SCOTTISH SCHOOLS EQUIPMENT RESEARCH CENTRE

Science & Technology Bulletin

For: Teachers and Technicians in Technical Subjects and the Sciences

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Contents

FOREWORD

Four-colour cover

This issue sees yet another change in the standards of presentation for this our SSERC journal and only serial publication. We trust that our readers and clients will see this full four colour cover as an improvement.

Sponsorship

This first issue in the new style has been sponsored by the Institution of Electrical Engineers (IEE) to which organisation we are most grateful.

We also have particular cause to thank Dianne Winfield and Karen Prince, of the Schools Education Liaison staff of the IEE, for their sustained interest in and support for the Centre's work.

Their recognition of the expertise of SSERC staff has been provided in practical ways. On several occasions they have seen the wider relevance of our work outwith Scotland and have arranged to re-publish SSERC material in *Electronics Education*, their own quality journal.

We intend accepting similar sponsorship of future issues from other third party agencies. By "third party" we mean organisations or companies which do not have any commercial interest in the educational equipment market.

Continued independence

SSERC will thus continue in its practice of not accepting direct financial support, fees or advertising from any commercial firm or other supplier where any conflict of interest might arise. This is to preserve our independence as a test and evaluation service for educational customers and so that we may continue to provide them with objective advice on the merits and demerits of specific pieces of equipment.

The Institution of Electrical Engineers

The IEE is the professional association for electrical engineers. It has a membership of approximately 140,000 men and women worldwide who have joined together to promote the advancement of electrical and electronic engineering. The Institution's interests and activities span power engineering, communications, computing, electronics and control. It is concerned also with many areas of related technologies as well as with management, design, education and training.

Through its educational work with schools the Institution aims to encourage increased understanding and awareness of the electrical engineering profession. It provides a range of curriculum support materials and careers information. It also links engineers directly into the classroom.

IEE educational resources

Included within the range of resources available from the Institution are :

Electronics Education - a journal building on pioneering work on the systems approach to teaching electronics and providing practical help and guidance for teachers. It is published three times a year and distributed free of charge to all secondary schools in the UK. This journal contains ideas and suggestions as to how electronics, computing and information technologies may be used to develop pupils' understanding of key scientific and technological ideas and concepts.

Games and simulations - cross curricular activities based on real life situations and which provide an exciting and stimulating way of illustrating the part played by science and technology in modern society.

Games in this series include :

- *Telecom Link*
- *Link-up*
- *Power for Pemang*

As well as aiming to develop understanding amongst pupils of societal aspects of technology and of factors affecting managerial decisions, these games offer opportunities to develop communicational and presentational skills as well as to examine ideas relevant within several subject areas.

Each game is presented as a file of photocopiable masters in a complete package with all the information needed to run the exercise.

SchoolNet - The IEE has worked over many years to make the expertise of the profession available to schools. In order to target its work even more carefully, and to develop support activities which schools actually require, the IEE has now developed its own school affiliate scheme called *SchoolNET*.

This will :

- enable the IEE to provide a more efficient service to teachers and schools;
- contain details of individual schools as to their interests in electronics and the engineering professions;
- help teachers to meet other similarly interested individuals and
- keep teachers in touch with new ideas and projects providing them with an opportunity for their involvement.

Should you be interested in any of the above activities or want to learn more of the work of the IEE then you should contact the Schools Education and Liaison section at the address given on the back cover of this bulletin issue.

INTRODUCTION

Editorial

Safety : Funding, communication and management

In the Safety Notes section of this issue we report on an electrical accident in a Scottish Education Authority school. The incident in question involved a power supply made to a design with safety standards over twenty years out of date. It is apparatus which, in more normal times, anyone would agree was outmoded, obsolete and ought long ago to have been replaced.

Unfortunately for most Scottish EAs, unable to collect community charge monies, these times seem far from normal. Funds for replacing capital items such as sets of power supplies are not at the top of any of their agenda.

We were not therefore suprised, when we followed up the reported accident to find four types of power supply, by the same maker, with other hazardous features. Examples of each model were still in regular use in the EA in which the accident had occurred.

The defects on these pieces of equipment would have been picked up in a simple routine inspection and monitoring programme. These deficiencies should have been put right or the apparatus disposed of and replaced. The school wherein the accident occurred had no such routine inspection programme.

This accident thus highlights issues of much wider concern.

In Bulletin 166, June 1990, we summarised the requirements of the Electricity at Work Regulations 1989 [1]. We followed that up in the next issue, in September 1990, with an account of the revisions made to the Health and Safety Executive's Guidance Note GS23 "Electrical Safety in Schools" [2].

It should be particularly noted that the original edition of GS23 was first published in September 1983 and that we have repeatedly drawn it to the attention of the SSERC membership ever since. Several EAs have had systems in place to meet the requirements of GS23 for at least six of those intervening eight years or so. Some EAs and independent schools are only now getting to grips with the revised version since the 1989 Regulations came into force.

It looks as though we may have to accept at least part of the responsibility for this unsatisfactory state of affairs. We clearly have failed to communicate sufficiently clearly, or at the right level, the need to meet statutory requirements for effective safety inspection and monitoring systems.

Under the Health and Safety at Work etc. Act 1974 the onus is put on employers to set up safe systems of work, as far as is reasonably practicable. We can fully understand that given current financial problems educational employers will wish to ensure that procedures and systems are indeed necessary and useful.

It is right and proper that any definition of "reasonably practicable" should take account of costs and weigh these against need and benefit.

But any such system, however imperfect, is preferable to no system at all.

Employees may well moan if the system as proposed is indeed less than perfect. The reasonable among them should however accept that health and safety, although necessarily important, is by no means the only priority of any employer. In our experience of education, staff almost always will seek to do their best to meet the duties placed on them by the Health and Safety at Work etc. Act (HASWA). These duties include a need to co-operate with their employer in operating systems designed to protect the health and safety of themselves, their colleagues in the workplace and of others who may use the premises. Two key principles underlie the HASWA. These are the so-called Robens principles of *self-regulation* and a *tri-partite* approach by HSE, employers and employees (often as represented by their Trades Union or professional association).

An employer is awkwardly placed where he has done his best, within relevant financial and time constraints, to put in place an effective system but some employees then do not, or will not, operate his arrangements. Leaving aside any contractual obligations to their employer, it is at least arguable that such employees are also failing to meet some of their own individual responsibilities under the Act. To date the one prosecution of an educational employee involved circumstances where a safety system had been put in place but the employee had ignored it.

More awkwardly placed still are those employees with an employer who has yet to even formally recognise the need to meet certain responsibilities as now amplified in the regulatory framework subsequent to the original enabling act. These often involve detailed aspects of setting up and maintaining safe systems of work such as regular inspection and monitoring procedures.

Possibly most awkwardly placed of all however are some managers currently in the service of such an employer.

References

1. "The Electricity at Work Regulations 1989", S.I. No.635, HMSO.

2. "Electrical Safety in schools (Electricity at Work Regulations 1989), Health and Safety Executive, General Series 23, September 1983, as revised February 1990, HMSO, ISBN 0 11 885426 7.

Diary dates

RSC meeting

Early in 1992 the Royal Society of Chemistry, Education Division (Scottish Region) is organising what promises to be an interesting seminar. This is entitled *Mini and Midi Problem Solving at the Bench* and will be conducted by Dr. R.A.Hadden, Research Fellow at the Centre for Science Education of the University of Glasgow.

We are informed that the seminar will provide opportunities for *hands-on* experience of practical, problem solving exercises which have been designed for the Standard and Higher Grade courses in chemistry.

The venue is to be Liberton High School, Edinburgh on Thursday the 30th of January 1992. The seminar will last from 7-00 to 9-30 pm with a tea interval.

ASE Scottish Region

Annual Meeting

The meeting will be held from Friday the 10th to Sunday 12th of April 1992 inclusive. The venue is a new one for the ASE - the Scottish College of Textiles in Galashiels. Further details are available from the Organising Committee Secretary (see Address List, inside rear cover).

International Festival

Hot on the heels[1] of the Scottish ASE's shindig will come the Edinburgh International Festival of Science and Technology. Indeed one slides over the other. The opening day of the Festival proper is to be the 11th of April 1992 with the programme then going on right through to the 25th. If you count the schools' programme, which begins about two weeks ahead of the official festival, the 1992 event is to stretch over about a month.

Being a national organisation ourselves we didn't feel we could get too closely involved with this festival which was seen, initially at least, as very much an Edinburgh event. The Festival has now come of age as it were. The schools' programme pulls in children from a wide area and the travelling exhibits and events go out into a' the airts. It would be churlish therefore for us not to actively assist the organisers and publicise relevant events.

The schools programme is now available. Copies of it and of that for the main Festival can be obtained by telephoning the Science Festival Box Office on:

031 557 4296

or by written application (see Address List).

1. I do so love a cliché!

Open and other courses

Up till now SSERC has tended to arrange its wide range of practical training and health and safety courses only through the advisorate, regional training officers, senior or chief technicians.

Some Scottish EAs have however set up neighbourhood groups and have devolved some responsibility to them for the identification of training needs and the setting up of some courses to meet these. We have already agreed to be a provider of training to such groupings.

We would be pleased to hear from other similar groups who would like to negotiate practical training on any aspect of equipment usage, technical support for the practical aspects of recent curriculum developments or in health and safety related areas. Fees are charged on a per person, per day basis and, it is said, offer particularly good value for money. Enquiries to the Director, SSERC in the first instance please.

We are also offering places on open courses of which so far we intend running two in 1992. These will be in Edinburgh and residential. Fees are to be charged on a more strictly commercial[2] basis at about £450 for the week inclusive of accommodation and all meals.

The first such course is on *Information Technology Applications in Science and Technology Education* and will run from the 12th to the 16th of April. The second is on *The Art of Scientific and Technical Writing and Publishing*. It will be held during the period 6th to the 10th of July 1992.

Once again for more details of these courses please contact the Director of SSERC. Places are limited and, for the Easter course especially, early enquiry is advisable.

2. Though by no means profiteering!

Safety Notes

Gas guidance - addendum

In the last issue of the Bulletin we summarised current requirements on the safe installation and maintenance of gas supply systems in educational establishments. In particular we gave a précis of and commented on Guidance Note IM/25 [1], jointly produced by British Gas and the Department of Education and Science.

It has since been brought to our attention that some local Scottish Gas personnel may be mis-interpreting a requirement which we dealt with in that article under the sub-section *Portable or movable equipment*. This was the need for flexible hoses with self-sealing plug and socket-end fittings.

In particular there has been a report of some confusion over the type of connections needed for gas ring burners. This type of burner is used more frequently in the domestic scene, but is used occasionally in schools and colleges for some autoclaves without built-in electrical heaters or for heating other large vessels. We have discussed the problem with British Gas and the conclusions are summarised below.

If such rings are semi-permanently connected, as they would be for example in a bed-sit, then they are required to have an armoured connecting hose with a self-sealing plug and socket at the mains supply end. Such an arrangement is most inconvenient for a laboratory bench where space is at a premium and burners are cleared away immediately after use.

In school laboratories Bunsens are exempt from the requirement to be connected with armoured tubing etc. This is mainly on account of the ease with which they can fall over because of the twisting force generated in this type of tubing when the position of a burner on the bench is adjusted. Gas rings being heavier, and having a lower centre of gravity, are more stable and less likely to be tipped over by their connecting tubing.

On the basis of the above therefore, if the rings are connected temporarily, say only for the duration of the experiment or process and they are under constant attendance, then they can be classed in the same way as Bunsen burners, that is as *bench-top experimental equipment* referred to in Section 6 of IM/25 [1]. Thus rubber tubing of adequate strength can be used. Most laboratory suppliers sell tubing designed for use with Bunsens.

An additional point stressed by our correspondent in British Gas Scotland was that it has always to be borne in mind that where gas fired equipment is used there must be "proper and adequate" ventilation and that this of course applies also to temporary burners.

Reference

1. Guidance Notes on Gas Safety in Educational Establishments, IM/25, British Gas and DES. Issued by British Gas, May 1989.

Electrical accident report

We recently circulated information to all of our relevant Scottish EA contacts on an electrical accident with a Radford power supply. A pupil who had connected 4 mm leads to the HT outlet of a Radford 59R *Labpack* received an electric shock and suffered burns to his hands.

This type of power supply has several low voltage electrical outlets which, in normal conditions, are inherently safe for use by pupils. They also have an HT outlet which has always caused us concern. This outlet was intended primarily for use with gas filled valves and teacher demonstration work with apparatus such as *Teltron* tubes. It presents serious risk of electric shock since it can deliver up to 100 mA at 300 V. We last warned of the dangers of this type of supply as recently as Bulletin 170 [1].

It was the HT outlet of the Radford 59R supply which caused the injuries to the pupil in this most recent incident. A simple means of rendering the HT outlet safe and dead is by removal of the HT fuse. This had been the practice in the school where the accident occurred. However this incident demonstrates that this can no longer be seen as a sufficient safeguard. A cause of the accident had been the replacement, unbeknown to the class teacher, of the fuse. Any safety measure which can be so easily overridden provides insufficient protection. We now make the following recommendations:

If other, low voltage, outlets on this type of hybrid supply are to continue to be used by pupils then the HT outlet should be rendered permanently safe and dead. This is to be done by disconnecting the HT transformer winding. SSERC has prepared a detailed set of technical notes[1] which show how this may be done. Such supplies which have not been so adapted must, as a whole, be permanently marked:

"Hazardous Live - Must not be used by pupils".

A supply with a hazardous live outlet should never have its HT fuse removed to allow temporary use of any other, low voltage, outlets by pupils. This measure does not provide fail-safe protection. For a full definition of "hazardous live" see the next article in this bulletin section.

It may be occasionally permissible for senior[2] pupils to work with such supplies at hazardous live provided that they have have had appropriate instruction on safe working procedures and are sufficiently closely supervised. Specialised shrouded connectors may be required and the working area must bear a prominent sign marked:

"DANGER - Hazardous Live".

1 Copies of these notes have already been circulated to the advisorate, EA Resource Centres, nominated health and safety contacts and subscribing independent schools. In any cases of difficulty additional sets are available from this Centre on request.

2 Senior pupils (students) are generally taken to be those over sixteen years of age.

Further hazards

Following the accident, the Centre has inspected four different old models of power supply made by Radford, still in use in the EA in question. We are concerned to find other hazardous features. In our judgement any school with such power supplies needs to act to put right all of these deficiencies before the apparatus can be deemed to be reasonably safe to work with. These features, not all of which are present in every model, are:

1. mains socket that is openable by hand on a removable, flexible cord;
2. presence of a voltage selector on the exterior of the enclosure with sockets at hazardous live;
3. inadequate earth bonding;
4. fuse holder, that is openable by hand, on a hazardous live conductor;
5. neon indicator across live and earth; and
6. underrated mains cord.

In addition, the integrity of strain relief on the mains cord at the point of entry to the enclosure, on certain models, is questionable.

Apparatus with any of these defects should be withdrawn from use until modified to an adequate standard. Serious consideration should be given to replacing apparatus with multiple defects.

Statutory requirements

As indicated in our Editorial, the Centre is concerned with wider issues which this accident has highlighted. Regulations 4(1) and 4(2) of the Electricity at Work Regulations 1989 require that:

4(1) all sytems shall at all times be of such construction as to prevent, so far as reasonably practicable, danger; and

4(2) as may be necessary to prevent danger, all systems shall be maintained so as to prevent, so far as reasonably practicable, such danger.

Regulation 4(2) is generally interpreted to mean that employers must set up a test programme whereby all apparatus is routinely and regularly inspected. Where such programmes are in place under Regulation 4(2), apparatus found to have had any of the defects referrred to above would, because of Regulation 4(1), have been withdrawn from service and either brought up to an adequate standard or disposed of and replaced.

Reference

1. "Higher Grade Chemistry - First ionisation energies", SSERC, Bulletin 170, June 1991.

