Acal.
Sartorius U3600	£689	3640g	M	£132	----£88---		(Z), Acal.
Ohaus G4000	£689	4000g	M	R	----£52----		Acal; Ptco.
Oertling OC51	£568	5000g	M	BCD	----£34----		(Z), Pcal, software gives plot gradient
Mettler PE6000	£695	6000g	M	-----£95----		none	Z,Acal.
Mettler PM4000	£1295	4100g	M	R & CL	£25	none	(Z),Acal;Ptco;Cap.In.
Cobos D-6000	£690	6000g	M	----£116----		none	Pcal; Cap.in.

TABLE 4 BALANCES WEIGHING TO 1g

Manufacturer/ model	Price	Ranges	Mains /batt?	Comput. output.	Lead	Software	Comments
Ohaus Lume-O-gram (D1001C)	£45	1000g (64g by 1g) (>64 by 2g)	B/BE	--none available--			L,no cal.
Salter TFE-501	£186	1030g 500g by 1g >500g by 2g	B/BE	--none available--			L, no cal.
Ravencourt 978A ('Labscale')	£54.80	2000g	B/BE	--none available--			L, no cal,
Ainsworth DS2000	£170	2000g	B/BE	--none available --			L, Pcal.
Ohaus C3001	£315	3000g	B/BE	R	----£52-----		L,Pcal.
Sartorius 1006MP9	£251	5000g	B/BE	--none available --			L,Pcal;Ptco.
Murikami LF-6000	£319	6000g	M	not fitted see next model			(Z), L, Pcal; Ptco.
Murikami LF-6000R	£386	6000g	M	R	included	none	(Z), L,Pcal; Ptco.

* *

TABLE 5 Other Miscellaneous balances

Manufacturer/ model	Price	Ranges	Mains /batt?	Comput. output.	Lead	Software	Comments
Avery Nutritional	£32	5000g by 5g	B	--none available--			L,incl. timer & calorie calculator.
Ohaus D2001C Lume-O-Gram	£45	2000g 128g by 2g 128 - 2000g by 5g	B/BE	--none available--			L, no cal.

Balances weighing to 0.1mg are not absolutely necessary for work in schools and are usually very expensive. However one reasonably priced example is:

Manufacturer/ model	Price	Ranges	Mains /batt?	Comput. output.	Lead	Software	Comments
Precisa 120A	£995	120g to 0.1mg	M	CL(£80)	---£25---		Acal;Ptco; Cap.in;Gds.

* *

Test reports

Full test reports are available only to Scottish schools and colleges in current membership of SSSERC. Please apply to the Director of the Centre.

Test procedures

In our test and evaluation programme performance, ease of use and safety are examined. For each model the test procedure covers fourteen such aspects. These are fully described in a SSSERC paper, available from the Centre [our reference "BALTP"]. However for the convenience of readers the major points are summarised below. Note that the section numbers correspond with those used for test reports. The opportunity is also taken to explain or comment on technical aspects or features affecting usage.

1. Reproducibility

The same object is weighed 50 times and the standard deviation calculated. If there is more than one range with different sensitivities, the test is repeated for each range.

2. Cyclical weighing errors

After calibration the balance is gradually loaded up with standard masses and then unloaded again. At each stage the read-out is recorded. The cycle is repeated four times. The test reveals any inaccuracy, non-linearity or fatigue.

3. Capacity

4. Speed of operation

This is measured with the balance both in its fastest and slowest weighing modes. The method of changing the integration time is noted.

5. Drift. (in read-out)

The balance is switched on for half an hour in a cold room with readings noted every 5 minutes. It is then transferred to another room at normal working temperatures. Should the read-out not settle in that time the drift test is continued as necessary.

6. Tilting

The balance is tilted by 1° in each of the four axial directions. Each time it is zeroed and the read-out then noted with a standard mass placed on the pan.

7. Off-centre loading

With a 100g mass in the centre and then in each of the other four 'cardinal' points any differences in read-out are noted.

8. Effects of voltage variation

The supply voltage is varied between +/- 10% of 240V. Any differences in read-out or in brightness of display are noted.

9. Effects of a strong magnet

An 'Eclipse Major' magnet is placed successively on each of four sides of the pan and any effect on the read-out noted.

10. Ease of reading

The size of the display and its type are noted. The distance from which the display can be read is subjectively assessed, taking into account the size of the window and its slope.

(An unsteady read-out may cause difficulties for pupils. On some models a symbol, often a 'g' is displayed when the balance has reached stability).

11. Ease of use

Comments under this heading are necessarily subjective and are based on knowledge of likely procedures followed by:

-a pupil in weighing (i.e. switching on, taring, changing ranges,) and

-by a teacher or technician in 'setting up' the balance, (i.e. calibration, choice of integration time, of units and mode. Some balances can be made to read in kg instead of g. In others the last digit can be blanked out.

Optional functions on balances intended for a wider market may be a nuisance. Pupils tend to fiddle with controls or software selecting other modes. It should be difficult for a pupil to make such changes, either deliberately or unwittingly. Luckily some balances allow 'locking-in' of chosen settings or the disabling of reset functions.

Other factors affecting usage include:

auto-ranging

Most dual range balances auto-range when being loaded up, but few do so as the mass decreases. For example, as soon as a mass of >30g is placed on a 300/30 X 0.01/0.001g balance, the sensitivity will automatically drop to 0.01g for the rest of the range. If the mass is now reduced, the higher sensitivity of 0.001g is not restored unless the material is temporarily removed and the balance tared.

Floating point, 'Delta' and 'Poly' facilities

These are features best explained by considering the example above. Once 31g has been placed on the pan, the read-out will be to 0.01g. However, taring the balance restores a reading to 0.001g for the next 30g. If desired this process can be repeated up to the top of the range, a useful facility for accurately weighing chemicals into a large glass vessel. Polyrange balances differ, in having three or more ranges of sensitivity instead of two.

zero-tracking.

With this facility activated a tared balance automatically compensates for any small and slow drift away from zero. The stability is thus apparently improved. The balance does not compensate for faster changes and it will record the 'true' change. Clearly this facility could be a nuisance when following slow weight changes, e.g. the loss of water from a plant. One manufacturer stated that this process only operated on the last three divisions from zero and only for changes of <1 division per second, that is on a 10 mg balance, when the read-out is less than 0.03 g and when it is changing more slowly than 0.01 gs . The corresponding figures for a 1 mg balance would be 0.003 & 0.001 gs respectively. It is often possible to disable this facility, but not every manufacturer tells you how to do this. He may not even tell you if zero tracking is fitted.

stability range control

On many balances a special symbol(e.g. a 'g') is a stability indicator. It appears when the signal from the balance is changing less than a preset number of digits. This indicates when to take the reading. On many models there are fixed limits of fluctuation on the stability indicator. On some newer models these limits can be set by the user. If, for example, the limit were set to 8 digits, the 'g' symbol would disappear for even the smallest fluctuation. If set to a high value the symbol would almost never disappear. This facility is of greatest value when logging transient data on a computer. Otherwise it is best left unused.

12. Calibration

Two major types of method are used by manufacturers:

internal preset

Older balances are usually calibrated by placing a standard mass on the pan and then adjusting an internal preset potentiometer until the read-out corresponds with the value of the mass. This preset is usually accessed through a small hole in the casing.

autocalibration

Many of the current models have a procedure putting the balance into an autocalibration mode. This procedure is enabled either by holding down the tare button for a long time or pressing a normally inaccessible micro-switch. Once in this mode the built-in software waits for a standard mass to be placed on the pan. The required value may actually be displayed. Some balances are 'intelligent' refusing any other size of mass and returning to the previous calibration. Some are sufficiently clever to place limits on an unexpected mass and calibrate on that. Others are 'simple minded' and accept any mass placed on the pan. These gullible balances may be fooled into calibration with an error factor of 0.5 or 2.

A few balances even have a built in standard mass, loaded by an internal servo motor.

In autocalibration an accurate standard is needed. Calibration is not a frequent operation and, though apparently more cumbersome, calibration by preset has advantages. With a secondary standard known to be say 99.991 g the read-out can be made to coincide exactly with that figure. A balance with autocalibration will accept as exact a nominal mass. All subsequent readings will be in error.

Standard calibration masses, especially if certificated and boxed, are expensive, £50 to £100 being typical prices. If an EA does not operate a contract service for electronic balances then several appropriate calibration masses may be needed. Balances calibrated with a preset control need a single standard mass, ideally one at least half of the balance capacity. A less expensive set of secondary or even tertiary standards for calibration by preset can then be made up.

If necessary, recalibration can be easily done for balances with a preset control. A secondary standard is put on the pan and the preset adjusted to give the original read-out. Balances with auto-calibration cannot be adjusted, but they can be checked.

13. Outputs

Many models have RS232 or BCD outputs fitted as standard. Some older models also had analogue outputs. For school use, the serial RS232 output is the preferred type. Where its provision is optional, the extra cost is usually less than £100. Later fitting is eased by those designs with an internal connection for the interface board, and a sized hole in the casing for the output socket. (This hole may have a removeable blanking plate).