Hazardous live

Descriptions from Bulletin and GS23

An electricity supply is deemed to be *hazardous live* if it is capable of rendering an electric shock or electric burn. Sometimes the Centre is called upon to specify what constitutes hazardous live. The requirement may come from internal reasons - in support of our apparatus evaluation programme - or from an external request.

Standards are never definitive. They are continually being reviewed, revised and updated. The last time we wrote about this matter in the Bulletin [1], we stated that "pupils under the age of 16 should not undertake practical work with uninsulated electrical conductors at voltages in excess of 25 V a.c. r.m.s. at 50 Hz".

Since giving that advice, GS23 *Electrical Safety in Schools* [2] has been revised. The relevant passages on practical work at hazardous live have been tightened. They now advise:

34 "Pupils in schools must not be allowed to be exposed to dangerous voltages above 25 V (see paragraph 35)......"

35 "Where setting up a project, experiment etc. is part of the learning process and if there is any possibility that the child might come into contact with parts live at more than 25 V, special precautions must be taken, unless the apparatus is incapable of inflicting a dangerous electric shock. Such experiments and practical exercises must be checked for potential hazards and supported by written instructions which draw attention to the possible risks and the precautions to be taken."

Further to this, the Guidance Note also advises that any apparatus which has exposed outlets at voltages greater than 50 V and short-circuit currents greater than 5 mA should be marked *unsuitable for use by children*.

Although the advice is deliberately loose so as to be not over-restrictive, the uncertainties which arise from the way it has been framed have generated several enquiries to the Centre from authorities looking for interpretation. Are the specified voltages absolute, or may one take them to be a.c. r.m.s. values? When are voltages between 25 V and 50 V dangerous?

Earlier this year the Centre issued, to those authorities that had sought it, advice on this muddy area between these two voltages. We will not repeat that advice here because we have already had cause to supersede it.

A newly published international standard for electrical measurement, control and laboratory equipment, IEC 1010-1 [3], helpfully fully specifies *hazardous live*. We quote it overleaf.

IEC 1010 description

"Values above the levels of 1 to 3 in normal condition are deemed to be hazardous live.

1. *Voltage*

   The voltage levels are 30 V r.m.s. and 42.4 V peak or 60 V d.c.

2. *Current*

   If the voltage exceeds one of the values in 1, the current levels are:

   - 0.5 mA r.m.s. for sinusoidal waveforms, 0.7 mA peak for non-sinusoidal waveform or mixed frequencies, or 2 mA d.c.,

   all as measured with circuits illustrated in the standard;

   - 70 mA r.m.s.

   again as measured with circuits[1] shown in the standard.

3. *Capacitance*

   If the voltage exceeds one of the values of 1, the capacitance levels are:

   - 45 μC charge for voltages up to 15 kV peak or d.c.;

   - 350 mJ stored energy for voltages above 15 kV peak or d.c."

IEC 1010 is clearly having a considerable impact. For the time being, and until we have any evidence or directive to the contrary, the Centre is itself using, and recommends that others in education use, the ten-ten specification of hazardous live.

We are aware that members of the British Educational Equipment Association (BEEA) have decided to design and manufacture products to this standard. These designs should be appearing as from September 1992. As part of the preparative work for this move toward IEC 1010, SSERC has already begun evaluating and testing equipment to the standard.

Recommended protocol

By using the ten-ten specification as a set of absolute limits, and the injunction from GS23 that pupils must not be exposed to dangerous voltages above 25 V, we have a very sound scheme for controlling work with live conductors.

There is further advice from GS23 which should also be heeded:

33. "Where there is a possibility of a person, pupil or otherwise, coming into contact with live conductors at voltages above 25 V or where large short circuit currents could flow, for example from lead acid 12 V batteries or similar, in experiments, the teachers and technicians involved should be electrically competent. This competence will necessitate technical knowledge or experience including:

(a) adequate knowledge of electricity;

(b) adequate experience of electrical work;

(c) adequate understanding of the system to be worked on and practical experience of that class of system;

(d) an understanding of the hazards which may arise and the precautions which need to be taken;

(e) ability to recognize at all times whether it is safe for work to continue."

In other words, a hierarchy of levels of work is recommended.

1. Unless the teacher is technically competent, pupils should not be able to work at voltages exceeding 25 V, or work with supplies that can deliver dangerously high currents.
2. Under teachers with the necessary competence, pupils may work with conductors up to the limits specified as hazardous live in IEC 1010.

3 Under teachers with the necessary competence, a senior pupil may work with conductors at hazardous live provided that the pupil has had appropriate oral and written instruction on safe working procedures and is sufficiently closely supervised. Such a working area should bear a prominent sign marked :*"DANGER - Hazardous live"*

1 This compensates for the change of physiological response of the body with frequency. This use of frequency dependent definition and measurement circuitry relates to possible burns at higher frequencies.

References

1. "HT Transmission Lines", SSERC, Bulletin 158, October 1987.
2. Electrical Safety in Schools (Electricity at Work Regulations 1989), Guidance Note GS23, Health and Safety Executive, 1990, HMSO, ISBN 0 11 885426 7.
3. IEC 1010-1: 1990 Safety requirements for electrical equipment for measurement, control and laboratory use, British Standards Institution.

Explosion

We have had a report of a serious incident in a Scottish secondary school when a bottle of silicon tetrachloride exploded. The explosion occurred when a technician attempted to open it. The only precaution which had been taken had been the wearing of protective gloves and it was matter of luck that the outcome of the incident was not more serious.

The EA in question has since circularised all of its science teaching staff to the need to refer to appropriate safety information. Under the COSHH regulations this is now more than ever necessary because of the explicit requirement to assess risk **before** handling any hazardous material. The hazards and risks associated with handling silicon tetrachloride are well documented. For example full information on safe handling of this substance is provided on the relevant HAZCARD.

This incident provides a reminder of the need to seek out and act on reliable safety information before handling such potentially dangerous substances. When the proper procedures are followed and precautions taken then the risks in handling this substance are reduced to a minimum.

Laboratory hazards from domestic appliances

Our attention has been drawn to a recent national safety circular issued by MSF (the union - Manufacturing, Science Finance). This was entitled "Use of Domestic Appliances in the Laboratory" and gave examples of a number of accidents and dangerous occurrences arising from laboratory use of electrical appliances of domestic pattern.

These incidents seem to fall into two broad categories. The first of these involved the use of microwave ovens for microbiological preparation work. Two dangerous occurrences arose from heating capped bottles of media in microwave ovens. In both of these the outcome was an explosion which blew the door off the oven and scattered broken glass and débris across the laboratory.

In the one case the certain cause was not heeding an oral instruction to slightly loosen the screw caps of bottles before switching on the oven. In the second an additional factor was using the oven on its maximum setting even though a notice on the oven door specified "Unscrew caps, max. setting 4".

The other group of accidents involved the use of flammable materials with domestic appliances which had not been suitably modified so as to sparkproof them and otherwise prevent them acting as sources of ignition.

In one incident hexane was mixed with another, inert, material in an electrical blender. The blender was not modified or protected in any way and the hexane ignited. The feet of the operator were burned.

In the other example quoted a small volume of ether had been stored in a refrigerator of domestic pattern which had not been fitted with sparkproof switches, doorlight etc. An explosion resulted.

Comments

Apart from the novel context of the use of microwaves as the means of heating containers of microbiological media, the root cause of the microwave oven incidents is well documented [e.g. ref.1]. The need to loosen caps to prevent pressure build-up is well known. Such loosening is standard practice in more conventional sterilisation procedures using steam.

It would appear that in one case this was overlooked or appropriate instruction was not followed. In the other case appropriate instructions were affixed to the door of the oven but appear not to have been heeded.

The underlying cause of the blender and refrigerator incidents is also well documented [2]. We have ourselves previously drawn the attention of readers to explosions in refrigerators of domestic pattern which had not been suitably modified so as to remove potential sources of ignition [3].

References

1. Appendix 1 of "Microbiology", Ch.5a of Topics in Safety, A.S.E., 1988, ISBN 0 86357 104 2.
2. "Refrigerators", Hazcards, CLEAPSE/SSSERC, original 1981 edition.
3. "Accident with di-ethyl ether in a refrigerator", "Safety Matters", SSSERC, Bulletin No. 128, June 1981.

Glue Guns

The Centre recently inspected a couple of imported glue guns submitted for evaluation by an educational supplier. Both were hazardous. One especially so. On the basis of our advice, the supplier prudently decided not to market them. However we are concerned that other suppliers may not have been so careful and that these guns may thus still be on sale. We are also concerned that there may be other makes of guns with these dangerous features. We therefore advise you to check your glue guns.

Electrical hazard

The principal hazard was the lack of a safety earth conductor together with understrength insulation. This was found on a gun, coloured blue, marked "Glue Gun", "120 V/10 W", "E 99745 JY-2009A". It did not bear the double insulation symbol.

We have inspected its insulation system and judge that it is not substantial enough for double insulation. The heater element is sited within a conical metal casting that protrudes to form the gun's nozzle (Fig.1). If the insulation here were to break down the nozzle would become hazardous live.

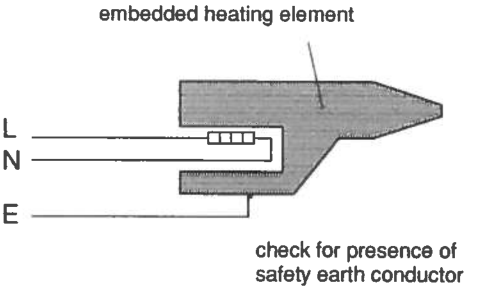


Fig.1

What checks should you make? Firstly ensure that the gun has a safety earth conductor bonded to the nozzle. If it hasn't, look for the double insulation symbol and some recognized form of test house marking as to its quality of design, and flash test at an a.c. voltage of not less than 3 kV. If these tests fail, your gun is of dubious quality. It may be advisable to dispose of it.

Risk of burns

Many models of glue gun have some form of heat insulator covering their nozzles. If not there is a risk of skin burns, or burn damage to the flexible cord. Such a design is therefore electrically unsafe because the mains cord can be damaged through accident or deliberate misuse.

Technical Articles

Higher Grade Chemistry

Reaction rates - powdered marble and acid

A method is described which allows measurements even of extremely rapid reactions between finely powdered marble and hydrochloric acid. The method relies on the use of an *internal dispenser* and of datalogging software.

Introduction

Learning outcome 7 of Unit 1 of the Revised Higher Grade Chemistry course involves rates of reaction between calcium carbonate, in the form of marble, and hydrochloric acid.

This reaction and the measurements are well enough known. But, how often have you allowed pupils to find out the hard way that with powdered marble the reaction is at least half over, long before they can even get a bung in the reaction vessel[1] or a balance display is steady enough to read[2] or to begin transmitting sensible data to a computer interface?

We think it is still worth experiencing what might be perceived as a failure. It certainly doesn't take much time for students to reach the conclusion "It's so fast that it's too difficult to measure". I have often mumbled these words as, I suspect, have many other chemistry teachers.

1 If you are using the gas syringe method.

2 If using a gravimetric method tracking reaction rate by weight loss.

One inexpensive way of tackling the problem is to follow the method using a gas syringe combined with a movement transducer and to make use of the *internal dispenser* described below.

The overall measurement system is shown in Figure 1. Note that the transducer needs to be inverted but for clarity the effect on its labelling is not shown.

Dispenser construction

Whilst neither string nor sealing wax are used, all you need is equally cheap:

Use wide bore but thin walled rubber tubing (*RT* in Figures 2a and 2b) which will just fit inside the side-arm filter tube. This rubber tubing should be long enough to lie in an arc, so holding the marble dust ready for dispensing, but not so long as to be cumbersome. Depending on the flexibility of the rubber 300 to 400 mm should be about right.

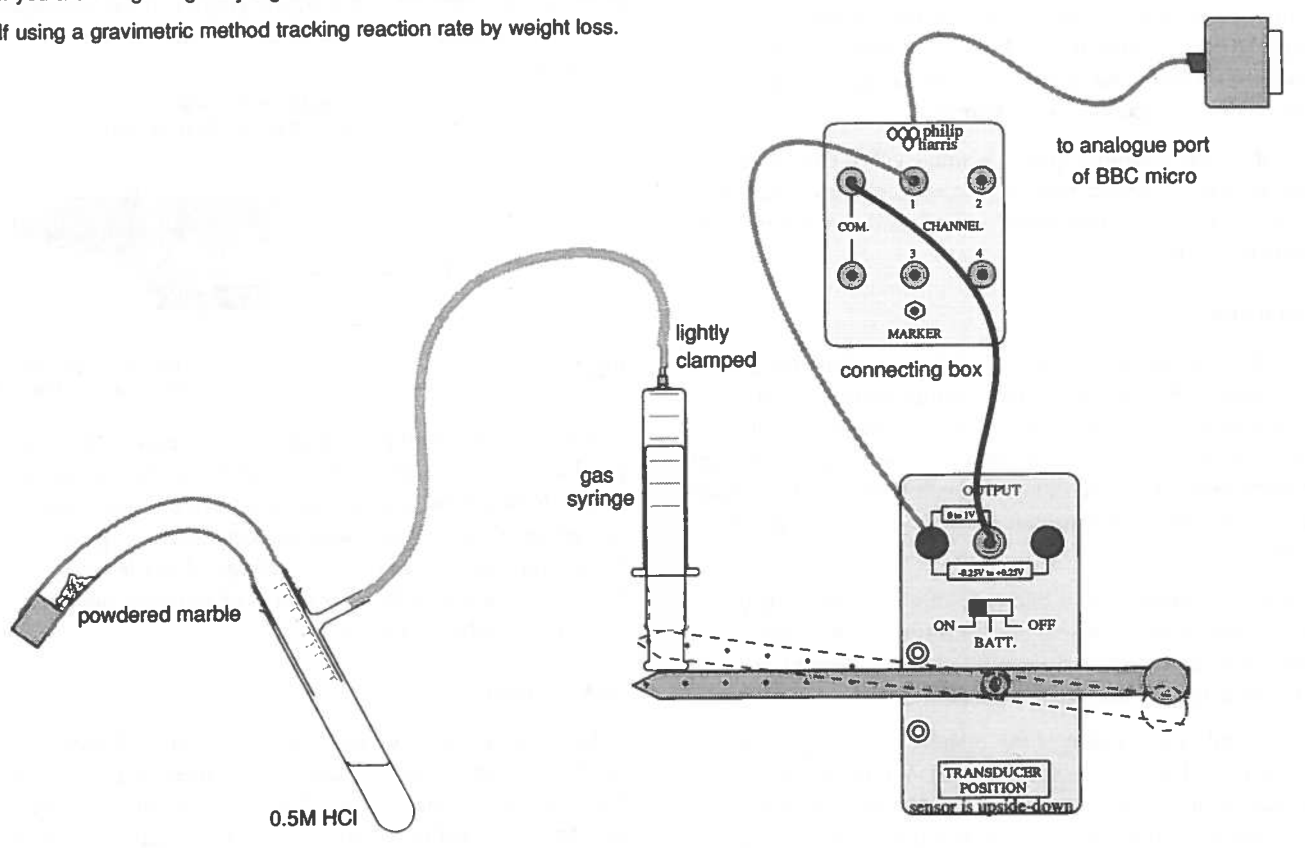


Fig.1. Overall measuring system - gas syringe method

Somewhat shorter lengths may be used if, before you start the reaction, the side-arm tube is kept tilted to prevent the powder from accidentally falling into the acid before you are ready (Fig 2a).

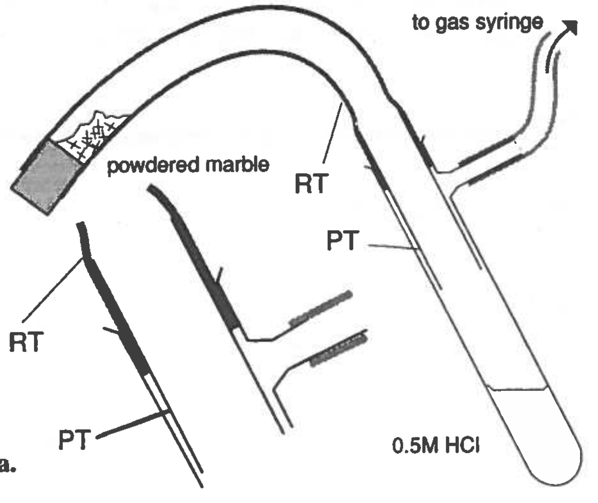


Fig.2a.

A bung is needed to fit in the other end of the tubing; for example a number 13 fits well inside commonly available rubber tubing of 16 mm bore and 3.2 mm wall.

Also required is a length of more rigid plastic tubing (*PT* in Figures 2a and 2b). This may be conveniently cut from the barrel of a 10 cm^3 plastic syringe and serves two purposes. It expands the rubber tubing a little and makes a better fit inside a 150 x 24 mm side-arm filter tube.

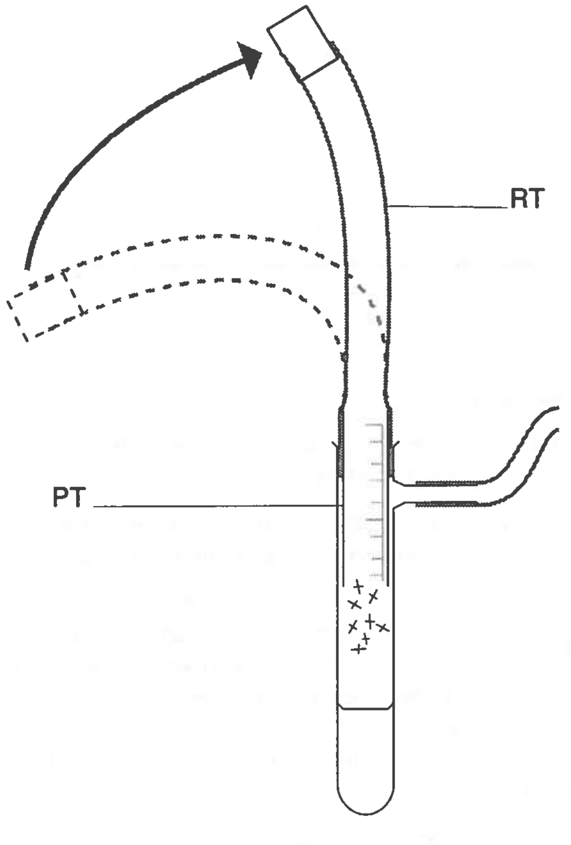


Fig.2b. - initiating the reaction

It also acts as a guide to prevent any of the powder from entering the gas syringe through the side-arm (Figure 2b).

Using the dispenser

The *internal dispenser* is pre-loaded with marble powder. Kept in the flexed state it is introduced into the mouth of the side-arm tube to seal it. All is then ready for the reaction to be initiated.

When you are ready to start logging it is simply a case of bending the flexible tubing up to a vertical position (see Figure 2b). Little or no time nor data need therefore be lost between commencement of the reaction and the onset of data capture.

Outline of method

1. Datadisc or Datadisc Plus[1] are loaded by autobooting.
2. When asked by the software for the length of time for logging enter two minutes. That will be more than sufficient for this reaction.
3. Using the syringe, for now detached from the side-arm tube, calibrate the output of the movement sensor in units of volume. This entails a two point calibration. With the syringe plunger pulled out to the maximum mark enter the volume setting shown. With the plunger fully home, enter zero volume units. It doesn't matter which of these points is entered first (see references [1] or [2] if you need more help).
4. Now dispense 15 cm^3 of 0.5M hydrochloric acid[2] into the reaction vessel and charge the rubber tubing with 1 g of powdered marble.
5. Raise the syringe plunger to read zero volume and connect the reaction tube to the syringe.
6. When ready, raise the flexible rubber dispenser and simultaneously start the logging by tapping the spacebar[3].
7. Repeat and obtain data for a reaction with small lumps of marble. Here you may need to log over a minimum of 15 mins.
8. From the two graphs measure the two rates in cm^3 CO_2 evolved per unit time from a straight part of the initial slope. You will find it useful to zoom in on selected parts of the reaction by using the *Display Utilities* menu at the foot of the graph[4].

1 For further detail of how to use these packages see SSERC Technique Sheets [1,2] or the supporting materials for the SEB Short Course on Electronics in Measurement [3].

2 You may wonder at the choice of 0.5M for concentration; if much higher concentrations are used, the effervesence is too vigorous and will spill over into the syringe. More concentrated acid can of course be used if a larger reaction vessel were chosen, say a Buchner filter flask.

3 It is probably better to start the logging a second or two before the reactants have met, for it is possible to chop off this part of the data afterwards (by using the Datadisc facility to Adjust axes).

4 For examples see overleaf and figures 4, 6 and 7 where this has been done.

Sample results

The raw results are shown for 15 cm^3 of 0.5M hydrochloric acid with 1 g powdered marble (Fig.6) and with 1 g small lumps (Fig.3). The remaining graphs are for the same runs but with the time axes adjusted to make for easier measurement of the slopes - powdered marble (Fig.7) and small lumps (Figures 4 and 5).

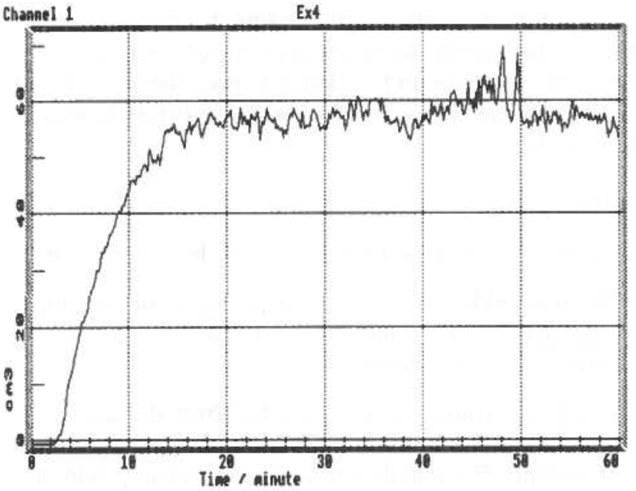


Fig.3

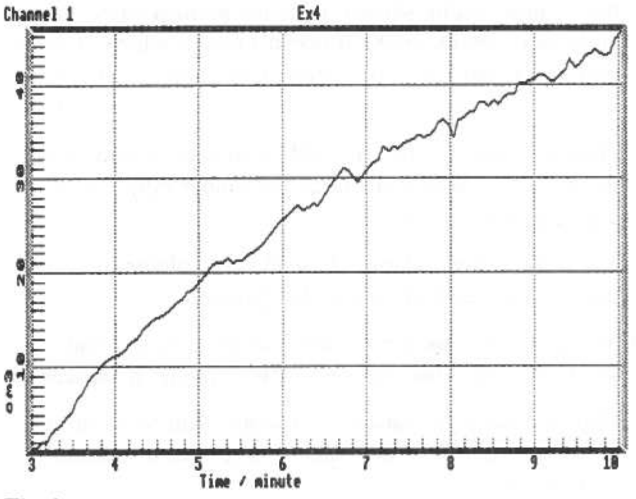


Fig.4

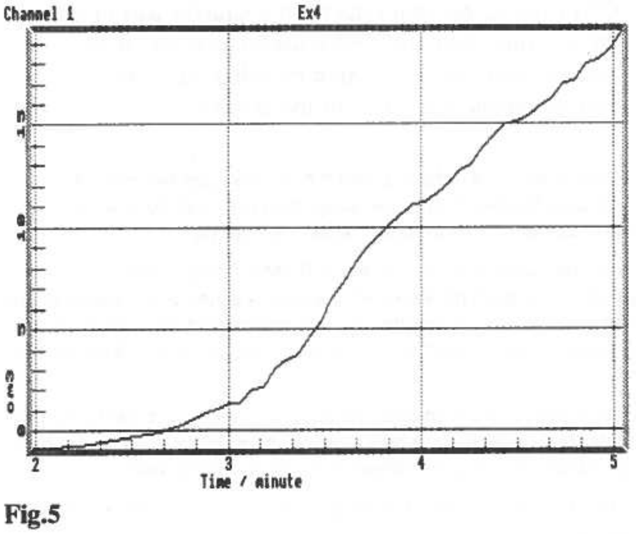


Fig.5

Examination of the graphs in Figures 7 and 4 will show that slopes for these two runs come out at 19 $cm^3\ s^{-1}$ and 0.15 $cm^3\ s^{-1}$.

Certainly, for the purposes of teaching at Higher Grade, this is much better better than having to mumble " --very fast"!

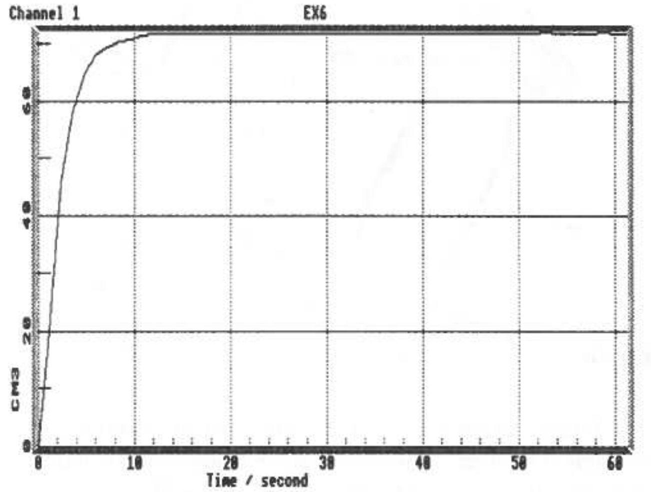


Fig.6

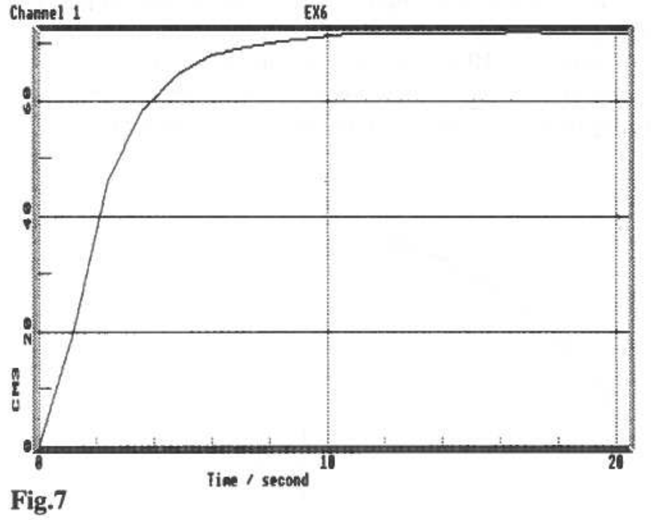


Fig.7

Additional points

Two further, interesting observations may be noted and possible reasons speculated upon:

- the long delay before the gas begins to evolve from the marble chips. It should be easy to test any hypotheses.

- the S-shape of the volume v. time graph in the initial stages (Fig.5). Why does the reaction rate appear to initially increase with time before following what we consider to be the *normal* type of decrease? You may need to *zoom in* on part only of the results. This is done by adjusting the axes in order to replot over a smaller part of the time axis in order to see this.

Answers on a post card please!

Pressure transducer method

It is possible to follow the reaction with a pressure transducer in place of the syringe, but the method will be somewhat flawed owing to the fact that relatively more carbon dioxide will dissolve under the pressure which builds up. Consequently the output signal will be artificially low. Nevertheless it will still be fine for comparisons.

Acknowledgement

Finally a word of thanks. Having looked at this problem some years ago it went onto the back burner. It had almost disappeared out of memory. But, at a recent ASE meeting, a timely question from Pat McLaughlin of Inveralmond Community High School spurred me into action again.

References

1. Technique sheets part of "Interfacing in Chemistry" notes, set of three parts available from SSERC.
2. "Standard Grade Chemistry Practical Guides", Vol 1, Topic 2, SSERC, 1988 (currently out of print).
3. Exemplar Materials for SEB Short Courses in Electronics, "Electronics in Measurement", Borders Regional Council, 1989, issued by SCCC. Reference booklets and cards on software and sensor usage are particularly useful.

HAZCONS

COSHH Assessment results : calcium carbonate dust - risk insignificant unless large amount prepared by grinding; 0.5M HCl so dilute cannot even be classed as 'Irritant' - still prudent to wear eye protection.

CSYS Chemistry

Experiment using a computer - pupil material

Instructional material is presented as an interim measure to assist teachers to meet a new requirement in the Sixth Year Studies syllabus. This states that at least one of the prescribed practical exercises is to be carried out using datalogging and computer interfacing techniques.

Introduction

In Bulletin 167 we outlined the use of some of the extra *Mathematical Utilities* in the upgraded data-logging software *Datadisc Plus*. We suggested two applications for Scottish senior school chemistry courses. Data-handling techniques and the experimental theory were described in detail and included:

calculation of derived values from raw data, log plots, differentiation, integration and X-Y plots.

Background

The SEB Arrangements documents for Standard Grade Chemistry mention the use of computers - mainly for computer simulations and plotting of statistical data, e.g. from the Periodic Table, but also for datalogging. Both at this level and at the Higher this last named use of the computer remains optional.

The revised CSYS Chemistry Arrangements, for implementation in and after 1992, however specifically require it. In at least one of the set experiments, a computer is to be used to log results.

Memorandum 16

Because of this and other changes to the syllabus, there are plans to update the national support material on practical work - SCDS[1] Memorandum 16. It could be some time before publication of that updated version.

As an interim measure, to assist teachers presenting in 1992 we are publishing here some sample materials for student use.

Student materials

This resource has been prepared by a practising chemistry teacher. It is however based on one of the chemistry experiments shown in Bulletin 167. We are most grateful to Barry Dunn, APT Chemistry at Auchmuty High, Glenrothes for the preparation of this resource and to Fife Education Committee for agreeing to Barry doing the work.

The instructions are intended for use by a novice (teacher or student). They are thus detailed and noticeably step-by-step. Once someone has used this datalogging package a few times its operation will become straightforward. Much of the detail will then be obsolete (we trust!).

Copyright

HAZCONS

COSHH risk asssessment results and suggested control measures : ethanol, 2-bromo-2-methylpropane (haloalkane) both highly flammable - ensure absence of sources of ignition; avoid inhalation of either vapour but for short exposure times at room temperature handling can be on the open bench; the alkyl halide (haloalkane) is an experimental animal carcinogen - when dispensing wear eye protection and suitable gloves (e.g. Silver Shield or nitrile for a short time); the product 2-methylpropan-2-ol is irritating to the skin but will be in dilute solution. Dispose carefully to waste with further dilution.

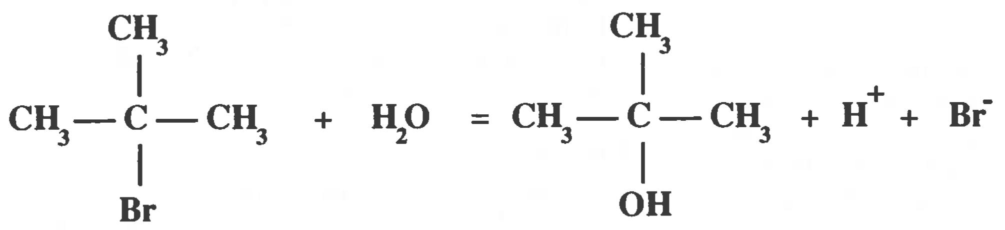
[1] SCDS, now known as SCCC.