14. General construction and electrical safety

Casing, switches, sockets, and outputs are all checked for general security, robustness and resistance to entry of spilt liquids, pins or paper clips. Input sockets, fuse holder and wiring, and general design are all examined against our in-house safety standards. Where possible the action of the mechanism is noted and comment made on how robust it appears. After checking with the manufacturer, and unless advised otherwise, a high voltage, insulation and earth (HVIE) test is applied to all exposed metal parts.

Test reports end with a short summary, including a statement on suitability for pupil use. Attention is drawn to any special features of design and to particularly good or poor aspects of the performance.

Servicing and maintenance

As indicated in our balance repair guide, an annual service contract for electronic balances is not worthwhile. There are few moving parts and the circuitry should be as reliable as any other modern, electronic equipment.

Recalibration can be easily carried out in school. (See above for comment on standard masses and secondary standards). This area is one potential advantage of an EA making a bulk purchase of a single make of balance.

The manufacturer's engineer will usually carry out a calibration during installation. Immediately afterwards, the secondary standard should be prepared the chosen mass being put on the pan and the read-out recorded. If the figures are safely archived the calibration may be checked at any future date. (See Section 12 above).

Electrical safety checks

Like other equipment operating at more than 50 V, balances should be routinely tested in accordance with guidance issued by the Health and Safety Executive (HSE Guidance Note GS23). The manufacturer should be consulted before first carrying out an HVIE test on any scale pan.

The test equipment applies a large current, usually at least 10 A. This may overheat thin metal hinges on the balance mechanism. If doubt remains, open the case carefully and apply the test current at the chassis end of the hinges, (point A in Fig.3). Switch off and disconnect the tester probe. Then with a multimeter check for continuity between the scale pan or its support pillar (point B in Fig. 3) and the chassis.

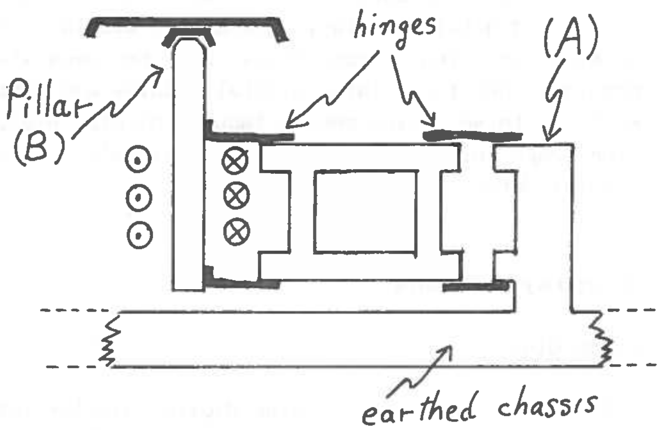

Fig.3 Test points "A" & "B"

* *

Interfacing software for electronic balances

A review

Introduction

Software packages for interfacing four popular makes of balance to the BBC micro' were examined. However only three are reported on here because the fourth package gave much trouble. It never worked properly despite several visits from the representative and receiving new disks. The source of that package must remain anonymous. We include the wee anecdote to make you wary. By now, most teachers need no reminding that not every piece of software is reliable, even where money changes hands.

Sources and prices

We report here on:

(a) the 'Oertling Balance Monitor';

(b) the 'Ohaus Electronic Balance Programs' and

(c) the 'Precisa Program for BBC-B micro-computer'.

These are reasonably priced at £34, £52 and £25 for disk based software and connector.

Operational basis

Those familiar with the ordinary 'Beeb' will know of the problems of memory restriction. These are particularly acute when graphics are needed in higher resolution modes. Software will either all be held in memory or also accessed from disk.

Memory based packages

The Ohaus and Precisa software is of this type. All the routines are loaded into the computer from disk. The disk is not accessed further except to save away data. Because of resulting memory restrictions the programs are relatively unsophisticated. The looked for advantage of memory based routines is an increase in speed of operation.

Disk driven packages

The Oertling package is of this pattern. Here the computer loads in routines for logging or displaying as and when required. This leaves a lot more free memory at any one time. The package thus offers a larger choice of more sophisticated utilities. The Data Disc from Philip Harris reviewed in Bulletin 154 operates in this way. The trade off is the slower operation of some, but by no means all, routines.

Comparative review

Overall verdict

For readers in a hurry we may as well get the important bit over. Any of the three packages are useful if you already possess the appropriate balance. However, in our view, the Oertling package is significantly better than the other two. The features of the Oertling are summarised below, providing a core for the review. Where the Ohaus and Precisa packages differ significantly from that pattern this is indicated.

The suppliers are aware of shortcomings in their software. It is likely that packages will be amended and improved. Further information will then be available from the Centre.

Operator choices

The Oertling software program is menu as well as disk driven. It has an **icon menu.** The choice of activity, i.e. logging, or loading and examining sets of data from disk is made by cycling through images in boxes. This is done using the space bar to move to the desired activity and by pressing the return key which enters whatever the picture represents as an activity.

The Precisa program has a simple three choice menu - digital display, graphical display or termination. That from Ohaus has two separate programs- OH2 for a large digital display and OH1 with a three choice menu - tabular display plot, line graph plot, and loading previously saved tabular data.

Display options

Large digits

All three possess a large digital display for use in demonstrations. However the Oertling version has a smoother, more rounded digital read-out. This can be frozen momentarily by pressing the tare pad on the balance. The readings may also be logged for later examination. This is not so with the other two packages.

Lists of readings

The Oertling package can produce such lists of (see Fig.1). This may be scrolled up and down by pressing 'U' and 'D', saved, or printed ('D').

The Ohaus package will accept 30 readings with the mean and standard deviation printed at the foot.

TIME (seconds)	WEIGHT (grammes)	
0	+0017.25	
1	+0016.97	
2	+0015.48	
3	+0012.62	U-up
4	+0010.64	
5	+0006.16	
6	-0001.56	D-down
7	-0005.82	
8	-0011.23	
9	-0015.01	
10	-0021.62	
11	-0026.57	P-print
12	-0034.48	
13	-0038.44	
14	-0041.28	X-exit

Experiment : LA

Fig.1 Oertling tabular display

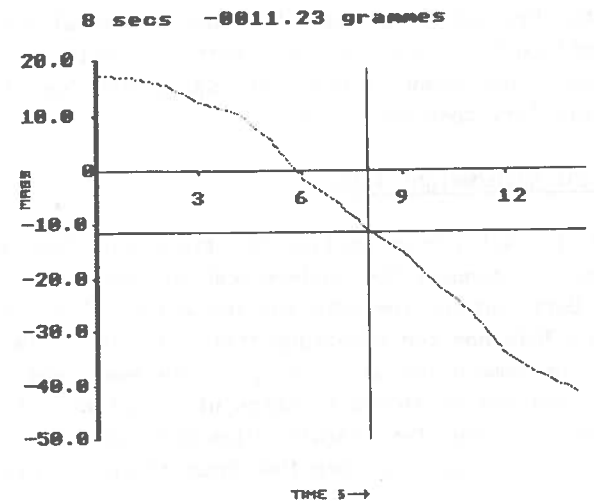

Fig.2 Oertling plot, scaling, 'crosswires'

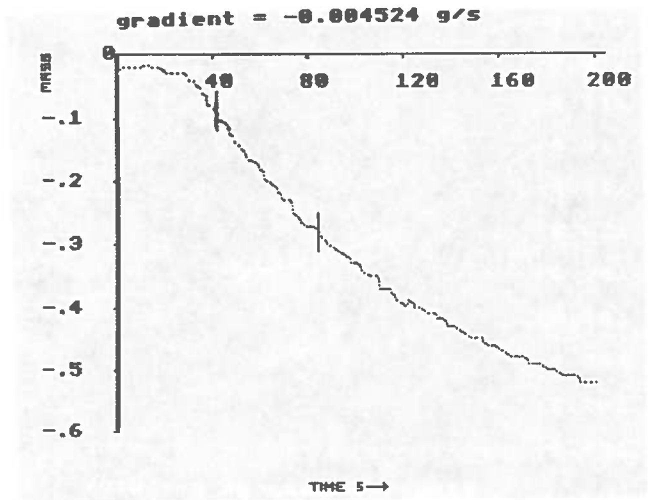

Fig.3 Oertling plot, scaling and cursors

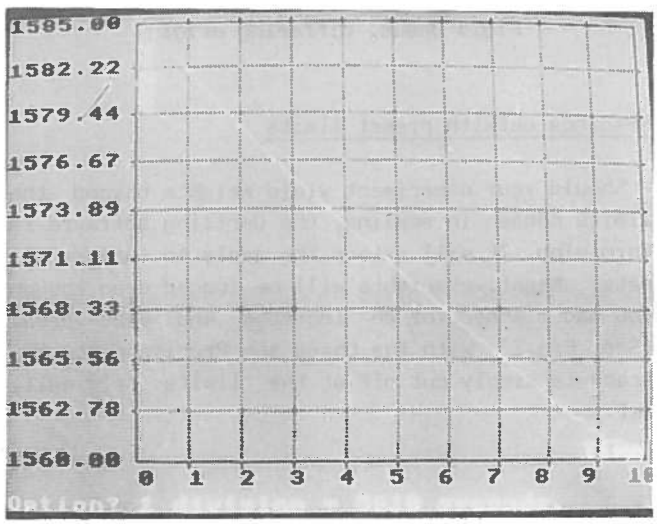

Fig.4 Silly scaling

Graphing

All three packages will plot graphs from logged data. However there are significant differences in the range of plots offered.

Scaling

With the Oertling software the scaling on the vertical axis is always sensible. That is, with intervals of either 0.1 or 0.01g between divisions. (Figs 2 and 3.)

This is not necessarily the case for the Precisa (see Fig. 4) and Ohaus graphing. There only fortuitous entry of an evenly divisible range will give sensible scaling.

On replay the Oertling vertical axis will always be automatically rescaled to best advantage. Suppose, for example, that on setting up the scaling before the experiment you mistakenly thought the weight loss would be about 20 g and it turned out to be, say, 0.1 g. The plot should be close to a horizontal line taking up only one two-hundredth of the vertical axis. With Oertling rescaling, on replay the vertical scale will be automatically expanded and a line of appreciable slope displayed.

The Precisa graphs may be rescaled manually by resetting the limits on the vertical axis. The Ohaus line graph cannot be saved and thus the possibility does not arise.

Weight gain/weight loss

Whilst setting up scaling the Ohaus and Precisa programs request the maximum and minimum weights. The Oertling routine asks for the weight loss or gain. This has the advantage that all 'runs' start at the same point on the graph. This makes easier the relation of slopes to rates of reaction, for example those for marble chips and hydrochloric acid. (For comparison see the Ohaus traces in Fig. 5).

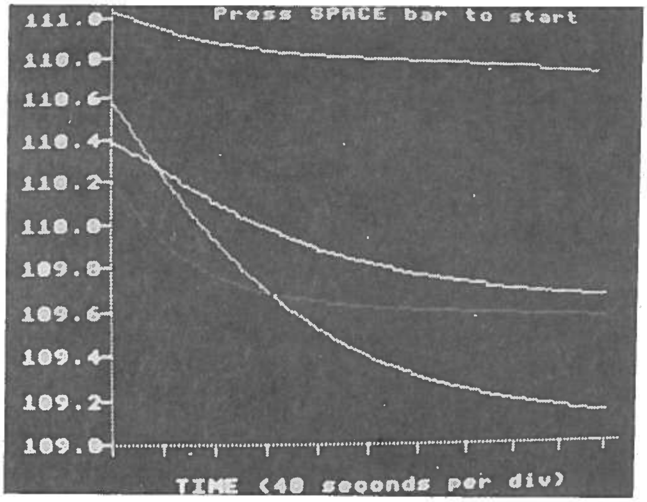

Fig.5 Ohaus, differing origins

Readings outwith preset limits

Should your experiment yield weights beyond the limits chosen in scaling, the Oertling software is forgiving. It will extend the scale to include all data. Negative weights will be logged even though you had planned for an increase and vice-versa. (See Fig.2) With the Ohaus and Precisa plots the trace is simply cut off at the limits originally set.

Looking at data

With Oertling software, all data, regardless of the first chosen display mode or format saved, can be examined in all the other possible ways:

- as a list of readings;
- bar graph suitably rescaled;
- statistical results with mean, standard deviation, linear correlation coefficient and the equation of the line of best fit;
- simple line graphs (as for Ohaus & Precisa);
- line graph with moveable crosswires;
- line graph with a pair of cursors, moveable left or right.

The crosswires show up more clearly on a colour monitor. The blue lines are then more distinct from the yellow axes (Fig. 2). The co-ordinates of the chosen point are displayed at the top of the graph.

In order to facilitate the reading of co-ordinates, at replay the Precisa program allows a grid to be superimposed on a previously saved graph.

The gradient between positioned cursors is displayed at the top (Fig 6).Note that figures 3 and 6, with gradients of ca. -0.0045 and -0.00895 gs^{-1}, both show weight loss in reactions of marble chips with molar and 2 molar hydrochloric acid respectively.

Data saved as a bar chart with the Ohaus package can be displayed in tabular form and vice-versa, but neither can be displayed as a line graph.

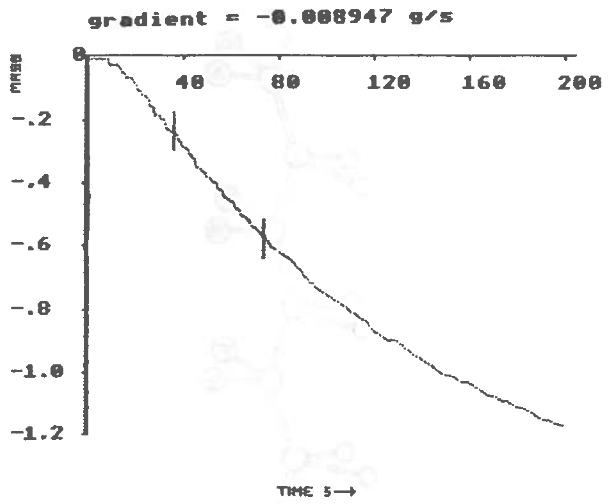

Fig.6 - gradient, rate of reaction marble chips and 2M HCl

Period of logging

The Oertling package will permit the logging of data for a longer maximum period. Its maximum is approximately 10 days compared with 2 to 3 days for the other two.

Handling files

<u>Listing, deleting</u>

Previously saved Oertling files can be listed within the program, or erased, using two of the user defined function keys. With the Ohaus and Precisa software it is necessary to go into BASIC and use the '*C.' and '*DELETE'name of file' operating system commands. The balance software has then to be reloaded.

<u>Protecting files</u>

The Oertling operating files are protected by locking. This is strangely not the case with the Precisa package and only in the instruction book is warning given about accidentally erasing them.

Features in common

Good features shared by all three packages include:

- the use of three different colours for the first three traces;

- on loading and during some processing stages the user is not looking at a blank screen. A row of disappearing dots gives an indication of the time left before control is returned to the operator.

Oertling's weaker points

There are two points on which the Oertling software scores less well.

(i) Only two extra graphs can be superimposed on the first as compared with a very large number of traces for Ohaus and Precisa.

(ii) It is a slightly more cumbersome process to superimpose a second or third trace on the first. It is necessary to go back to the icon menu and redraw the scalings on the axes. This is not too arduous because there are default values. With the Ohaus and the Precisa software a single key will initate the plotting of the next trace. However the Oertling package will again automatically rescale to make that trace with the biggest change in weight, cover all of the vertical axis.

'VELA' and balances

An additional opportunity exists for those with a 'VELA' gathering dust in a cupboard. An optional Oertling program and connector will sensibly allow long term logging without tying up a Beeb. You can also get some results even when others are hogging the computer, word processing those dreaded worksheets. Logged data can later be downloaded, displayed, graphed and saved to disk.

* * * * * *

Kynar Piezo Film

- a novel transducer

Abstract

Kynar Piezo Film is a new material which can be used for many types of transducer. Its piezoelectric property will convert a mechanical force into an electrical signal. If placed between two colliding bodies the transient signal it generates can be put into a fast data recorder to give a force-time plot.

The film has a second electrical property, pyroelectricity, which is the generation of charge in reaction to a change in temperature. This property can be used to detect long wave infra red radiation.

General account

Kynar Film is a thin polymeric material which is pliant, flexible, tough and lightweight. Normally, it is metallised on its top and bottom surfaces, so that it has capacitance. It can be connected to other components or to an oscilloscope by attaching leads direct to these top and bottom electrodes.

Kynar Film is made from polyvinylidene fluoride; it is sometimes referred to as 'PVDF Film'. PVDF is a semi-crystalline polymer consisting of very long molecules which are a series of (CH_2 - CF_2) structures. In manufacture the film is stretched to polarise some of these molecules, giving pairs of hydrogen atoms down one side of the chain and pairs of fluorine atoms down the other side (Fig.1). Therefore when the film is in use any stress applied will affect the polarisation. Because of the way it is produced the film is poled; that is the sign of the electrical output is determined by the polarity of the applied stress.

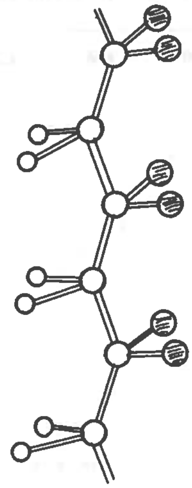

Fig.1 - Molecular structure of PVDF

Electrical Properties

If the film is stressed a voltage is generated which is directly proportional to the applied stress (Fig.2). Stress is defined as the applied force divided by the area of contact between the two bodies. The film is stressed by bending, stretching or squashing. This effect is the **generator action** of piezoelectricity.

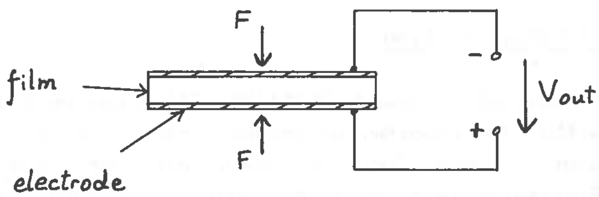

Fig.2 - Generator action

Conversely, if a voltage is applied we get the **motor action:** the film will elongate or contract depending on the polarity of the applied voltage (Fig.3).