EXPERIMENT G2 - Initial Rate Method (multiple short time runs)

The kinetics of the hydrolysis of (2-bromo-2-methylpropane)

Theory

This reaction proceeds according to the following equation:



alkyl halide

Fig.1 - Hydrolysis of an alkyl halide

The production of H^+Br^- (hydrobromic acid) means that the conductivity of the solution will increase as the hydrolysis proceeds. Therefore for dilute solutions the conductance will be proportional to the concentration of H^+ and Br^- ions. The reaction will be too fast if pure water is used, so the water is mixed with ethanol.

The rate of a chemical reaction is the change in the concentration with time. For reactants this will be a decrease but for products this will be an increase (Fig.2).

The rate of reaction at any instant is given by the gradient i.e. rate of change of concentration. We know the concentration at the start (time = 0) because we can control the starting conditions. If the reaction takes a long time to complete, then a small part of the initial curve can be regarded as a straight line. Thus we can obtain the gradient at the start which approximates to the gradient of OX.

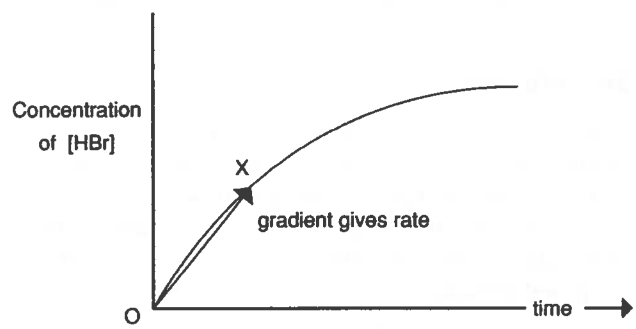


Fig.2 - Change in concentration of HBr with time

If we carry out the reaction using several different initial concentrations of the alkyl halide we can see how the rate depends on the concentration of this chemical.

The two most likely possibilities are that a straight line graph is obtained either for rate $\propto$ concentration - indicating a first order reaction - or for rate $\propto$ $(\text{concentration})^2$ which points to a reaction of second order.

Experimental details

Reagents

ethanol (industrial)
distilled water
2-bromo-2-methylpropane

Apparatus

bath, water (thermostatically controlled[1] at any temp. 20-30°C)
thermometer[1], -10-110°C
flask, conical (100 cm^3)
flask, conical (250 cm^3)
flask, volumetric (50 cm^3)
eye protection and gloves

[1] These first two items are used if great accuracy is required. Reasonable results may be obtained at room temperature provided that it does not vary greatly during a run, or between consecutive runs)

Apparatus (continued)

leads, low voltage
2 x measuring cylinders, glass (100 cm^3)
2 x pipettes, glass (1cm^3 bulb or graduated by 0.1 cm^3 divisions)
pipette filler (plastic pump)
interfacing equipment, 4-Channel Connecting Box + software
meter, conductivity
probe, conductivity

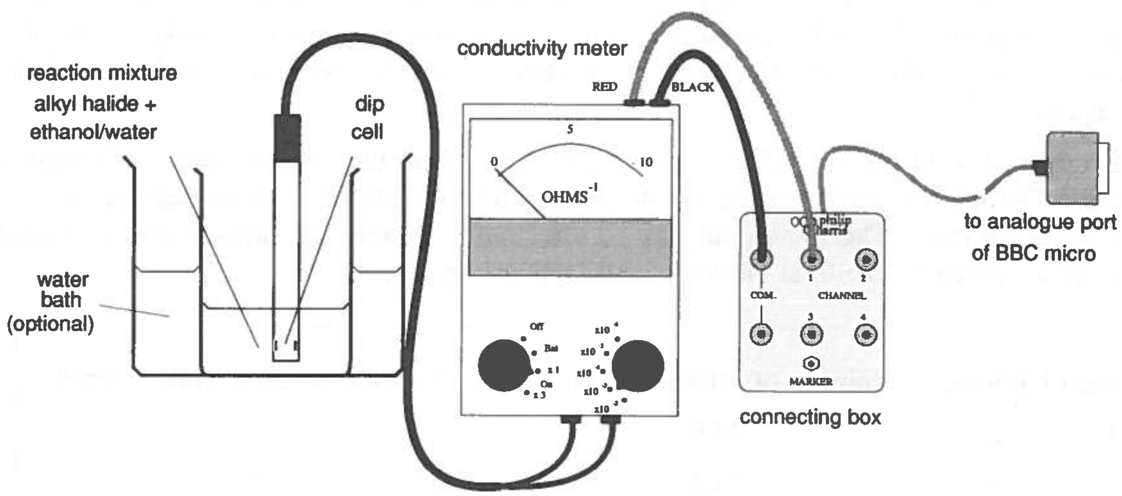


Fig.3 - Datalogging conductivity

Procedure

Note that where a letter or word is enclosed in angled brackets e.g. <Escape>, <Return> etc. the computer key or keys indicated are to be pressed. Words or phrases in *italics* generally signify something that appears on screen or on an interface e.g. a menu name or menu choice.

1. Prepare 125 cm^3 of aqueous ethanol in a dry 250 cm^3 conical flask by mixing 100 cm^3 of ethanol with 25 cm^3 of distilled water. If a water bath is used place this mixture in the bath to equilibrate its temperature with that of the bath (20°C or thereabouts is suitable).

2. Set up the apparatus as in Fig.3. Adjust the conductivity meter to the 1 x 10^{-3} Siemens scale.

3. Pipette 25 cm^3 of the ethanol/water mixture into a 50 cm^3 beaker. Use a 1 cm^3 graduated pipette to remove 1 cm^3 of this mixture and discard.

4. Load the *Datadisc Plus* program disc into drive 0 of the disc drive and AUTOBOOT - Press <Shift & Break>, lift <Break> then <Shift> to obtain the *Main Menu.* If you want to store data on a disc other than the *Datadisc Plus* program disc press <D> to *Change drive for data.* Collect a blank formatted disc and place it in the second drive. If you have twin $5^1/_4$″ drives then the top side of the bottom drive is drive 1 and the underside of the bottom drive is drive 3.

5. From the *Main Menu* press <Return> to indicate that you are ready to record *Analogue data.*

6. Press <Return> from the *Recording Options* menu for recording on one channel against time.

7. Press <Return> to record on channel 1. This channel is used because the connections are to channel 1 on the connecting box.

8. Enter <2MIN> and press <Return> to log data for 2 minutes.

9. Using a graduated pipette add 1 cm^3 of 2-bromo-2-methylpropane to a second 50 cm^3 beaker and put in the conductivity probe. (cont./over)

10. Add the 24 cm^3 of ethanol/water mixture prepared earlier to the beaker containing the alkyl halide and probe. Shake the mixture and at the same time press the <SPACEBAR> on the computer to begin logging data.

You will see a line moving from left to right on a bare graph with only a rough scaling on the axes. This real-time display of voltage vs. time may show a very small apparent variation in plotted voltage. Do not panic. Software of the Datadisc Plus type looks for the maximum and minimum voltages and will automatically rescale. It will display a more pleasing graph once the data has been processed.

11. Press <N> for *New Recording* when the graph has been drawn on screen. The program then states *Currently set to record for 2MINS on channel 1 (VOLTS)* and asks *Do you wish to change this?* Type <N> and press <Return>. The software moves your original data to channel 2 - make a note of what chemicals were used for this channel of data. The system is ready to record a second set of data on channel 1 again.

12. Repeat steps 3 to 11 for Runs 2 to 4 in Table 1. Note where the software puts each channel of data as before. The table summarises this below. When all four channels contain data i.e. runs 1- 4 there is no room to record more. Therefore omit step 11 after run 4. Change the proportions of ethanol/water to alkyl halide as directed. The total volume should always be 25 cm^3.

Run	Channel	Volume of ethanol/water (cm^3)	Volume of alkyl halide (cm^3)
1	2	24.0	1.0
2	3	24.2	0.8
3	4	24.6	0.4
4	1	24.8	0.2
5	repeat on 1	24.9	0.1

Table 1

13. You now should have four channels of data and details of which channel applies to which run (Table 1). When the last run has been displayed on screen press <U> for the *Display Utilities Menu.*

14. It would be a good idea to save your valuable data at this stage so type <S>. Enter a <filename> and then some details about the experiment when prompted. This should include a brief description of which run corresponds to which channel, the date, the user etc. Press <Shift and Return> together to finish saving.

15. Select <2> from the *Display Utilities Menu* to display *Two or more* (channels) *against time.* Type <Y> for each of the channels to select them for display (some older versions of *Datadisc Plus* may ask you to press the <Tab> key instead). You can now compare visually what effect the initial volume of alkyl halide has on the rate at which the conductivity of the solution changes. Press <P> with the graphs on screen to get a hard copy on the printer.

Using the Mathematical Utilities to calculate rates (gradients)

16. Press <Escape> when the four channels of data are displayed on screen. Select <U> for the *Options and Utilities* from the *Display Menu.*

17. Before we can calculate the best fit straight line we must have at least one free channel. This is OK since you saved all the data at stage 14. Move the highlighting bar using the <down> cursor key to *Delete channel* and press <Return>.

18. Type <4> to select channel 4 for deletion and confirm by pressing the <Delete> key.

19. Type <Y> to select *Least squares fit*. The following display appears on the *Mathematical Utilities* menu:

> *Least squares fit of y = Ax + B*
> *Enter either the channel number*
> *for x or T for time as x ->*

Type <T> and press <Return> as the x-axis of the rate graph represents time.

20. You are asked to *Enter the channel number for y ->*. Enter <1> and press <Return>. The program then shows percentage completeness values up to 100 as it processes the results. The display then appears as:

> *y = (gradient)x + (intercept on y-axis)*
> *y represents channel 1 data* (best fit straight line goes on channel 4)
> *x represents time (s)*

The important number to record on paper is the gradient. Refer back to your notes and Table 1 to ascertain to which run this applies. The *Correlation coefficient* should be 1 for a good straight line fit with positive gradient or -1 for one with negative gradient. If desired type <2> from the *Display Utilities* menu and then <Y> for channels 1 and 4 to see how well the best fit straight line (channel 4) corresponds to the original data (channel 1).

21. Repeat steps 17-20 and derive the gradients for channels 2 and 3. Make a table showing *initial volume of alkyl halide vs gradient.*

22. Carry out steps 17 and 18 to delete channel 1. This is to make space for the channel 4 data we deleted at step 18 the first time round.

23. From the *Display Utilities menu* type <W> to *Add data from another file*. If there is only the <filename> you saved at step 14 the program will tell you that *The chosen file has 4 channels of data but there is space to load only 1. Choose now.* Press <4> and <Return> to select channel 4. This should now load in to channel 1 on the *Display Utilities* menu.

24. Repeat steps 17-20 and derive the gradient for this run. Enter it on your Table. Remember that this refers to Run 3 data recorded originally.

25. If time permits you can press <M> to return to the *Main Menu* and repeat the experimental procedure and analysis for Run 5. Enter the relevant details on your Table.

26. Use your results to produce a graph of initial rate versus initial volume of alkyl halide (proportional to initial concentration).

27. Write down the rate law by filling in the value of n in:

Rate $\propto$ [alkyl halide]^n i.e. Rate = constant k [alkyl halide]^n

Note that we can convert this expression to the logarithmic form:

log(rate) = log(constant k) + $n$log[alkyl halide]

Try plotting a graph of log(rate) against log[alkyl halide].

The value of n is the gradient of this graph.

Technical articles

Higher Grade Physics : Photodiodes

This article describes practical work in support of the recently alterered section on photodiodes in the Revised Higher Physics syllabus.

Part One: *I-V* characteristics and light dependence

Suggested Activity: Measure variation of current with applied p.d. for a forward-biased and a reverse-biased photodiode under a constant fixed level of illumination.

Suggested Activity: Show that the reverse leakage current increases with light intensity.

Both Suggested Activities can be undertaken in tandem in a series of experiments to plot out the variation in current with applied p.d. across the photodiode. Two graphs are required - one for the photodiode in darkness, the other under uniform illumination. The outcome is a pair of superposed graphs (Fig.1).

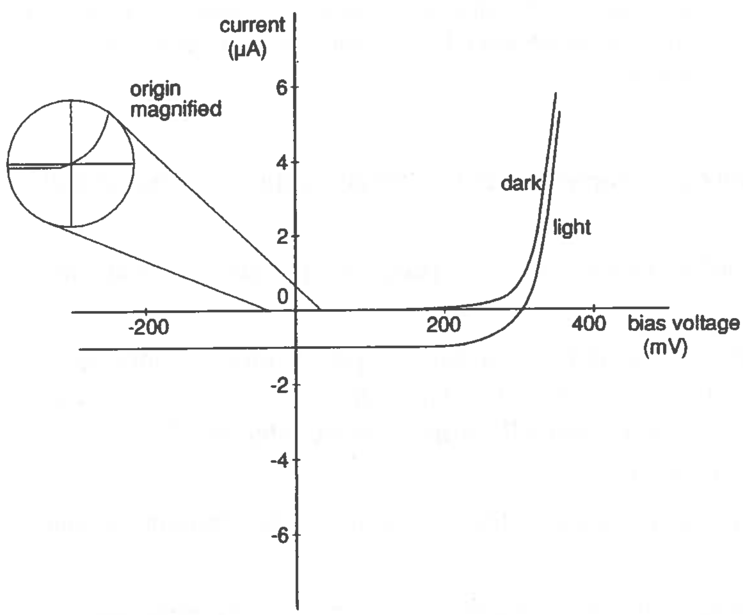


Fig.1 ***I-V*** **characteristics of photodiode**

It can be seen that

the reverse leakage current is very small, is almost independent of biasing voltage, and increases with light intensity;

the *I-V* plot shifts bottom right under illumination;

there is fine detail around the origin which can be unravelled by experimental technique.

Experimental details

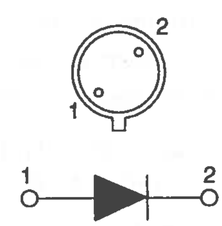
Three ways of measuring *I-V* characteristics are given. They all depend on using a pair of digital multimeters. The only demanding criterion is that one of the multimeters[1] should have a d.c. current range reading to 200 μA full scale, and a resolution of 0.1 μA.

The photodiode should be sensitive to visible radiation. The cheapest in the RS Catalogue which is suitable is stock number 305-462, which costs about £3. A pin-out diagram is given (Fig.2). From its specification, the maximum forward current this diode can conduct is 100 mA. The maximum forward bias voltage is 1 V.

The *I-V* plots in this article were obtained from a more expensive photodiode, BPX65, which costs £4.52 from Farnell Electronic Components.

Since we began preparing this article, Farnell have introduced a range of inexpensive photodiodes. Some would not be suitable, being exclusively infrared sensitive. However there are four that are sensitive to daylight and cost around a £1 or less. They are types BPW34, SFH206K, SFH217 and SFH2030[2]. The first in this list is especially recommended. Having a light sensitive surface area of 7.5 mm^2, it generates a photocurrent which is about ten times greater than the smaller RS 305-462, or BPX65.

Fig.2 Pin-out diagram of photodiode RS 305-462



The photodiode should be mounted face upwards on a small horizontal board. Either 0.1" stripboard measuring 40 mm x 40 mm, or prototype board, or a Unilab Alpha solder board panel (223.085) would suffice. The terminals should be labelled *anode* and *cathode*.

To achieve dark conditions, the photodiode should be covered with a black, plastic, 35 mm film can. For light conditions, the photodiode should be exposed to steady indoor illumination from either diffuse daylight or artificial ceiling lights. Under most weather conditions, the light

[1] Multimeters, some having this specification, were reviewed in Bulletin 167, September 1990.

[2] Farnell order codes are BPW34, 212-714, 212-726 and 212-740.

level over the ten minutes it takes to record the readings is usually reasonably constant. Only if sunlight is highly variable, such as on a day with cumulus clouds, might it be necessary to block out daylight and substitute artificial lighting. The provision of bench lamps is not required.