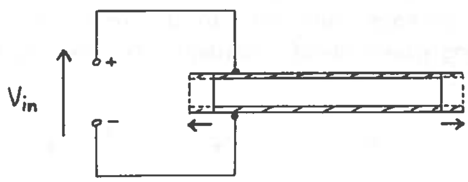

Fig.3 - Motor action

When the film is taped in an arched posture to a rigid surface both effects can be demonstrated: if the leads are taken to an oscilloscope the transducer acts like a microphone; if the leads are taken to a signal generator it acts like a loudspeaker.

The pyroelectric effect can be observed if the film is mounted flat on a bench and taped down such that it cannot flex and so generate piezoelectricity. If the leads are taken to an oscilloscope which is set to its maximum sensitivity then breathing on the film will warm it up and generate an output (Fig.4).

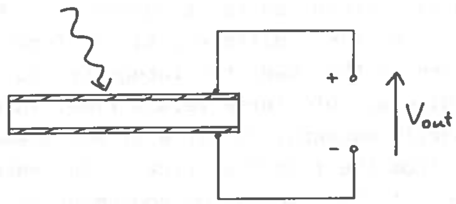

Fig.4 - Pyroelectric action

Connecting leads

Wire should not be soldered directly to the electrodes of the film, but should be soldered to an intermediary conducting pad such as a piece of copper foil which has a conductive adhesive backing. Once the solder joints are secure the pads should then be fastened to the electrodes of the film (Fig.5).

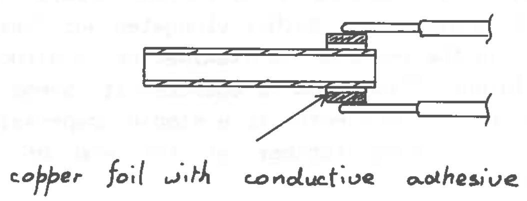

Fig.5 - Attachment of leads

A suitable type of copper foil is the 3M metal foil electrical tape, type 1181, which is available from R W Greeff. But since a whole reel is expensive, small bits of copper foil can be obtained from SSSERC.

Kynar Film can be fixed to a surface with either electrical tape or Sellotape. The film is pliable and can be fastened to cylindrical, as well as flat, surfaces.

Screened film

A small tab of unscreened film, about the area of a fingernail, costs around 50 pence. Larger areas of the film can be purchased in sheet form, and cut with a pair of sharp scissors or a sharp knife to any required shape or size, taking care that any swarf does not short the electrodes together.

An electrically screened version of the film is easier to work with as the screening prevents any capacitive pick-up. The manufacturers supply such a version, in one size only. It has a coaxial lead attached to the film: the top electrode to the signal line; the bottom electrode to the screen. To achieve screening the top electrode is covered by an electrically insulated layer, which itself is coated with a conducting ink that makes electrical connection to the bottom electrode (Fig.6). The film is thus within a Faraday cage and is isolated from stray signals.

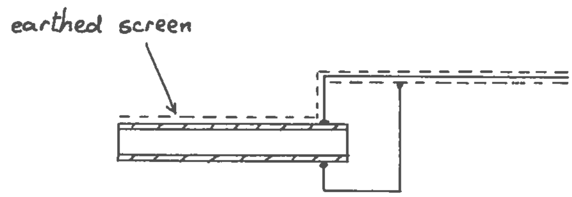

Fig.6 - Screened film

The screened film is protected from mechanical damage by being encased within a polythene envelope; its greater robustness than naked film is a further recommendation.

Caution - risk of electrical damage

The user should beware of applying too large a stress such as by jabbing the film with a point or edge. Such an action may generate a transient pulse of many kilovolts, which may damage electronic monitoring apparatus connected to the film.

Where to obtain Kynar Film

Kynar Film is made by the Pennwalt Corporation of Pennsylvania; this firm has a division in Europe called Syrinx Innovations Ltd. The film, together with certain specialised items required with its use, may be obtained through SSSERC. Please see Surplus Equipment for details.

Pennwalt have produced a Technical Manual [1] which describes the properties of the film; this Manual may be obtained from Syrinx. The Manual should be consulted for technical specifications, but does not give a detailed explanation of how to use the film so as to get meaningful results. Teachers are not recommended to buy it unless they wish to use the film in a theoretical, as well as an empirical, manner.

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Force-time plots and measurement of impulse

Introduction

"The wicket didn't do much, and
when it did it did too much"

Six o'Clock News, BBC 1

The force-time transient exerted on a ball as it hits a surface can be investigated by letting the ball drop on Kynar Piezo Film. The technique was described by Karlow [2] in the 'Physics Teacher'; although his method led to a graph of dF/dt-t, that is the time differential of force versus time, which he then had to integrate to get a direct display of force versus time. This seems unnecessarily awkward. To get a direct measurement of force from the film the trick is to match the impedance of the measuring equipment to that of the film.

Mechanical set-up

There are several ways of mounting the film in this kind of investigation: (1) by taping the film to a bench and dropping the ball directly on it; (2) by inserting a layer of foam between the film and the bench; and (3) by mounting the film on the bench and placing foam on top.

Each has its own merits. The piezoelectric signal is simpler to interpret in (1) and (3) because only one mode of distortion occurs - the film is squashed, it neither elongates nor flexes. But (2) is the one that is examined here; although the film both flexes and is squeezed it seems to behave as if subjected to a simple compression. This is discussed further at the end of the article.

Another reason for using foam to cushion the impulse is that it simplifies the mechanics of the experiment - it is possible to match the type of foam to the type of ball so that there is no rebound. One foam which has this property is 'Sensifoam', which is made by the Creative Foam Corporation. The specification is ¼ inch thick

Sensifoam, type 3693; SSSERC has a stock for resale. The two types of ball which we find do not bounce on Sensifoam are cricket balls and steel ball bearings. For crude mechanical reasons either type will do, but for aesthetic reasons it has to be the cricket ball - which is worth any number of ball bearings.

Analysis of electrical circuit

On impact a voltage corresponding to the force is generated across the electrodes of the film. This voltage is measured by applying it to an inverting amplifier with a very high input impedance (Fig.1) and a gain of x(-1), so that the feedback and input resistors have the same resistance. The output voltage from the amplifier is then measured by conventional fast-data-capture means.

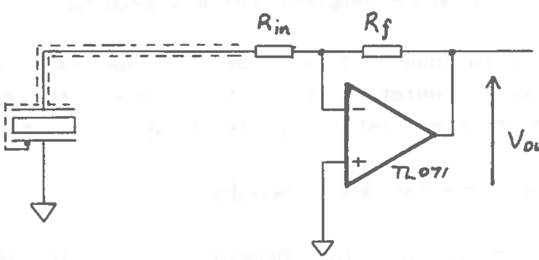

Fig.1 - Circuit to detect piezo voltage

The input impedance of this amplifier is one gigohm. To appreciate why it should be as large as this it is necessary to consider the equivalent circuit of the system. Piezoelectric components are not easy to model; they have capacitance, but also behave like generators. The input resistor of the amplifier is effectively the load connected across the film since the inverting input of the op amp is held at ground potential. But the input resistor is not the actual load across the piezo generator because the capacitance of the film must also be accounted. So it would seem that a simple model which appears to explain what happens is that of a voltage source with a capacitor and resistor connected in series across it (Fig.2). The capacitor has the capacitance of the film, which is 6 nanofarads; the resistor has the resistance of the input resistor of the amplifier, which is 1 gigohm.

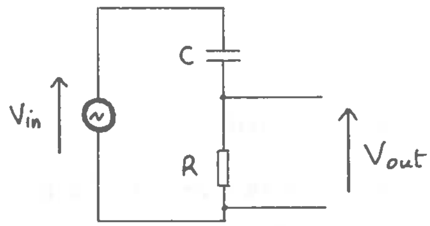

Fig.2 - Equivalent circuit

The equivalent circuit is a high-pass RC filter. The frequency response of such a filter is shown in Figure 3; the frequency which attenuates by 3 dB is f = 1/2πRC.

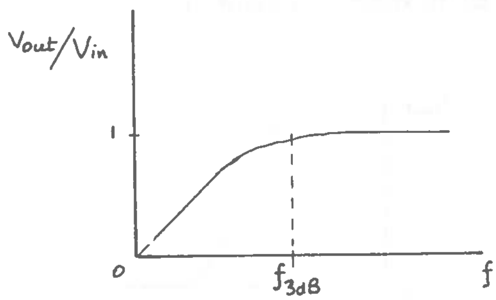

Fig.3 - High-pass filter frequency response

As a rule of thumb it is better to avoid working within two decades of the 3 dB frequency. This RC circuit has two working regions with entirely different properties, and a confusing region in between.

The capacitance of the RC filter is fixed, as it is a property of the film. Therefore the value of R has to be selected so that the 3 dB frequency of the filter is at least 100 times lower than the frequency of the impulse signal, V_{in}.

If the period of impact is around 2 to 20 ms, the frequency of the main component of the impulse signal will range between 25 to 250 Hz, which should be expanded at least tenfold to include some of the harmonics. The 3 dB filter frequency should therefore be around 25 mHz, three decades down on the input frequency.

The input resistance is calculated thus (C for the film is 6 nF):

$$R = 1/(2\pi fC)$$

$$R = 1/(2\pi \times 25 \times 10^{-3} \times 6 \times 10^{-9})$$

$$R = 10^{9}\ \Omega$$

So the value of R should be around one gigohm, of which SSSERC has a stock for resale because this value is not readily obtainable in small quantity.

The performance of the circuit seems to agree with this analysis. The general response for R = 1 GΩ is shown in Figure 4.

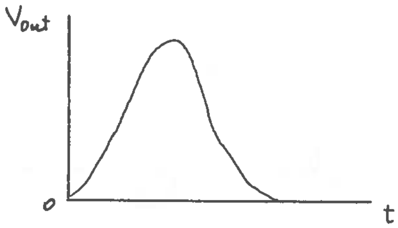

Fig.4 - Response for R = 1 GΩ

The value of R used by Karlow was 100 kΩ, which gives a 3 dB frequency for the RC load of around 250 Hz. Therefore for the range of input frequencies being used the RC load would act as a differentiater, which explains why his output signal corresponded to dF/dt versus time (Fig.5).

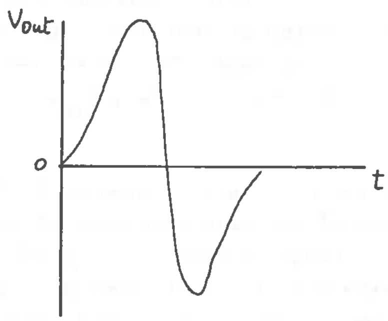

Fig.5 - Response for R = 100 kΩ

If the piezo film is connected directly to an A to D converter, without an intermediary amplifier as a load, then the response is a function of the input impedance of the A to D circuitry. This will typically be around one to ten megohm. The RC load will therefore have a compound effect: it will act as a poor high-pass filter, but also perform a partial differentiation. The response will be a lop-sided curve (Fig.6).

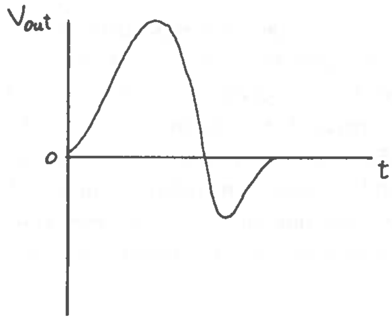

Fig.6 - Response for R = 1-10 MΩ

These various effects can all be seen with different resistors connected across the film. These are the first order effects of the system.

A water-bucket model

For explaining the generation of piezo-elec tricity I will use an analogy. Suppose our model is a bucket of water with porous walls and an impermeable outer skin (Fig.7).

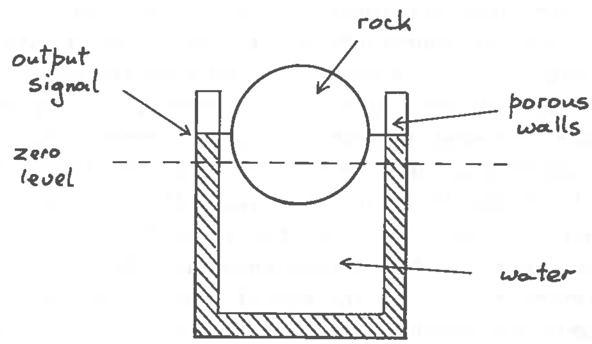

Fig.7 - Water-bucket model

The water molecules represent electric charge, or electrons. There is a scale on the side of the bucket which indicates the height of the water level - this is equivalent to the voltage output, V_{out}. When the water is settled and at rest, the level represents V_{out} being equal to zero volts.

Suppose we now dunk a large rock into and out of the water - the level rises and falls in correspondence to the first order effect of the system, the transient voltage signal observed. But because the walls are porous some of the water has been trapped temporarily within them; thus at the end of the transient impulse the water level has an offset. This represents electrons which have left the Kynar film during the impulse, thereby giving the film, which after all is a capacitor, a residual charge.

In the model, water slowly seeps out of the walls back into the bucket, restoring the level to normal. This is the residual charge on the film decaying with a time constant of RC, which for our value of components is 6 s. The larger the value of R, the less porous are the walls, and the less pronounced is the offset after the primary effect is over.

Second order effects

There are various other second order effects, which will now be described. The transient signal which is obtained as a result of applying stress to the film often has a small offset component after the main peak has passed (Fig.8). This is a compound effect. One cause, which will be systematic in occurrence, is the weight of the ball, which exerts a static stress once the ball has come to rest. This will produce a small positive offset.

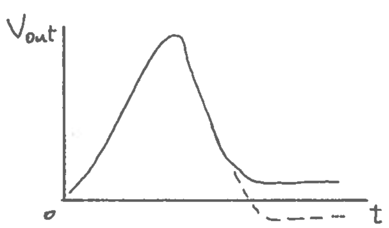

Fig.8 - Offset after the peak

A second effect, which is random in occurrence, is due to the manner in which the ball comes to rest. If the foam is not given time to relax between drops then a depression develops under the film, which is no longer on a horizontal surface. After impact the ball may then roll due to whatever local incline the film may have. This may then generate a secondary signal. An even greater signal may be caused by the ball, film and foam oscillating. If this occurs it tends to happen between 20 and 100 ms after the ball first touches the film, and therefore does not usually superpose on the impulse signal.

Yet another effect is the charge generated by pyroelectricity: sometimes the ball will be warmed by handling; sometimes the film will absorb radiation from the hand of the experimenter. The impact itself may cause self heating in the film. This effect generates a negative going signal which peaks about 9 s after the impact - it will not have a noticeable affect on the impulse curve.

The choice of amplifier

Since the value of the input resistor is extremely high the op amp must have a high input impedance and low offset current. One suitable type is the BIFET TL071, which has an input impedance of 1 TΩ and a typical offset current of 5 pA. This offset current will generate an offset voltage of:

$$V = IR$$

$$V = 5 \times 10^{-12} \times 10^{9}$$

$$V = 5 \text{ mV}$$

- this is small compared with the impulse signal, which is of the order of 1 to 10 volts.

Because the typical output signal from the film is around 10 V the gain of the amplifier should either be x(-1), or x(-0.1); the inversion is required because of the poling of the film, which generates a negative voltage when hit by the ball.

The amplifier characteristics have been tested using feedback resistors of 100 MΩ and 1 GΩ. They are summarised in Table 1. The input test signal was a sine wave of 3 V amplitude.

R_f	100 MΩ		1 GΩ	
f	V_{out}	phase	V_{out}	phase
(Hz)	(V)	(°)	(V)	(°)
0.1	0.28	0	3	0
1	0.26	0	3	0
10	0.27	0	3	-10
100	0.25	0	1.9	-40
1k	0.35	-40	0.6	-10
10k	0.60	0	0.7	-5
100k	0.54	-30	0.6	-40

Table 1 - Amplifier characteristics

Of the two amplifiers, the one with the 100 MΩ feedback resistor and gain of x(-0.1) has the better frequency performance. The correspondence between its input and ouput signals is fairly good over the frequency range of this application, although the higher harmonics will be distorted. However the amplifier with the gain of x(-1) has the better signal-to-noise performance.

If the signal is attenuated, such as by an amplifier gain of x(-0.1), then any noise which is generated either within the op amp or A to D converter will become more significant. Both the op amp and 100 MΩ resistor are stocked by RS Components (stock numbers 304-245 and 158-222).

Transient display

The transient event should be recorded on a microcomputer which has a fast A to D converter sampling at around 10 kHz. Another suitable instrument is VELA. The graphs shown below were obtained with the Unilab Interface connected to the BBC Microcomputer, using Grapher software [3]. This software has a feature that is particularly useful in our application: it can determine the area under the curve. Therefore the force-time curve can be integrated by software to give a measurement of impulse. The onset of data capture is triggered by a rising voltage at the Interface.

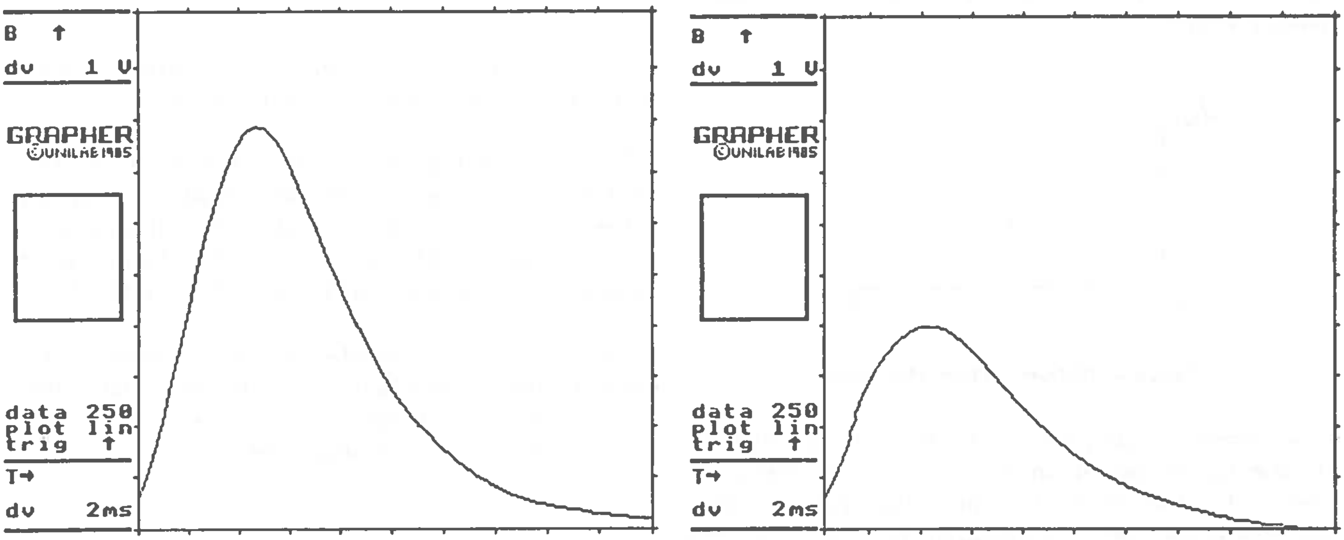

Fig.9 - Graphs of force versus time.
(a) - 20 cm drop (b) - 6 cm drop

Summary comments on the method of detection

Considerable space has been taken to analyse the detection system. This should answer the question which many will rightly ask: "How do you know that the graph you observe is an actual representation of force versus time?" It does seem that the representation is fairly true; the imperfections are due to the factors which have been described in the article; any distortion caused by the influence of these factors is thought to be minor.