Voltmeter-ammeter method

The circuit is shown in Figure 3. The bias voltage is drawn from a potentiometer across a 1.5 V cell. The polarity of the battery should be reversed to reverse the photodiode bias voltage. By this arrangement, continuously variable bias voltages between -1 V and 0 V for reverse bias, and not exceeding +1 V for forward bias are obtainable.

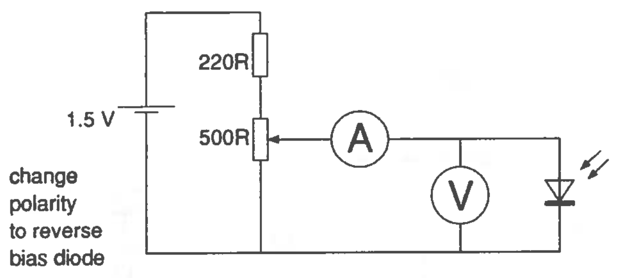


Fig.3 Circuit diagram for voltmeter-ammeter method

The position of the meters deserves attention. Taking the impedance of the digital voltmeter to be 10 MΩ, a bias voltage of 1.0 V causes the ammeter to read high by 0.1 µA, which is its least significant digit. This error only becomes appreciable when reading reverse bias currents. If the reverse bias voltage is increased in one volt steps from 0 V to -10 V, the leakage current will be seen to increment by 0.1 µA a volt, i.e. from 0.0 µA at 0.0 V to -1.0 µA at -10 V. Restricting the reverse bias voltage range with this circuit to -1 V should prevent this error from being significant.

I-V plots taken under dark conditions for three separate ammeter ranges are shown (Figures 4, 5 and 6). It can be seen that the point where conduction appears to start moves successively leftwards with increase in ammeter resolution.

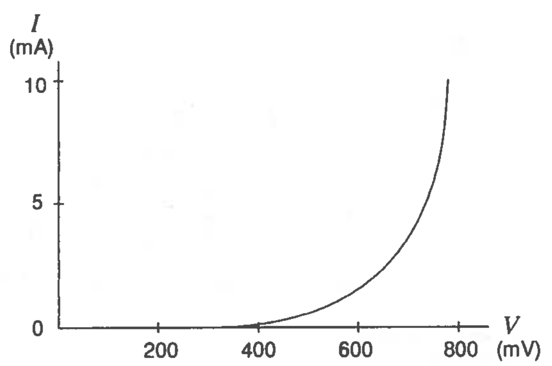


Fig 4 *I-V* plot, dark conditions, 20 mA ammeter range

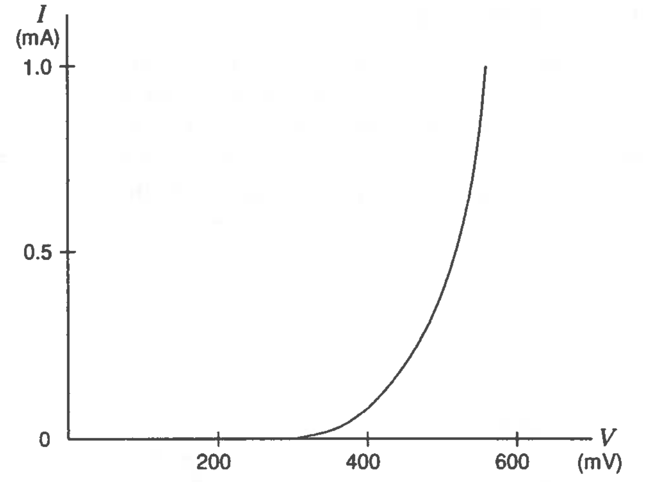


Fig 5 *I-V* plot, dark conditions, 2 mA ammeter range

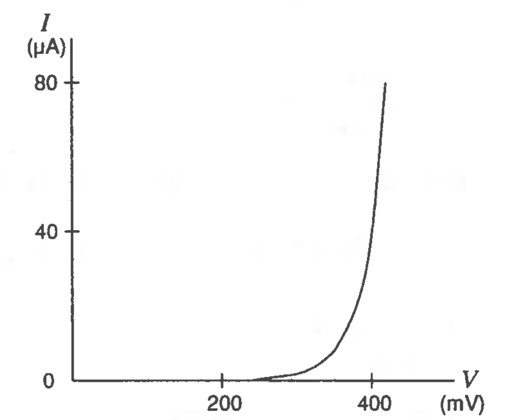


Fig 6 *I-V* plot, dark conditions, 200 µA ammeter range

If the 200 µA range is used, the reverse leakage current under illumination is just large enough to read and the desired pair of graphs can be obtained (Fig.7). The advantage of using this method is that it is the simplest of the ones that are described. However it fails to detect the presence of conduction under dark conditions at bias voltages less than 200 mV in the forward direction.

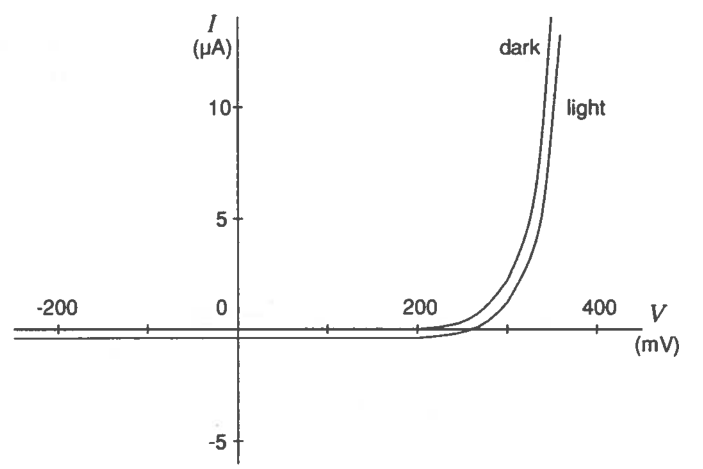


Fig.7 Complete *I-V* plot, 200 µA ammeter range

Two-voltmeter method

This method is more complex than the one just described. Its advantage comes from being able to investigate current to a resolution of 10 nA by measuring the p.d. dropped across a resistor in series with the photodiode. The complexity arises because both the bias voltage V_{bias} and current I are derived by calculation (Fig.8).

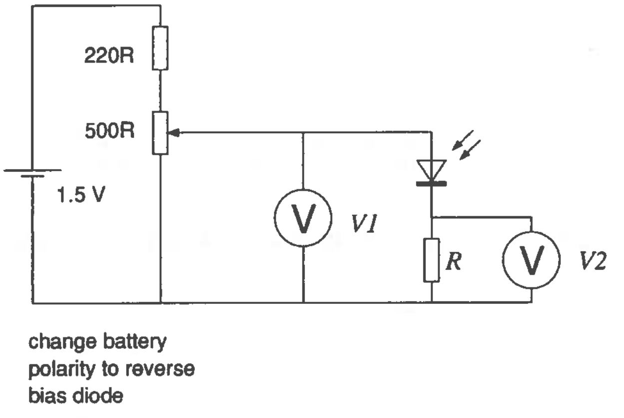


Fig.8 Circuit diagram for two-voltmeter method

If the voltmeter readings are V_1 and V_2, it can be seen that

$V_{bias} = V_1 - V_2$ and

$I = V_2/R$

If R is 10 kΩ, the error due to the resistance of the voltmeter across it is insignificant. The current I becomes $10^{-4}\cdot V_2$ amps. By using the 200 mV range on the meter that measures V_2 its resolution of 0.1 mV is equivalent to a resolution of 10^{-8} A, or 10 nA.

Under dark conditions, conduction is seen to start for a forward voltage of 100 mV (Fig.9).

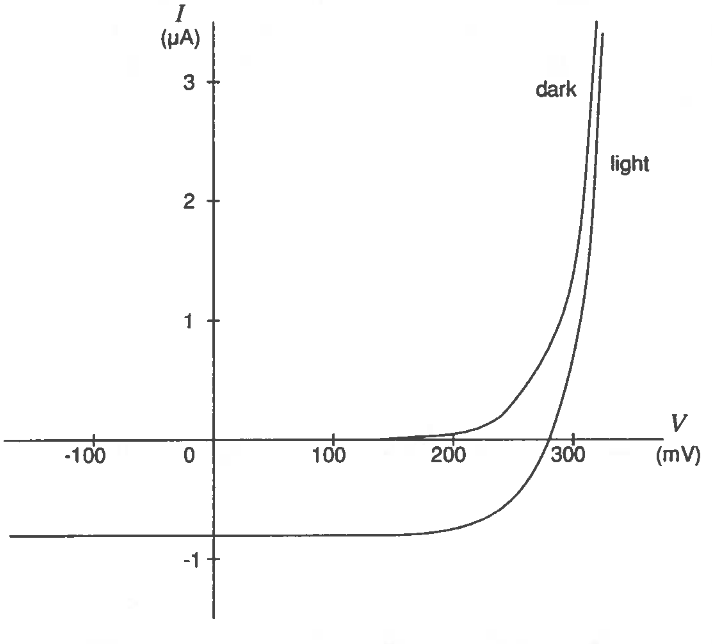


Fig.9 Complete I-V plot, two-voltmeter method

By replacing the 10 kΩ resistor in R for one whose value is 1 MΩ, current can be measured to a resolution of 0.1 nA. If this substitution is made, the photodiode leakage current in darkness under 0 V bias is seen to be 0.0 nA. Under forward bias, conduction is seen to start at about 50 mV. Whilst this increase in sensitivity lets you explore the characteristics more fully, unless the resistance of the voltmeter is also considered, the derived value of current is 10% too low.

Taking the method further, were R to be removed altogether (Fig.10), because of the 10 MΩ resistance of the voltmeter, I in amps can be derived from $10^{-7}\cdot V_2$. Using a 200 mV range, the resolution increases to 10 pA. However, many teachers may find this version too obtuse. The method is pointed out, but not recommended.

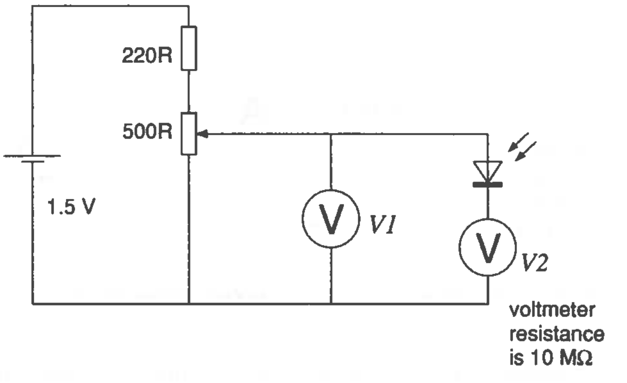


Fig.10 Increasing the sensitivity of the two-voltmeter method

Op-amp method

Op-amps may be used to measure very tiny currents using current to voltage conversion (Fig.11). Taking advantage of the extremely high input impedance of some op-amp types, one can with confidence assume that all the current I travels through the feedback resistor R_f. Because the non-inverting input is tied to 0 V, the inverting input is also always 0 V. It is the perfect ammeter - one whose resistance is zero.

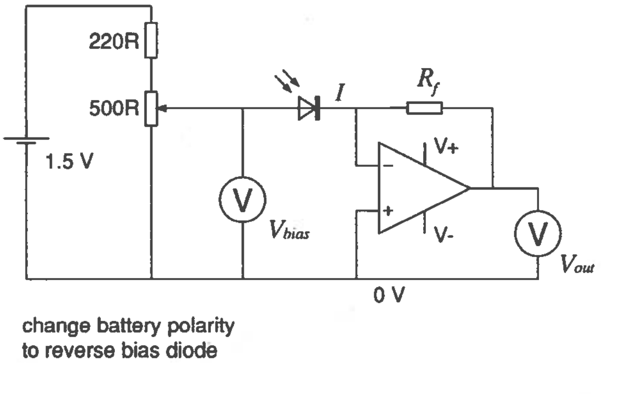


Fig.11 Circuit diagram, op-amp method

It should be obvious then that

$I = -V_{out}/R_f$

If R_f is 10 MΩ, I is equal to $-10^{-7} \cdot V_{out}$ amps. Using a 200 mV range when measuring V_{out}, the resolution is 10 pA.

The Amplifier Investigations Board in the Unilab Alpha kit may be used. It contains a CMOS op-amp, ICL7612, which has a suitably high input impedance. In the absence of this board, any standard FET or BIFET such as TL071[3] may be used.

Under dark conditions, the graph is seen to vary continuously from an apparent reverse leakage current of about -0.2 nA at 0 V bias in the forward bias region (Fig.12). Under reverse biasing, the leakage current remains fixed at -0.2 nA. This value of -0.2 nA is a systematic error, being caused by a 2 mV offset voltage in the op-amp.

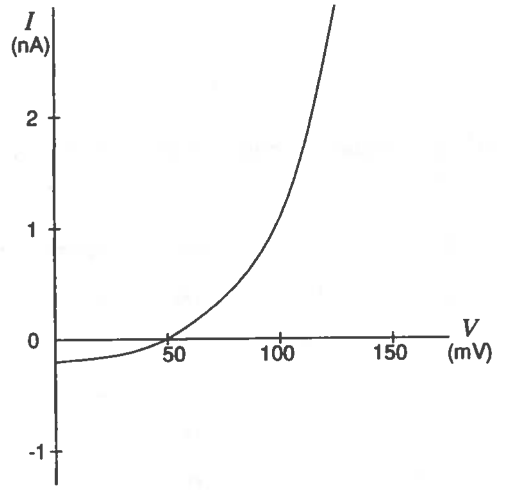


Fig.12 *I-V* plot, dark conditions, op-amp method

Because of the sizeable reverse leakage current under illumination, a 1.0 MΩ resistor was found to be more suitable for R_f. The composite plot is shown (Fig.13).

It should be realised from this example that small errors can arise from offset voltages or offset or bias currents in the op-amp. This could be used as an example of errors being introduced by the method of observation.

It can be noticed that the reverse leakage current under light differs from graph to graph (Figures 7, 9 and 13). These differences are not due to the method. They are entirely caused by changes in the level of illumination.

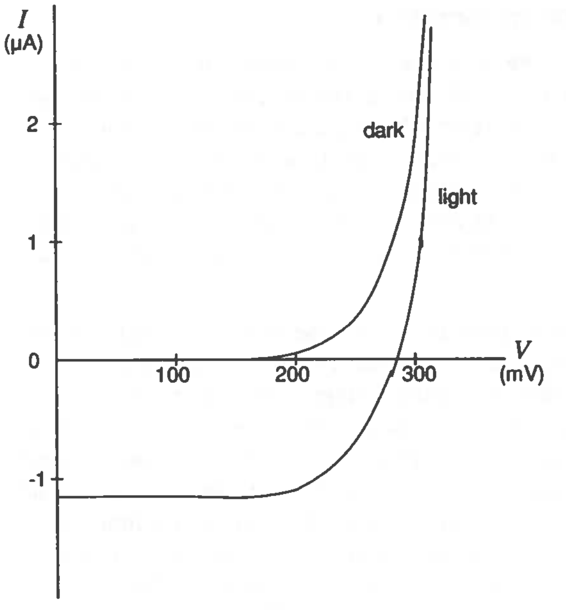


Fig.13 - *I-V* plots, light and dark conditions, op-amp method

Teaching strategy

The article has hitherto described some different means of obtaining the *I-V* characteristics of the photodiode. The following suggested teaching order is given.

1. The characteristics are initially plotted to a resolution of 0.1 μA using the ammeter-voltmeter method. You could, if time permits, refine the measurement of current by working successively with 20 mA, 2 mA and 200 μA ranges. This would gradually unveil the smaller and smaller currents which exist near zero biasing.

2. The characteristics should be replotted in finer detail using one of the two other more precise methods - either the two-voltmeter, or op-amp, method. This helps reveal that the photocurrent is light dependent across many orders of magnitude.