It is easy to obtain an output from Kynar Film, but not so easy to obtain an output which is meaningful. This justifies the lengthiness of this write-up. The confusing effects which can so readily be obtained can be avoided by understanding how the film and its circuit works.

An empirical test

Some typical graphs which can be obtained by this method are shown in Figure 9. These were achieved by dropping a cricket ball on screened film which was mounted on top of Sensifoam. A 1 GΩ feedback resistor was used in these observations, but the output from the amplifier was attenuated by x0.85 before being applied to the Interface.

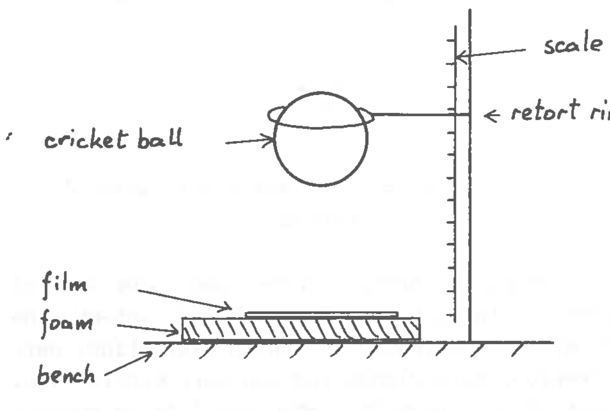

Fig.10 - The dropping gantry

Some care and skill is required if accurate measurements are to be made. It is important that the ball is held steady before release, and that it does not hit the film half-on. We have built a dropping gantry which has a retort ring against which the ball is held before being dropped (Fig.10).

The laboratory bench on which the film and foam are sitting should be massive and be securely mounted. It is quite common that laboratory benches do not meet this standard; warping causes them to rock, or be insecure. If this condition prevails then a further secondary effect may be noticed: the impact generates a vibration in the bench, which is picked up by the film. This superposes an oscillation which has a frequency of around 1 kHz on the F-t signal.

Measurements are shown in Table 2 for a range of drops (h) between 2 and 35 cm. The peak voltage (V), time of impact (Δt) and impulse (I) are given.

h/(cm)	V/(V)	Δt/(ms)	I/(V.ms)
2	2.5	19	26.3
4	3.7	19	31.7
6	4.0	20	34.6
10	5.6	18	47.9
15	7.0	18	54.9
20	7.8	18	60.4
25	9.2	17	65.9
30	10.2	18	74.4
35	11	17	80

Table 2 - Measurements of impulse versus height

The graph of I versus $\sqrt{h}$ is a straight line, with offset (Fig.11). This is in agreement with theory:

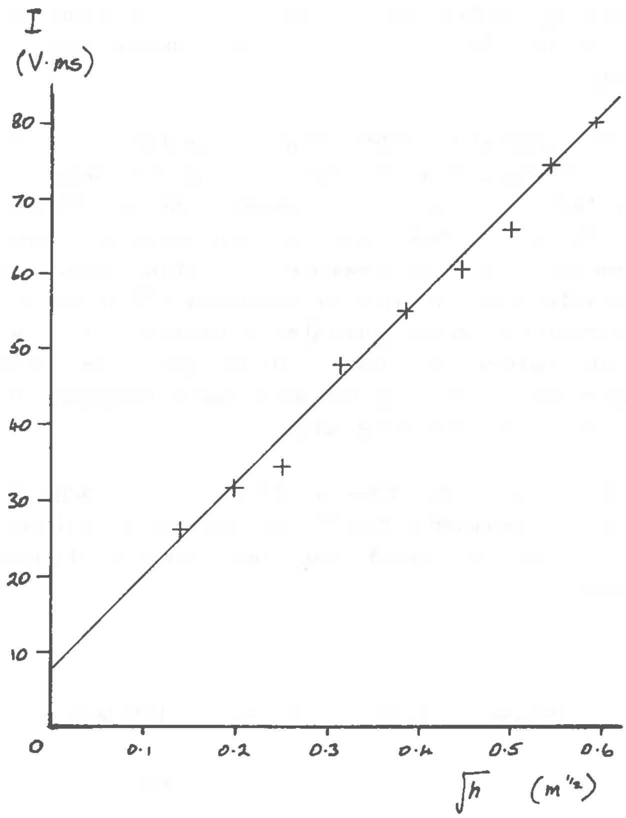

Fig.11 - Graph of I versus $\sqrt{h}$

velocity just before impact $= \sqrt{2gh}$

=> force exerted on film $= m(a + g)$

$= m(\sqrt{2gh}/\Delta t + g)$

=> impulse $= m(\sqrt{2gh} + g\Delta t)$

The term $mg\Delta t$ is effectively constant, partly because it is much smaller than the other term $m\sqrt{2gh}$, and partly because Δt does not change much (between 17 and 20 ms) in the set of readings. Therefore the form of the impulse equation is:

$$I = k\sqrt{h} + c$$

where I is impulse, k is the gradient and c is a constant. What is observed thus ties in with the theoretical form (Fig.11). This can be used as an empirical means of calibrating the system.

Piezo film theory

The voltage V generated by the film due to an applied stress X is given [1] by:

$$V = gXt$$

where g is the piezoelectric voltage constant for Kynar Piezo Film, and whose value depends on the mode of stretch or compression. For a stress applied perpendicular to the surface the value of g is shown below. t is the thickness of the film.

$$g = -339 \times 10^{-3}\ Vm^{-1}/Nm^{-2}$$

$$t = 28\ \mu m$$

$X = F/A$ where A is area of contact

This equation applies when just one mode of compression takes place. But with our set-up the film will experience a hybrid distortion: part compression, part elongation and part contraction. However it does seem that when the film is mounted on top of foam the only significant mode is a compression perpendicular to the surface. Here is a numerical example using the drop of 20 cm, whose F-t graph is illustrated above (Fig.9a).

$m = 0.158$ kg	mass of ball
$\Delta t = 17$ ms	time of impact
$h = 0.20$ m	height fallen
$2r = 8$ mm	diameter of area of contact
$I = 60.4$ V.ms	area under F-t graph
$t = 28\ \mu m$	thickness of film
$g = 10\ ms^{-2}$	gravitational accl.
$g = -0.339\ Vm^{-1}/Nm^{-2}$	Kynar piezo constant

impulse $F\Delta t = m(\sqrt{2gh} + g\Delta t)$

$F\Delta t = 0.158(\sqrt{2x10x0.2} + 10x0.017)$

$F\Delta t = 0.34$ Ns

average force $F = 0.34/0.017 = 20$ N

stress $X = F/A$

$X = 20/\pi \times 4 \times 4 \times 10^{-6}$

$X = 4 \times 10^{5}\ Nm^{-2}$

voltage generated $V = gXt$

$V = -0.339 \times 4 \times 10^{5} \times 28 \times 10^{-6}$

$V = -3.8$ V

Therefore by theory the average output voltage from the film for this impact is -3.8 V. To see how this compares with the measured signal it has to be remembered that that signal had been inverted and attenuated by a factor of x0.85:

average voltage $V = -60.4/ (0.85x17)$

$V = -4.2$ V

Thus the measured signal from the film agrees with the value which is obtained by theory from the specification of the film - though it should be mentioned that this is only an order of magnitude agreement because of the difficulty of accurately measuring the area of contact. Therefore the impulse and average force can be directly, if only roughly, calculated from three measurements: (1) the period of the impact, (2) the integral of the V-t curve; and (3) the area of contact. An empirical calibration is not strictly required. The user may either base the measurement of force on the physics of piezo film theory, or on the empirical calibration which was described earlier.

Warning - risk of damage to film

Many repeated blows may change the physical characteristics of the film. It is suggested that the experimeter waits a little between impacts to let the film relax. So far we have fractured the electrodes on one piece of screened film. The cause of damage is unknown, but it is thought to be due to ripping a strip of electrical tape carelessly off the surface of the film.

Conclusion

The behaviour of Kynar Film is still not fully understood; however from these investigations it looks as though the film can be used in a meaningful way to observe force-time transients. In his excellent memorandum on the physics of sport Bell [4] writes: "If we could monitor the actual changes of force during (an impact) we could then work out the area beneath the force/time graph." It is hoped that this transducer will find application in this branch of physics as well as in laboratory dynamics.

* *

Measurement of long wave infra red radiation

Introduction

The infra red spectrum can be crudely divided into two parts: the part between 700 nm and 1600 nm, which is used for telecommunications; and the rest, which includes the spectrum emitted by bodies which are warm rather than excessively hot. There are many detectors of the short wave part - photodiodes and phototransistors for instance - which are cheap, easy to use, sensitive and reliable, and which can be used for accurate, quantitative measurement [5]. It is in the long wave part that there have been hitherto no sensors which match all of these characteristics.

Kynar Piezo Film is exceedingly sensitive to changes in temperature; it behaves as a reliable detector of long wave infra red radiation and can be used for quantitative measurement. One such use is in a comparison of emissions from the different faces of a Leslie's cube.

Method of use

When the film is irradiated electric charge is generated which is proportional to the temperature change of the film. This charge is detected by measuring the discharge voltage across a load resistor, which is the input resistor of an inverting amplifier (Fig.1). The amplifier output is measured with a digital voltmeter.

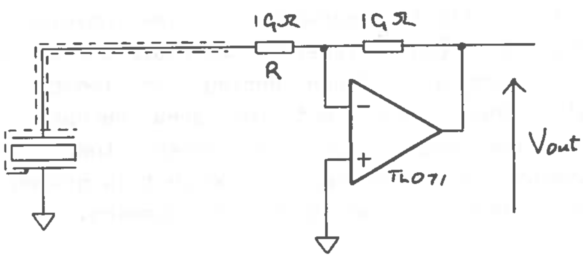

Fig.1 - Detection circuit

If the film is irradiated a transient signal is observed on the meter: there being a negative swing at the onset of irradiation, followed by a slow decay to zero while the temperature of the film stabilises. When the irradiation stops there is a corresponding positive signal as the film cools down (Fig.2).

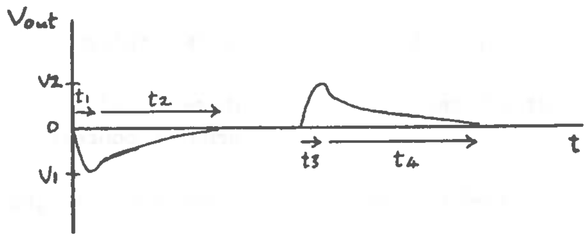

Fig.2 - Shape of transient signal

The nature of these transients, and the sensitivity, depend on the resistance R of the amplifier's input resistor (Table 1).

R/Ω	V1/mV	V2/mV	t1/s	t2/s	t3/s	t4/s
1M	-1	2	0	0	0	0
10M	-17	16	1	5	1	5
100M	-170	120	3	60	3	60
1G	-660	650	9	150	9	150

Table 1 - Dependence on R

These figures were obtained by using, as a heat source, a blackened beaker of water at 60°C, placed 10 cm from the film. The film itself was mounted in a vertical plane in thermal contact with a bar of steel, which was at room temperature - the steel bar is effectively an infinite heat sink. It seems desirable to mount the film on a body which has both large thermal and mechanical inertia. Because the film itself has low thermal mass it is easily disturbed by draughts of air; any such disturbance is lessened by mounting it in this way. It is also important that the film is not subjected to stress, which can readily be caused by vibrations being picked up from footsteps. If the film is securely taped down on a large block of metal then it will not pick up this sort of noise.

The preferred input resistance in this application is one gigohm. This was the only value with which the results were reliable. The transient signal changes slowly enough for the peak to be accurately read on a digital meter.

The peak of the transient output, V1, is believed to give a measure of absorbed energy: the justification is that the voltage output is proportional to the temperature change, which is proportional to the absorbed energy. This assertion has been checked by investigating the variation in V1 with the temperatures T1 and T2 of the steel bar and the hot, radiating body.

Stefan's Law

A blackened vessel holding about 500 cm^3 of water was used as the source. This was placed 10 cm from the film. The readings which were taken are shown in Table 2; a graph of V1 versus ($T2^4$ - $T1^4$) is shown in Figure 3.

T2/°C	T1/°C	V1/mV	($T2^4$ - $T1^4$)/K^4
80	24	-1172	7.81×10^9
75	24	-1071	6.95
70	24	-946	6.13
65	24	-838	5.23
60	24	-663	4.58
50	24	-487	3.16
40	24	-290	1.97
30	23	-125	0.83
20	23	32	-0.24
10	23	152	-1.20
0.5	23	263	-2.01

Table 2 - Stefan's Law readings

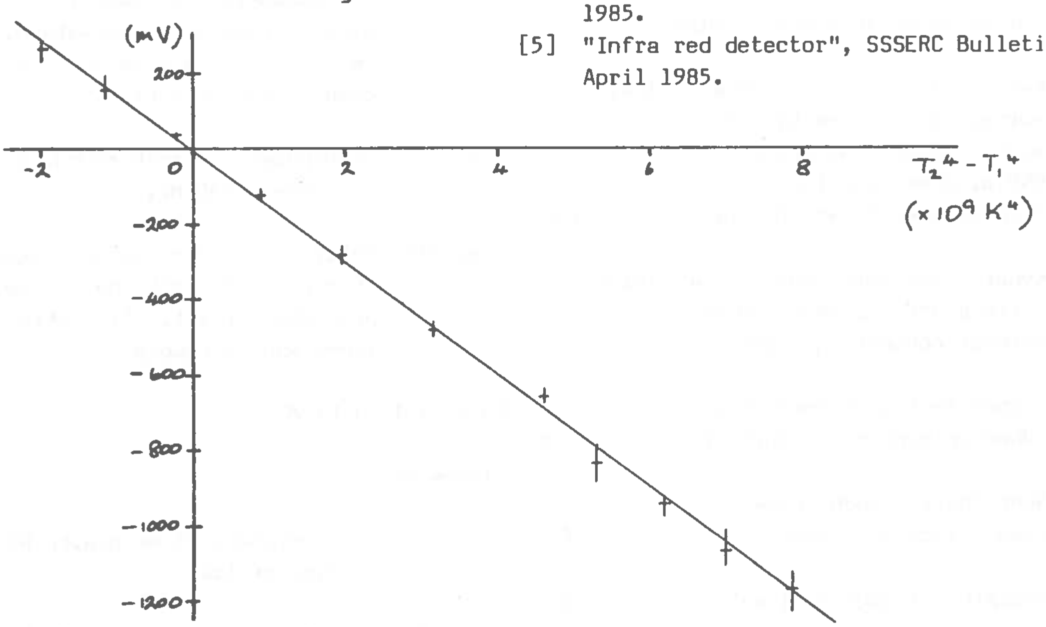

Fig.3 - Stefan's Law

Whilst more experimentation over a larger temperature range is required before making a definitive judgement, it does seem that the film is suitable for quantitative work in this part of the infra red spectrum.

If the temperature T2 of the radiating body is below room temperature then an interesting feature is the polarity of the output, which indicates that the surface of the film emits energy at a greater rate than it absorbs.

Acknowledgement

The author is very grateful for the time generously and fulsomely given by Richard Brown and Scott Strachan, both of Syrinx Innovations Ltd. The discussions we had were of great assistance to me.

References

[1] Pennwalt Corporation, "Kynar Piezo Film Technical Manual".

[2] Karlow, E.A., "Piezoelectric film reveals F versus t of ball bounce", 'The Physics Teacher', March 1985.

[3] "Interface reviews", SSSERC Bulletin No.154, November 1986.

[4] Bell, J.C., "The physics of sport", Education for the Industrial Society Project, SCDS, 1985.

[5] "Infra red detector", SSSERC Bulletin No.145, April 1985.

S U R P L U S   E Q U I P M E N T   O F F E R S

The items in this issue are very much a mixed batch. By courtesy of the East of Scotland School of Agriculture, University of Edinburgh we are able to offer some glassware. The South of Scotland Electricity Board have given us a further stock of kilowatt hour meters. We have also made some purchases in bulk, either because there was a short-lived special offer or because useful items were unavailable from educational suppliers or not obtainable in quantities sufficiently small for purchase by individual schools. Into that last category fall items for applications of Kynar Piezo Film. It should be noted that with donations and privileged purchases our charges and mark-up are usually only to cover our handling and checking costs. With bulk purchases we try to pass on to customers much of the benefit of discounts received.

In general this offer is subject to the conditions laid down in Bulletin 116. Items 513 to 523 inclusive are **subject to our ballot procedures.** Entries should preferably be submitted on a postcard and with an indicated order of priority.

Kynar Film related items

The following materials may be obtained through SSSERC to carry out the applications described in the family of articles in Physics Notes.