Underlying this practical work is the need to be watchful for errors of observation. Particular attention could be given to:

the effect which taking a measurement has on that which is being observed;

the resistances of ammeters and voltmeters;

the relative positions of ammeters and voltmeters;

the precision *vis à vis* the accuracy of meters;

the uncertainty in the last digit of digital meters;

the tiny offset errors which can exist with op-amp circuits.

[3] BIFET op-amp TL071, RS Components, stock number 304-245.

Physical interpretation

When the photodiode is zero biased, that is no external voltage is applied, and in darkness, no voltage is generated across it. However when light falls on the photodiode the photodiode produces an e.m.f., which can be measured directly with a voltmeter. The e.m.f. increases with increasing light intensity. This effect is the basis of solar cells, and the photodiode is said to be in the *photovoltaic* mode.

When a photodiode is reverse biased it is said to be in the *photoconductive* mode. The current that flows is independent of biasing voltage over quite a large range, typically between 5 and 15 volts. This current, known as the *photocurrent*, is generated by the production of electron hole pairs by the incident photons on the p-n junction and is directly proportional to the light intensity falling on that junction. The photodiode in its photoconductive mode is thus a very good detector of light intensity. The photocurrent is proportional to light intensity over many orders of magnitude.

Part Two: Light dependence

Suggested Activity: Show that the reverse leakage current increases with light intensity.

Having shown from the I-V characteristics that the reverse leakage current is light dependent, the relationship might now be quantitatively investigated. This should show that the reverse leakage current is directly proportional to light intensity. The procedure, known as the two-lamp method, was described in Bulletin 145 [1]. It is summarized here.

The working space should be a light-tight enclosure such as a box, or cupboard, or drawer, whose inside surfaces have been painted matt black. Two similar lamps A and B are mounted adjacent to one another at the mid-point of one of the sides. The photodiode is mounted on the mid-point of the opposite side (Fig.14). The lamps are wired to separate power supplies with switches and dimmer controls. The reverse leakage current should be obtained by any of the means already suggested. Only the lamps and photodiode should be inside the enclosure. The other apparatus should be external.

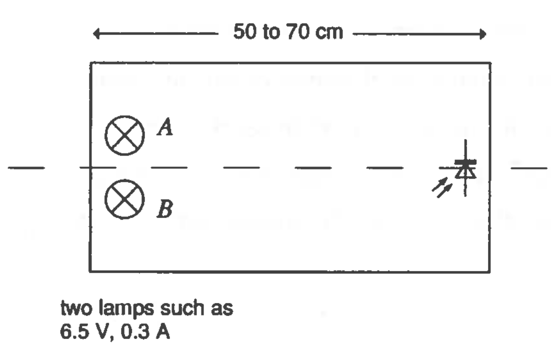


Fig.14 Plan of enclosure with lamps and photodiode

First only lamp A is lit, at arbitrary brightness, and the leakage current recorded. Then B only, and the brightness adjusted so that the leakage current has the same value as obtained from A. Finally both A and B are lit. If the relationship is linear, the leakage current would precisely double. The procedure should then be repeated for different initial settings of A.

Sample readings for two photodiodes are given (Tables 1 and 2). From the technical data sheet, one might expect the photodiode to have a linear response. Measurements do not wholly bear this out.

A	*B*	*A+B*	**error**	**%error**
2.2	2.2	4.3	0.1	2
4.2	4.1	8.0	0.3	4
7.9	8.1	15.4	0.6	4
15.9	15.8	30.5	1.2	4
32.0	31.8	61.2	2.6	4
60.2	60.0	115.2	5.2	4
114	112	217	9	4

Table 1 Two-lamp method readings for photodiode RS 305-462

A	*B*	*A+B*	**error**	**%error**
0.37	0.37	0.74	0.00	0
0.55	0.55	1.07	0.03	3
0.75	0.69	1.42	0.02	2
1.24	1.21	2.45	0.00	0
1.60	1.45	3.03	0.02	1
2.16	2.11	4.21	0.05	2
2.71	2.44	5.13	0.02	1

Table 2 Two-lamp method readings for photodiode TIL 100

The teaching point from this exercise is that photodiodes are widely used, in reverse bias mode, as sensors of light. Their performance is often satisfactorily linear.

Part Three: Fast response

Suggested Activity: Show that the switching action of the photodiode is extremely fast.

Mechanical chopper

Two ideas are suggested. The first is the direct approach of mechanically chopping light in front of a photodiode. The Centre sells in Surplus two types of encoder disc made of stainless steel. One has fifteen slots. The other, thirty[4]. Either would do, but you'll get faster chopping with the thirty slot disc.

[4] Stock numbers 378 and 642.

If the disc is fitted to the shaft of a small motor - preferably a precision one so that it runs steadily - you should be able to achieve a chopping frequency of several kilohertz.

For the light source, use a high intensity 3 mm diameter red LED with a clear rather than diffused lens and narrow viewing angle. Suitable LEDs are HLMP1321 (24p) from Farnell and 590-339 (28p), supplied in packs of five, from RS. A suitable dropping resistor, given a supply voltage of 5 V, is 220 Ω. For the sensor, use the photodiode in reverse bias, and observe on a CRO the reverse leakage current dropped across a resistor (Fig.15) whose value is critical. It must lie between 1 kΩ and 10 kΩ.

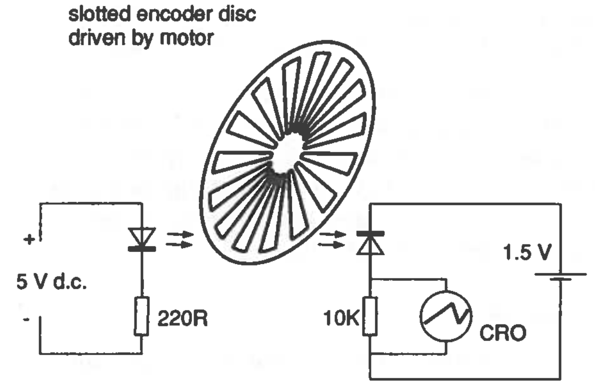


Fig.15 Fast switching action with mechanical chopper

If the signal from the photodiode is fed to an audio amplifier with loudspeaker, and the motor's speed varied, corresponding changes in the frequency of the audible tone will be heard.

If the edge of a fleck of paper is allowed to touch the spinning disc, the paper sings at the same pitch as the loudspeaker.

Electronic switching

For the second idea, the high intensity red LED should be driven from a function or signal generator whose frequency is continuously variable to at least 100 kHz, though 1 MHz is preferable. If you use an oscillator with a TTL type of output, remember that TTL devices sink current rather than drive loads. A separate 5 V supply is therefore needed to power the LED (Fig.16).

If using a signal generator with square wave output, the LED should be driven directly from the high impedance output, taking care to set the voltage to suit the LED and its series resistor. Because square wave signals are a.c., a diode should be connected in parallel with the LED to prevent it being damaged by too high a reverse voltage (Fig.17).

All the photodiode types referred to at the beginning of the article have been tested to 1 MHz, and all have been found to work at that rate. The most satisfactory are BPW34 and SFH206K, giving the largest output signals. Because of their relative shapes, BPW34 is probably the better buy.

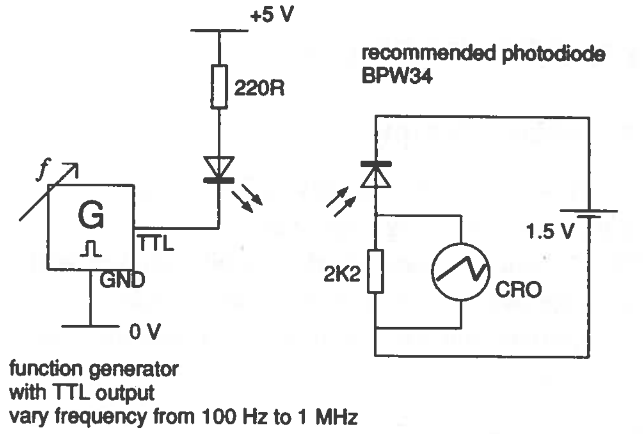


Fig.16 Fast switching action to 1 MHz using TTL output

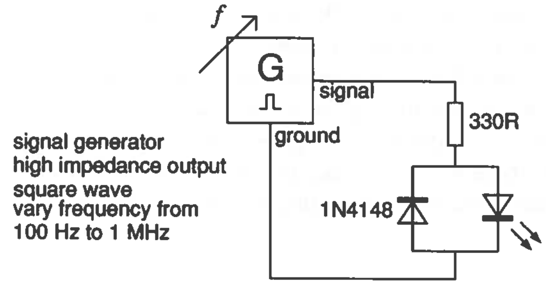


Fig.17 Driving a LED from a signal generator

The amplitude of the photodiode signal suffers from high frequency roll-off as 1 MHz is approached. If the value of the series resistance is 10 kΩ, roll-off starts about 200 kHz and by 1 MHz the amplitude has reduced eightfold. However if the resistance is 2.2 kΩ, roll-off doesn't start till about 500 kHz and the 1 MHz amplitude is 60% of its value before roll-off. A 2.2 kΩ resistor seems your best bet provided you can make do with its smallish amplitude signal.

Frequency responses for the worst and best signals are tabulated (Table 3). The responses of the other diodes mentioned in the text lie somewhere between these extremes.

Diode	Resistor	Amplitude			Roll-off frequency
		10 kHz	100 kHz	1MHz	
	(kΩ)	(mV)	(mV)	(mV)	(kHz)
BPW34	2.2	180	180	100	500
	10	800	800	100	200
RS305-	2.2	11	10	6	500
462	10	40	-	-	100

Table 3 - High frequency roll-off

Acknowledgement

The two-voltmeter method was given to us by Peter Bates, at that time of Edinburgh University's Department of Electrical Engineering on secondment from Firrhill High School, now at West Lothian College.

Reference

1. "Linearity of radiation detectors and the inverse square law", SSERC, Bulletin 145, April 1985.

Equipment Notes

Autoclave review

We report on three models of laboratory autoclave and a large pressure cooker. Performance criteria are described together with test procedures. The results of such tests are summarised and recommendations on purchasing are made.

Scope of article

This is as outlined in the abstract above. The article does not deal in detail with the technical background to autoclave design and usage. Readers are assumed to have a working knowledge of the general principles of steam sterilisation for microbiological work at school and non-advanced FE levels. These principles were summarised in SSERC Bulletin 126 [1] and the material was subsequently incorporated in both editions of Topics in Safety [2].

Criteria for equipment choice

Autoclaves intended for laboratory scale use tend to be of the vertical, cylindrical, non-jacketed type. *Non-jacketed* refers to the lack of any special arrangements for collecting condensate and providing partial vacuum for the drying off of sterilised materials. Pathology and commercial laboratories as well as hospitals use such devices. Some of the latter may be so large as to allow walk-in access and have doors rather than mere lids[1].

Capacity and cycle times

The above distinction is not trivially drawn. The point is that the design and operation both of portable laboratory autoclaves and pressure cookers are essentially the same. The major difference lies in the size of the vessels and hence their capacities. That in turn leads to differences in overall sterilisation cycle times which depend partly on thermal capacities. Hence different heating up and cooling times have to be added on to a holding time which itself may well be common to several types of autoclave or cooker.

It follows that one penalty for having a large vessel may be an increase in turn-round times for the preparation and disposal of a given amount of media etc.

Coursework and costs

Price is also roughly a function of size. A large laboratory autoclave is probably justifiable only where the coursework and student numbers require a sufficient scale of preparation and disposal work[2].

Several cookers

Even where the scale of the work might justify the purchase of an autoclave, and where that purchase can be financed, it is still worth considering the alternative purchase of several pressure cookers (say, three or four) and the ancilliary gas rings or hotplates. This is not only cost-effective but offers flexibility of usage as well as shorter cycle times for individual loads. It is a ploy which may be ruled out where tall items have to be sterilised.

One other distinct advantage of pressure cookers, where these are of the type where pressure is set by means of weights, is a facility to lower the pressure and hence the temperature. This may be necessary when certain media have to be sterilised which may caramelise or be otherwise damaged at higher temperatures. Clearly lowering the temperature will mean increasing the holding time.

Pressure cookers of domestic pattern tend to be more attractively priced in local department or discount stores than they are in the specialist educational suppliers' catalogues. The type to buy is the taller form such as the Prestige *Hi-dome* model rather than the more recently introduced models with flatter lids.

Steam sterilisers

Where an autoclave cannot be afforded but pressure cookers present problems with capacity, or height, then it may be worth considering one of the larger models of a portable *steam steriliser*[3]. We have not to date included this type of device in our testing programme but it was reviewed by CLEAPSS, our English sister organisation. What we can report on here is a large pressure cooker designed for use by the catering trade. This has a capacity approaching that of a lab autoclave but operates at a somewhat lower pressure.

Electrical or gas heating

All of the devices reported on here, other than the *Duromatic Hotel* pressure cooker, are electrically heated. This is because we wished to assess electrical safety features. Gas heated models of the ST19 autoclave are however still available and are less expensive than electrical models. Results of earlier trials with such gas heated models indicate satisfactory performance in our time/temperature and bacteriological tests.

Evaluation and test procedures

Features examined

We looked at and report on physical and mechanical features of likely interest such as dimensions, capacity etc. We also examined mechanical arrangements which impinge on safety such as lid fastening and restraint arrangements, safety valves and pressure relief devices etc.

1 Hence the title of one relevant guidance note which is entitled "Safety at autoclaves".

2 In "scale" we include both size of individual containers (e.g. Petri dishes or Universal bottles as against a tall-form fermenter for example) and overall numbers of individual media containers. The latter clearly depends on the level of sophistication of the microbiology courses being taught and pupil or student numbers.

3 Such as AUX-210-W from Griffin and George or an equivalent model from the NCBE.

Performance criteria

The references cited [1, 2] in the section "Scope of article" both point to Medical Research Council (MRC) recommendations on holding times at three different, relative steam pressures (and hence temperatures)[1].

In the context of this present article all three sets of conditions are of interest. The first has been the norm in school practice for some time - a holding time of 15 to 20 minutes at 121 °C (i.e. at 103 kPa). The second MRC recommendation of interest here is a holding time of 10 minutes or so at 126 °C (at 137 kPa) and the third an even shorter holding period of 3 minutes at 134 °C (at 206 kPa). In this review we look to see how each model performs against one or more such standards.

Tests

Size of the overall load and of individual containers has a bearing on heat penetration. Tests were thus applied in media at both the McCartney Bottle and the 500 cm^3 Medical Flat scale. Two types of tests were used at each such scale.

Time and temperature

Two test devices were used - *Brownes' Tubes* and *TST Indicator strips*[2] usually one of each at each load position. These test items change colour only when they have been exposed to steam at the correct temperature for a minimum time.

Bacteriological test

Bacillus stearothermophilus spore strips were included in containers at each scale and incubated under the standard test procedure for this test thereafter.

It must be stressed that the *B. stearothermophilus* spore test is a particularly demanding one. It is intended for use where the most strict assurance of sterility is needed. Spores of this organism are heat resistant in the extreme. They may survive, albeit in small numbers, long after likely contaminants in any educational practical have perished. Results cannot be interpreted in simple *pass* or *fail* terms - i.e. has there been any or no growth after treatment - but account has also be taken of the time for growth to become apparent. This lag time is generally indicative of the number of spores which managed to survive the heat treatment.

These biological test results are therefore not necessarily directly applicable to requirements for educational work. Marginal failures may not lead to the ruling out of the purchase or use of a particular model of autoclave. The test results are however useful, particularly in assessing a rank order of performance over a range of sterilising devices or procedures.

[1] Some of the models tested were clearly designed to meet other, international criteria but which exceed or differ only slightly from the MRC requirements.

[2] Different TST strips are needed for 10 minutes at 126°C (type 7526) and 15 minutes at 121°C (type 2342).

Noise

This is often reported as a nuisance factor with pressure cookers and autoclaves. Noise levels were thus monitored with a calibrated sound level meter positioned at a standard distance and orientation to the device under test.

Cycle time

As indicated in the introductory section, this is of great importance in the efficient running of microbiological coursework. Little is gained from a large autoclave if it is outstripped overall by smaller vessels with quicker turn-round times.

Four times are quoted in our results. These are:

Time 1 - from switching on or lighting gas to achieving operating pressure;

Time 2 - holding time (often the same but some devices allow higher temperatures and thus shorter holding times);

Time 3 - typical time to cool so that internal pressure has equilibrated again with atmospheric;

Time 4 - total of times 1-3 inclusive - the overall cycle time.

Safety features

Mechanical

Any special positive, physical safety features are described and commented upon.

Electrical safety

Where applicable, devices were subjected to an HVIE[3] test routine with a PAT[4]. Wiring layouts were examined for good design, separation of HT and LT circuitry, protection of cabling from heat damage etc.

Miscellaneous

Any features of particular interest are noted and particular apparent advantages or demerits of the equipment may be subject to opinionative comment.

Summary tables

The results of our evaluation exercise are tabulated overleaf.

Note that all dimensions are approximate and unless otherwise stated are in mm.

[3] HVIE - High Voltage Insulation and Earth

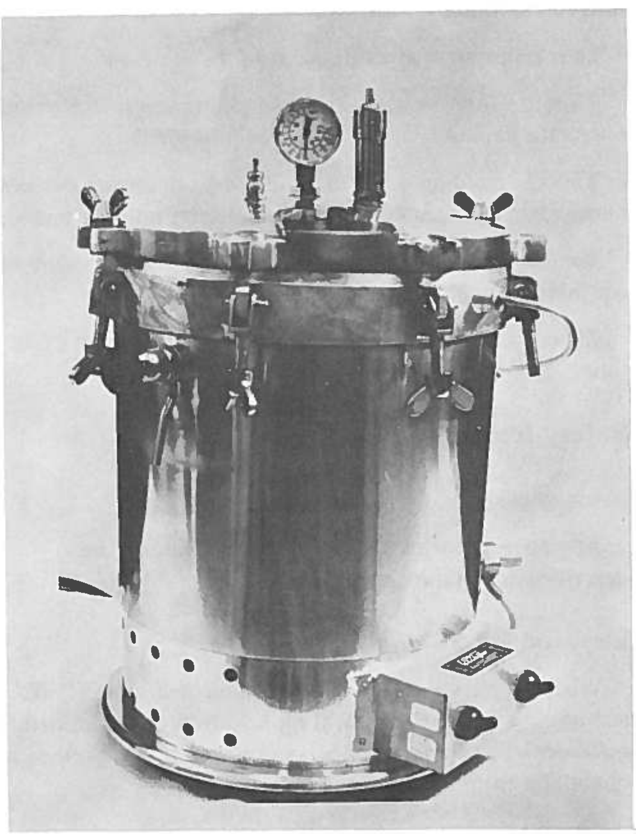
[4] PAT - Portable Appliance Tester.

ST19 (Express) Steam Steriliser

Supply details

Manufacturer: Dixons Surgical Instruments Ltd.
Supplier: (Of test sample) Griffin & George AUX-261-010B (several sources including other mainstream educational suppliers).
Guide Price: £712

General description



An electrically heated, thermostatically controlled, portable autoclave.

Type: vertically loaded cylinder with shallow, domed lid (see illustration). Note that our test results apply only to one recently purchased sample 1990).

Dimensions : External: height (excl.gauge and valves) 440, diameter 370. Internal: height 273, diameter 289.

Weight: including supply cable ca. 15.75 kgf.

Capacity: nominal 16 l media > 4.5 l (9 x 500 cm^3 medical flats). **Material**: aluminium alloy.

Heating: Two electrical heating elements under base.

Power rating: Total is 1.85 kW from one element rated at 700 W and a second at 1.15 kW. Supply is assumed to be 240 V 50 Hz a.c.

Prestige 2075

Supply details

Manufacturer: Prestige Medical
Suppliers: Allardyce Healthcare Ltd, Griffin & George

Guide Prices: Allardyce - £430 (plus VAT) G.& G. £525

General description

An automatic, electrically heated, autoclave with electronic control of temperature and cycle time.

Type: vertically loaded cylindrical chamber with a domed lid (see illustration).

Dimensions : External: height (excluding handle) 380, diameter 230. Internal: height 255 diameter 210

Weight: including supply cable 4.6 kgf.

Capacity: ≤ 2.5 l of media. **Material** : alloy & plastics

Heating: electrical, heater element built-in to cylinder base.

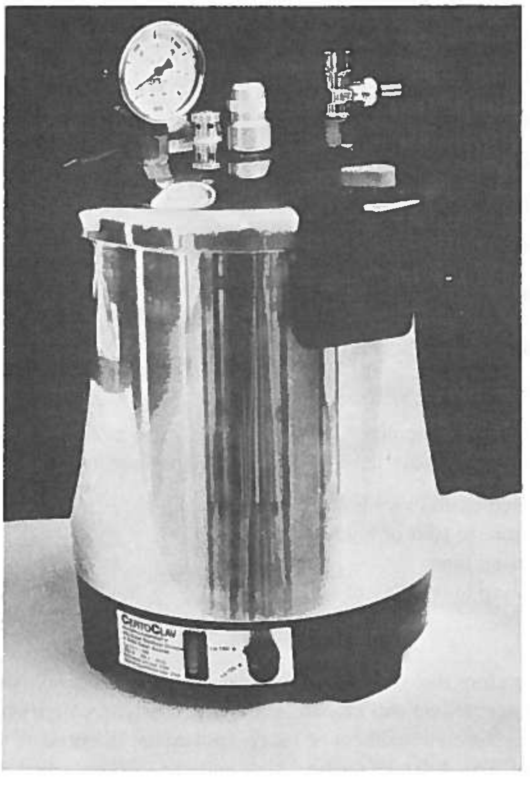
Power rating is nominally 1,500 W at 220/240 V 50 Hz. a.c.

CERTOclav CV 1600/11

Supply details

Manufacturer: KELOmat (Steam Steriliser Division),
Supplier: Jencons (Scientific) Limited
Guide Price: £428.45 (trivet and other accessories at extra cost).

General description



An electrically heated, thermostatically controlled, portable autoclave.

Type: vertically loaded cylinder with shallow, domed lid (see illustration).

Dimensions: External: height (excl. gauge and valves) 300 diameter 240. Internal: height 240 diameter 215.

Weight: including supply cable ca. 6 kgf

Capacity: nominal 10 l media ≥ 3 l (6 x 500 cm^3 medical flats) **Material**: aluminium alloy

Heating: by electrical heating element built-in to a grooved base and thus in intimate contact with material of cylinder.

Power rating: Nominally 1,600 W but that is stated for a supply voltage of 220 V 50 a.c. The true rating on a 240 V a.c. mains supply is probably closer to 2 kW.

Duromatic Pressure Cooker 3266d

Supply details

Manufacturer: Kuhn-Rikon (Switzerland)
Supplier: Kuhn-Rikon (UK) Ltd.
Guide Prices: Retail £135.00 Educational Trade Price £85.48.

General description

An externally heated (gas or electricity) large volume pressure cooker.

Type: vertically loaded cylinder with shallow, domed lid (see illustration).

Dimensions: External: height (excl.valve) 255 diameter 315 with handles 390. Internal: height ex. lid 215 diameter 270

Weight: including supply cable ca. 5.5 kgf

Capacity: nominal 12 l media > 5 l (10 x 500 cm^3 medical flats) **Material**: aluminium alloy

Heating: By external heat source either gas ring or electrical hotplate etc. Throughout our tests a gas ring was used as the heat source.

Power rating: Not applicable.

ST19 (Express) cont.

Performance

Specification

Available temperature and pressure combinations:

115 °C at 1.3 bar (relative)

121 °C at 1.5 bar

These are set by a spring-loaded, two position, pressure valve. Overall rate of heating set with combinations of the positions of two external switch dollies with over-riding thermostatic control.

Time/temperature tests

McCartney bottles - with the thermostat at the original factory setting results were marginal and variable (apparently partially dependent on volume of water used). With the thermostat re-adjusted (plus half a turn) results were satisfactory.

Medical flats - as above.

Bacteriological tests

Pattern of results variable as for time/temperature tests but at the medical flat scale were always less than wholly satisfactory. See overall summary on page 30.

Noise levels

Relatively quiet with a peak of 50 dB at operating pressures during holding time with steam escaping from the valve.

Overall cycle times

Times in minutes for supposedly 121° C pressure control but with factory set thermostat position and manufacturer's recommended volume of water of ca. 2.25 l (4 pints). Lapsed times since initial switch-on are shown in square brackets:

switch-on to closure of safety valve	24	[24]
closure to start of holding time	13	[37]
holding time	20	[57]
cooling to opening of safety valve	30	[87]

Overall cycle times are thus relatively long, of the order of $1^1/_2$ hours not counting loading and unloading. Our copy of the instructions is also unnecessarily cautious in insisting on an overnight, or equivalent, cooling down period when liquid media have been autoclaved. So long as the internal pressure has dropped back and equilibrated with the atmosphere and a few minutes allowed afterward then the valve may be safely opened.

Safety

Mechanical features

Lid and locking: by means of drop bolts and wing nuts. There are 8 of these and 2 of the wing nuts are *collared* and thus *captive* in their fittings on the lid.

Handle: this is of metal and not in any case intended for use whilst the device is operating. Most parts of the autoclave, including this carrying handle, quickly become too hot to touch after switch-on and remain so for a considerable time after the end of the holding period. The only exceptions are the PTFE handle on the *aircock* valve and a thermosetting plastic handle on the *draw-off-cock*. These are sensible design features.

Prestige 2075 cont.

Performance

Specification

Available temperature and pressure combinations:

126 °C and 1.6 bar relative pressure (23 psi).

Automatic control ensures that this combination is held for 11 minutes. After a *Start Cycle* button is pressed the reminder of the cycle is under automatic control. Lights on a control panel indicate *power on*, *heating*, and *Sterilising* 126 °C.

Time/temperature tests

McCartney bottle - satisfactory

Medical flat - satisfactory

Bacteriological tests

McCartney bottle - satisfactory

Medical flat - satisfactory

Noise levels

Once the pressure venting/safety valve has closed then little steam escapes and noise levels are remarkably low (50 to 60 dB at bench level 1 m from device).

Overall cycle times

Times are in minutes and are means from 5 cycles. Figures in square brackets are lapsed times since initial switch-on.

switch-on to closure of safety valve	6	[6]
closure to start of holding time	3	[9]
holding time	11	[20]
cooling to opening of safety valve	11	[31]

Therefore the overall cycle time is ca. 30 minutes not counting the times to load and unload. These, obviously, are dependent on nature, size and numbers of media containers. In our tests the load was of five, 400 cm^3 medical flats and one, 500 cm^3 medical flat. The overall time could be reduced by ten minutes if the pressure were more rapidly reduced by manually venting off the autoclave. Such rapid de-pressurisation may however cause media in bottles to boil over and be wasted. It is therefore a breach of best practice when liquid media are being autoclaved.

Safety

Mechanical features

Lid and locking: domed and flanged (as on pressure cookers of domestic pattern also made by Prestige). The lid is rotated into a positively locked position with engagement of the flanges. The lid is thus effectively self-locking and thereafter it cannot be removed neither during operation nor afterward until the internal pressure has dropped back to atmospheric.

Handles etc : These are of glass-filled polyester and stay cool even when the autoclave is operating (when the body of the device, not surprisingly, gets very hot).

Certoclav cont.

Performance

Specification

Available temperature and pressure combinations:

125 °C at 1.4 bar (relative)

140 °C at 2.7 bar

These are set by means of a thermostat and an adjustable pressure valve with a positive locating and locking action.

Time/temperature tests

McCartney bottles - satisfactory

Medical flats - satisfactory

Bacteriological tests

McCartney bottles - satisfactory

Medical flats - satisfactory

Noise levels

Peak at operating pressures during holding time with steam escaping from the valve - 70 to 75 dB at bench level 1 m away.

Overall cycle times

Times given are in minutes, means of 5 cycles, lapsed times since initial switch-on are shown in square brackets:

switch-on to closure of safety valve	8 [8]
closure to start of holding time	4 [12]
holding time	15 [27]
cooling to opening of safety valve	23 [50]

Overall cycle times are thus of the order of 50 minutes not counting loading and unloading. This time may be reduced by some 14 minutes by manually venting off but this is certainly not recommended for liquid loads.

Safety

Mechanical features

Lid and locking: Four interlocking flanges on each of base and lid plus an additional locking device (built into one handle) with definite *open* and *closed* positions. This device cannot be turned to the open position whilst the autoclave is operating at above atmospheric pressure.

Handles: Of thermosetting plastic materials and stay acceptably cool during operation.

Duromatic 3266d cont.

Performance

Specification

Available temperature and pressure combinations:

115 to ≥ 123 °C at 0.8 - 1.2 bar (relative).

The applied pressure and thus the internal temperature depend on manual adjustments to the heat input during the holding period (period of free steaming after displacement of air).

Time/temperature tests

Universal bottles - consistently passed relevant Browne's tube tests.

Medical flats - as above, consistently passed directly relevant tests, but did not always fully turn a 126 °C TST indicator strip (a not unexpected result).

Bacteriological tests

McCartney bottles - satisfactory with cooker in full steaming (1 - 1.2 bar) mode.

Medical flats - signs of growth in ≤ 8 hours.

Noise levels

Relatively noisy when free steaming with readings of 70 - 75 dB at maximum operating pressures during holdingtime.

Overall cycle times

Times shown are in minutes and are for a cycle where adjustment of the heat source kept the pressure oscillating between 1 and 1.2 bar (14 - 17 psi). Earlier trials showed that 1 litre of water was sufficient (rather than larger volume recommended for cooking). Lapsed times since initial lighting of the gas ring are shown in square brackets:

lighting gas to achieving pressure	20 [20]
holding time	20 [40]
cooling to allow opening of lid	20 [60]

Overall cycle times are thus of the order of one hour not counting loading and unloading.

Safety

Mechanical features

Lid and locking: The top of the cooker body carries six flanges which align with apertures in the rim of the lid. The lid can locate and lock in only one position. The locking action also operates a pair of small, red, spring-loaded buttons. These buttons protrude prominently when the lid is properly fitted, closed and locked.

Should the lid be incorrectly fitted then these same buttons ensure that the gasket is distorted slightly and allows an escape of steam.

Handles: These are of thermo-setting plastic and consequently stay cooler than the metal body of the cooker.

ST19 (Express) cont.

Pressure indication and relief

Pressure gauge: 45 mm int. dia. gauge. Indicates 0-30 psi, kgcm^{-2}, "in/Hg", "cm/Hg" and temperature (100 - 135 °C).

Valves: The two stage *pressure control valve*, with its spring-loaded ball mechanism, operates reasonably well but the selection of the alternative pressure settings could have been more definitely felt and, or, indicated.

Temperature control

A degree of control is provided over rates of heating. This is done by combinational settings of two switches which control the two heating elements.

A factory-set thermostat is basally and radially mounted in the cylinder. The factory settings may be adjusted after removal of a protective cap.

It is not made clear in the manufacturer's instructions that current models leave the factory with the thermostat set for 115° C. At that setting the holding time would have to be increased significantly. It also means that the second element never cuts in - even when the *high* position is selected with the switch settings. This made for confusion and difficulty in our test programme. It came to light only after our sample had failed some of the test routines. We then had to adjust the thermostat and repeat our tests.

The thermostat is backed up by a thermal cut-out mounted on the cylinder base. This is a useful additional safeguard should the thermostat fail and the autoclave boil dry.

Electrical Safety

HVIE tests

Our sample performed satisfactorily in our insulation and earth test routines. One Trading Standards Office has however reported marginal failure in flash tests on a newly purchased sample. (Note however that we do not recommend that schools regularly flash test apparatus as part of a routine test and maintenance programme). For other comment arising from the work of Trading Standards Officers see below.