Item 502	Kynar Film, screened, 28 μm thick, surface area 18 mm by 100 mm, with coaxial lead and either BNC or 4 mm connectors (please specify which type)	£20
Item 503	Kynar Film, unscreened, 28 μm thick, surface area 12 mm by 30 mm, without connecting leads	55p
Item 504	Copper foil with conductive adhesive backing, 1 inch strip	10p
Item 505	Sensifoam, $\frac{1}{4}$ inch thick, area 6 inch by 6 inch	£1
Item 506	Resistor, 1 gigohm, $\frac{1}{4}$ watt	80p

Optically transmitting fibre

We have recently managed to purchase a bulk supply of a plastic, optically transmitting fibre. This we are able to offer as:

Item 507	Plastic optical fibre, per metre a single, plastic fibre 1 mm dia. Please state length required.	35p

We are most grateful to Pilkington Glass plc for assisting us to obtain this material. For one application see the article in Bulletin 140 on the optical transmission of sound; for another, in Bulletin 151, on the cold light source.

Components etc.

We still have stocks of many of the standard components as advertised in recent months. However items 508 to 512 inclusive are new lines.

Item 508	Miniature, 3 mm, red LED, high-intensity. 10 for	5p 45p
Item 509	Miniature reed switch, body dimensions 29 x 3.5 mm, lead length 10 mm contacts normally open.	10p
Item 510	Microphone,as for cassette recorder dynamic type with desk-stand, 200 Ω switched, 90 cm lead and 2.5/3.5 mm combination jack plug.	80p
Item 511	Loudspeaker, 3 inch round, 8 Ω, 2 W, res. freq. 250 Hz.	50p
Item 512	Motor, 12 V, d.c.,as for cassette recorder. Attached p.c.b. provides for 4 t.t.l. control lines and 5V supply.	50p

B A L L O T   I T E M S

Glassware

Item 513	Petri dishes, 93 mm dia.to BS 611. per box of 144	5p £5
Item 514	Test tubes, rimmed, per 100 borosilicate ['Pyrex'] 75 x 12 mm.	£1

Item 515 Test tubes, soda glass, per 100 £1
rimless, 75 x 10 mm

Photographic

Item 516 Print paper, Kodabrome II, per box £5
resin coated, 5" x 7", 100 sheets.

Item 517 Bulk Ilford HP5 film, 200' can £8

Item 518 Bulk Ilford HP4 film, 200' can £8

Item 519 Ilford HP5, 220 B/W film, 5 pack £3
400 ASA.

Item 520 Ilford Tri-X Pan film, 220 B/W, each £1
320 ASA.

Item 521 Kodak Vericolour 120 film type L, £1

Item 522 Ektachrome, transparency film, each £1

Electricity Meters

Item 523 Kilowatt hour meter, domestic £2
pattern, electromechanical digital display. Can be dismounted to extract the suspension mechanism with which to build a Curie Point motor (see Bulletin 153.

END OF BALLOT ITEMS

Advance Notice - Surplus Offer

Through the generosity of Philip Harris Ltd. the next issue of the Bulletin will carry a number of Harris items which they have kindly offered to the Centre. These are all fairly recent bits of equipment but which are not listed in the latest Harris catalogue. Because the apparatus has been donated, the prices will be little more than nominal handling charges. So, watch out for the February 1987 issue - Bulletin 156.

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TRADE NEWS

Power supplies for electronics

A low cost series of bench power supplies has been introduced by Farnell Instruments Limited. They feature mains input to low voltage regulated outputs. The most useful model in the series would seem to be the item E895007, which has a triple rail output: 4 to 6 V, 12 to 15 V and -12 to -15 V all adjustable. Each of the three rails has a current rating of 500 mA, but in practice currents of about 800 mA can be obtained. There is short circuit and reverse power protection, together with thermal shutdown for excessive loading. The price of this item is only £45 - a snip for what it offers, though the housing is not quite as robust as we would desire.

In addition to power supplies Farnell Instruments stock and manufacture quite a range of products for schools; these are listed in their catalogue 'Electronics in Training and Education'. One small item deserves a mention: an adaptor for connecting 4 mm leads to BNC input sockets, which are common on modern oscilloscopes.

Servicing, repairs and calibration

During the last two years the Scottish Electronic and Calibration Company have been building up a reputation for servicing, repairing and calibrating laboratory equipment. Items which the firm handles include: stroboscopes, signal generators, Avo meters, oscilloscopes, power supplies, joulemeters, certain models of balance, vacuum pumps, a.v. equipment and BBC Micro-computers. We are informed they are willing to tackle any item, including obsolete equipment for which spare parts are no longer manufactured. The firm uplift and deliver. A list of typical repair charges is available on request.

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Metragram Instruments Limited, Radlett House, West Hill, Apsley Guise, Bucks. MK17 8DJ; Tel. 0908 582262.

MISAC, c/o Institute of Biology, 20 Queensberry Place, London SW7 2DZ; Tel. 01 581 8333.

MISAC Local Advisers:

Aberdeen Mr M.S. Davidson, Microbiology Department, The Macauley Institute for Soil Research, Craigiebuckler, Aberdeen AB9 2AJ.

Dr G.W. Gooday, Department of Microbiology, Marischal College, University of Aberdeen, Aberdeen AB9 1AS.

Ayr Dr S.G. Deans, West of Scotland Agricultural College, Division of Biological Sciences, Department of Microbiology, Donald Hendrie Building, Auchincruive, near Ayr KA6 5HW.

Edinburgh Dr J.F. Lowe, Department of Microbiology, University of Edinburgh, School of Agriculture, West Mains Road, Edinburgh EH9 3JG.

Mr R.M. McLarty, Department of Bacteriology, University of Edinburgh, School of Agriculture, West Mains Road, Edinburgh EH9 3JG.

Glasgow Dr L.P. Macham, Department of Biological Sciences, Glasgow College of Technology, Cowcaddens Road, Glasgow G4 0BA.

Dr D.E.S. Stewart-Tull, Department of Microbiology, University of Glasgow, Alexander Stone Building, Garscube Estate, Bearsden, Glasgow G61 1QH.

National Centre for School Biotechnology, Department of Microbiology, University of Reading, London Road, Reading RG1 5AQ; Tel. 0734 873743.

Norlab Instruments, Site 9, Kirkhill Place, Kirkhill Industrial Estate, Dyce, Aberdeen; Tel. 0224 724849.

Oertling Division, W & T Avery Limited, Smethwick, Warley, West Midlands B66 2LP; Tel 021 565 1919.

Ohaus Scale Europe Limited, Unit L, Broad Lane, Cottenham, Cambridge CB4 4SW; Tel. 0954 51343.

Pennwalt Corporation, 900 First Avenue, PO Box C, King of Prussia, Pennsylvania 19406-0018, USA; Tel. 010 1 215 337 6710.

Ravencourt Limited, Cobbs Nook, Newstead Lane, Stamford, Lincs. PE9 4JJ; Tel. 0780 57370.

RS Components, PO Box 99, Corby, Northants. NN17 9RS; Tel. 0536 201201.

Salter Industrial Measurement Limited, Spring Road, Smethwick, Warley, West Midlands B66 1PE; Tel. 021 553 1855.

Sartorius Limited, 18 Avenue Road, Belmont, Surrey SM2 6JD; Tel. 01 642 8691.

Scotlab Instrument Sales Limited, Unit 15, Earn Avenue, Righead Industrial Estate, Bellshill, Lanarkshire ML4 3JQ; Tel. 0698 841616.

Scottish Electronic and Calibration Company, 1 Mafeking Terrace, Neilston, Glasgow G78 3LP; Tel. 041 880 5904.
branch: The Security Centre, 102A Manor Street, Falkirk FK1 1NU; Tel. 0324 35867.

Stevens and Son (Weighing Machines) Limited, Unit 4, Executive Park, Hatfield Road, St Albans, Herts. AL1 4TA; Tel. 0727 38101.

Syrinx Innovations Limited, 74 Great King Street, Edinburgh EH3 6QU; Tel. 031 558 1144.

Unilab Limited, Clarendon Road, Blackburn BB1 9TA; Tel. 0254 57643.

Whatman Labsales Limited, Unit 1, Coldred Road, Parkwood, Maidstone, Kent ME15 9XN; Tel. 0622 674821/2/3/4.

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Key to balance suppliers

Models of balance as listed in the tables on pages 9 to 13 are available from suppliers in the above address list. In some cases e.g. Cherlyn, Ravencourt and Whatman the name's the same. For other models a key is needed. Makes of balance are given first and are matched to suppliers as follows:

Ainsworth - Adam Equipment Co.
Cobos & Murikami - Stevens & Sons
Bosch - Scotlab Instrument
Gravitron - International Electronics

Mettler - Griffin (older PE models superceded by PM series available while stocks last; Brash; Mackay & Lynn; McQuilikin.

Oertling - Oertling. Also marketed by Philip Harris as **Stanton** (model nos. are reverse of equivalent Oertling e.g. Oertling OB152 is Stanton 251BO).

Ohaus - Griffin; Harris; IMS and McQuilkin.
Salter - Salter and Mackay & Lynn
Stanton - See Harris (and Oertling equivalent).
Precisa - Metragram; McQuilkin and Norlab.
Sartorius - BDH; Harris; IMS; McQuilkin.

Note that European Instruments and Scotlab Instruments can supply most makes except: Cobos; Gravitron; Murukami; Ravencourt; Salter and Whatman. Also beware of badge engineering, especially at the lower end of the market. In this sector buying on price may well be the best course.

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S.S.S.E.R.C.

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