Wiring layout and design

Apart from relatively minor details of design, to which Trading Standards officers have already objected, we judged the wiring and layout to be satisfactory. The details objected to included less than ideal sleeving arrangements on one conductor and imperfect fixing of a ceramic terminal block (over-size washer). Scottish EA resource centres and safety officers have already been alerted as to these small defects[1]. (Note that these points may not be relevant on some earlier models with solid core rather than multi-stranded conductors).

Protection for the wiring

In addition to the thermostat there is a thermal cut-out. This is affixed to the underside of the base and is in the live side. It will go open-circuit should the thermostat fail, the autoclave boil dry etc. There is no internal fusing for the device. In unmodified versions, conductors in the base subject to possible heat damage are provided with fibre glass sleeving. Factory modified examples and those altered with the kit will have slight improvements to those sleeving arrangements.

Prestige 2075 cont.

Pressure indication and relief

Pressure gauge: none, but not really necessary given automatic operation

Valves: An *automatic pressure control valve* operates at above 30 psi (ca.1.1 bar, 2 bar relative) and releases steam toward the back of the autoclave and away from the operator.

A *pressure venting/safety valve* backs up the pressure control valve in the event of failure of the latter.

An *offset device* deforms the gasket in such manner as to allow an escape of steam should the lid be incorrectly fitted.

Temperature control

In addition to its electronic temperature sensing and control circuitry this model has a thermal cut-out which shuts off power and indicates *fault* on the control panel should the autoclave boil dry and its temperature rise above a set limit. In our tests we deliberately operated the autoclave incorrectly in order to verify the efficacy of this cut-out.

We carried out several test runs with insufficient water (only 50 cm^3) so that within five minutes of switch-on the autoclave boiled dry. In each of these tests the heater then cut out and the *fault* light was activated.

In other tests we operated the autoclave with the safety valve deliberately left open so that steam was continually vented off over about thirty minutes. At the end of that period the autoclave had again boiled dry. The thermal cut-off then tripped, shut down the heater and activated the *fault* indicator.

Electrical Safety

HVIE Tests

All results satisfactory

Wiring layout and design

This is good with several features of the wiring layout being exemplary. Particularly liked are the separate routeing and restraint of the live and neutral plus earth cores in two circumferential channels on either side of the circular base.

Protection for the wiring

In addition to the electronic temperature control and the thermal cut-out there is also internal fusing of the device. This is a cartridge fuse placed in the live side immediately after the power supply input (an IEC chassis plug of an approved type).

All the conductors in the base, and thus subject to possible thermal damage from the heater, are insulated with silicone sleeves rated up to 180 °C. Measurements with thermocouples within and on the autoclave base recorded maximum temperatures during operation of ca. 134 °C. This seems a reasonable margin of safety. (In any case the thermal cut-out should operate at above 138 °C).

[1] ST19 Footnote: The current owners of the manufacturing company will modify recent models made under that ownership (serial numbers pre-fixed with a "D"). For earlier made examples a modification kit is being made available. (See the Safety Notes section of SSERC Bulletin 171 and our earlier circular letter to Scottish EAs). Note however that details of design have been changed several times over the years.

Certoclav cont.

Pressure indication and relief

Pressure gauge: 55 mm dia. gauge, claimed as *calibrated*. Indicates 0 - 4 bar, 0 - 50 psi and the two recommended operating temperatures - 125 and 140 °C.

Valves: A two stage *pressure control valve*. We found this to operate well with the selection of the alternative pressure settings to be positive with little or no possibility of confusion.

A safety *steam release "switch"* backs up the control valve.

A manual *steam release valve* (stopcock type) is provided.

The safety valve design is said to include an *ABS (Anti-blocking system)*.

Temperature control

This is by means of a rotary control with two positions - one for each operating temperature. The heater supply is controlled by means of a rocker switch with a built-in, amber, indicator lamp.

The rotary control is coupled to a bimetallic thermostat. The control positions are only approximately related to temperature but sufficiently close for operational purposes. The pressure gauge in any case has marked bands which indicate both operating pressures. A special thermometer is available as an optional accessory but this costs £56.75.

The main thermostat is backed up by a thermal cut-out mounted on the cylinder base. This is a useful additional safeguard which goes open circuit should the thermostat fail and the temperature exceed a set limit. But see also the section on the protection of wiring.

Electrical Safety

HVIE tests

The evaluation sample performed satisfactorily in our insulation and earth test routines.

Wiring layout and design

These were acceptably safe. Nonetheless the equipment could be significantly improved if more thought were given to the cable routes, and thus the separation, of the live, neutral and earth cores as well as to the positioning of the thermal cut-out. Much of the wiring is *bird's-nest*ed within the basal enclosure. It is somewhat untidy and lacks the careful separation and restraint of the Prestige Medical layout.

Protection for the wiring

The thermostat is wired into the live side of the circuit but the thermal safety cut-out is on the neutral. If tripped, the cut-out will go open-circuit. It will then shut down the heater. A large section of the wiring will however remain live from input to cut-out. That may place any would be fault-finder or repairer at risk. A better and much safer design would place the safety cut-out in series with the thermostat in the live side.

This design error is compounded by the lack of any input fusing to protect the internal wiring of the device. In the event, admittedly unlikely, of a double failure where both thermostat and cut-out contacts remain closed then the only protection for the device will be the fuse in the three pin plug.

Duromatic 3266d cont.

Pressure indication and relief

Pressure gauge: None as such - see below.

Valves : The *pressure/indicator* valve has two red marks. At below +0.02 bar (0.3 psi relative) the indicator is in its *rest* position and neither mark is visible. When the pressure rises to 0.8 bar relative (5 psi) the first red ring appears (and indicates a need to adjust an electrical hotplate should one be used). The second ring is just visible at 0.8 bar (11 psi). This second ring rises to its full extent at 1 - 1.2 bar (14 - 17 psi) when there will be a vigorous escape of steam from under this combined valve and indicator.

In a culinary context this condition would indicate excess pressure and need to turn down the heat or remove the cooker from it. We found however that we could tweak the heating and keep the cooker operating and the pressure oscillating between 1 and 1.2 bar (14 to 17 psi).

Other safety devices:

Should the main pressure/indicator valve fail then several back-up safety features can come into play. These are:

- *distortion of the gasket* at pressures in excess of ca.2.5 bar (36 psi) allowing downward escape of steam through holes in the lid flanges,

- an *additional safety valve* which operates at about 1.5 bar (22 psi),

- complete *displacement of the gasket* through the flanges at about 4 bar (58 psi) again with escape of steam in a downward direction away from an operator.

Temperature control

Not really applicable. Some indication of the need to adjust the heat source is provided by the red marks on the pressure indicator (see previous section).

Electrical Safety

Not applicable

Certoclav - Electrical safety cont.

Earth bonding arrangements on the base of the vessel are good but the main safety earth point is not properly marked. The rating plate markings are however complete.

As in the Prestige device, silicone sleeving on the wiring protects it from thermal damage. Measurements with a thermocouple indicate acceptable margins of safety when the autoclave is in use at either pressure setting (≡ 125 °C or 140 °C).

Miscellaneous comments

ST19 (Express)

None

Prestige 2075

Body colour

Although the composite polymer handles remain cool throughout operation the cylinder itself does get very hot. A warning pictogram is provided on the control panel. The pale *cool* colours used in the general finish of the autoclave however may be a design error and poor psychology. They mean that an operator can forget just how hot parts of the autoclave body may become.

Certoclav CV1600/11

Base fixings

The only securement of the plastic enclosure to the base of the metal body of the autoclave is one large, axial screw. This screw and protrusion of the shaft of the thermostat control through an aperture in said enclosure are the only means of preventing its rotation. The addition of anti-rotation lugs would improve matters.

Ingress of water

For normal sterilisation procedures the manufacturers suggest the use of 1 litre of water (de-ionised or distilled for corrosion prevention)). This however results in such a depth of liquid that small containers - Universal or McCartney bottles - have to be supported in some way. If not so supported, on a trivet say, then they may simply float. Also, since their enclosures must not be tightly sealed, steam tends to enter them. During the cooling down period at the end of the cycle it condenses. Media are thus unintentionally diluted and spoiled. Larger containers such as medical flats present no such problems.

Summary

Dixon ST19 (Express)

For - large capacity; effective mechanical and pressure relief safety features as well as a thermal cut-out; low noise level and good pressure indication arrangements.

Against - relatively expensive; variable results in performance tests; doesn't justify the *portable* claim; drop bolt and wing nut arrangement for lid fastenings is cumbersome and symptomatic of a now somewhat outmoded design.

Prestige 2075

For - truly portable; ease of automatic operation; good performance in tests; rapid cycle times which offset lower capacity than that of the ST19; low noise level, excellent wiring design and layout with good safety arrangements such as the thermostat and thermal cut-out.

Against - capacity restricted; automatic operation and electronic control mean that most of the safety arrangements are reliant on active electronic devices rather than by simpler mechanical means, no means of lowering temperature and extending cycle when preparing media susceptible to heat damage.

CERTOclav CV 1600//11

For - competitively priced; lightweight and portable; second best cycle times; good overall performance in tests and effective safety arrangements.

Against - electrical safety is acceptable but the actual wiring layout could be greatly improved; poor basal fixings; thermal cut-out on the neutral side and no internal input fusing.

Duromatic 3266d

For - relatively large capacity; good mechanical safety features and lid fitting arrangements; good performance in all but most demanding biological test and inexpensive.

Against - operating pressure and thus internal temperature oscillates about 120°C and reliable sterilisation of large media containers means significantly extending holding times; relatively noisy when free steaming.

Best buy?

The **Prestige Model 2075** at ca. £430 comes out best overall.

Should Jencons (Scientific) persuade its manufacturers to rectify the weaknesses in the **CERTOclav** wiring layout then such a modified design would run the Prestige model a close second. The **Dixon's ST19** model - despite much redesign work on matters of detail - is now definitely showing its age. It should perhaps now be considered for school use only where its particularly large capacity is needed.

The **Duromatic 3266d** hotel model pressure cooker is a useful and inexpensive find but is really only suitable for elementary microbiological work at Levels 1 and 2.

Still worth considering for routine, elementary work, but not reviewed in detail here, are the **Portable Steam Steriliser** (sold by NCBE and Griffin & George) and the **Prestige Hi-dome** pressure cooker.

References

1. "Microbiology in schools", SSSERC, "Biology Notes", Bulletin 126, March 1981.
2. "Microbiology", A.S.E., Chapter 5a, "Topics in Safety", 1982 revised edition 1988.

Surplus Equipment Offers

General conditions

In general this offer is subject to the conditions laid down in Bulletins 158 (October 1987) and 171 (October 1991). Orders from Strathclyde Regional customers are subject to a surcharge of 25%.

Acknowledgement

The Centre is grateful to Unilab, who have donated a pulley wheel kit to fit on the Centre's tachogenerators. The kit's axle adaptor has been specially manufactured for us by Unilab.

New lines, new stock

752	Shandon chromatography solvent trough.	£1.00
753	Submersible pump, 6 V to 12 V d.c., 8 litres/min, 0.6 bar, dry operation protected.	£4.55
754	Stereo microscope, Vickers, long arm type with knuckle joint, mechanically coupled eyepiece tube, x10 eyepiece, x1 and x2 objectives on tumble change, built-in illuminator, some with second illuminator for either top or basal illumination, weight 12 kg, very stable even with arm swung away from base. Suitable for biology, primary, electronics, etc., equivalent present day model would cost in excess of £250. Delivery can be arranged for multiple purchases, otherwise has to be uplifted.	£100.00
755	Pulley wheel kit comprising: plastic pulley wheel, 30 mm dia. with 4 mm dia. hole and deep V-notch, two M4 grub screws to secure pulley wheel, Allen key for grub screws, and 3 mm to 4 mm axle adaptor. The whole making up a kit devised for SSERC tachogenerators with 3 mm dia. shafts. Specially supplied to SSERC by Unilab.	25p

Most of our other, stock, lines remain on offer for sale. Please see Bulletin 171 for a full list.

Trade News

Wire wrapping tools

We've had several enquiries from schools this session on wire wrapping tools. It appears that supplies of the *Combi Tool*, Maplin stock number FY32K, or Vero stock number 163-28300A, are no longer available. The cheapest substitute is the *3-in-1 Tool* retailed by both Farnell Electronic Components and RS Components. This strips, wraps and unwraps wire. With the *3-in-1*, we find that persons unskilled in wire-wrapping very soon learn how to make reliable connections. Other more expensive makes may be more efficient in skilled hands, but take longer to master. The *3-in-1 Tool* is therefore our current recommended buy.

Farnell is the cheaper source of supply at £11.52 (stock number WSU30M). The RS price is £12.34 (stock number 544-005). Both companies offer discounts for quantity sales.

New range of power supplies from Griffin

Griffin and George have brought out a new range of power supplies, some with the novel feature of having their voltage set by a remote infrared controller. We understand that the range consists of:

Lockavolt power supply: 2 V, 4 V, 6 V, 9 V, 12 V and 14 V a.c. or d.c. at 4 A

Voltage regulated power supply, switched mode, dual rail: ±5 V, ±6 V, ±9 V, ±12 V and ±15 V at 1 A

Voltage regulated power supply, switched mode, single rail: 5 V, 6 V, 9 V and 12 V

Battery replacement supply: 1.5 V, 3 V, 4.5 V and 6 V, up to 1 A

Multitap transformer

The Centre has carried out a technical evaluation of the Lockavolt Power Supply and has found it to be satisfactorily sound. Performance details are available to Scottish readers on request to the Director.

New power supplies from Unilab

Unilab have added three models to their existing highly successful range. These are:

2 V/12 V Power Supply (022.112): This supply is fitted with a key switch to let the teacher select and lock the output to either 2 V or 12 V. Both a.c. and d.c. terminals are provided. The 2 V output is able to supply 10 A when short circuited. It has been designed for use with the Westminster electromagnetic experiments and similar applications. The 12 V output is rated 5 A maximum and can supply heaters, lamps, rayboxes, etc. The supply costs £61.73.

Student Power Supply (022.113): This has four separate outputs selected by a lockable switch. These comprise the two outputs described under the *2 V/12 V Power Supply*, a continuously variable 0 V to 9 V d.c. regulated output, rated 1.5 A maximum, for use in physics, electronics and technology applications requiring a fine degree of control, and a further d.c. regulated output rated 5 V, 1 A, for general use in electronics. The cost is £103.72.

Beaver Power Supply (022.111): Designed for primary schools, the Beaver's output is continuously variable from 1.5 V to 6 V d.c. at a maximum current of 1.5 A. The price is £36.51.

The Centre has carried out technical evaluations on these new Unilab supplies. Reports are available on request to the Director.

New J J M products

In Bulletin 170 we reviewed the *Grampian Op-amp Board* from J J M Electronics, a new company set up by a Morayshire physics teacher. Following that article the company has sent us samples of additional products for use in the Electricity Unit in the Revised Higher Physics syllabus, possibly in conjunction with the Op-amp Board.

All the items are mounted on printed circuit boards and are unboxed. Communication with other boards or other apparatus is made with 4 mm connectors. The quality of construction is good. The new items comprise:

12 V Regulator: dual rail voltage regulated supply for running the Op-amp Board, or most other op-amps; input 12 V to 15 V a.c., output ±12 V, 100 mA; £8.95.

Wheatstone Bridge: board with sets of sockets to accommodate four 0.25 W resistors (not supplied) to build up a Wheatstone bridge circuit; arranged as two sets of potential dividers across power rails; £5.20.

Decade Resistance Board: bank of 1% precision resistors wired in series; includes nine 1 Ω values, nine 10 Ω values and eleven 100 Ω values; £8.20.

NPN Transistor: low power *npn* transistor with collector floating, emitter earthed and base floating with 1 kΩ protection resistor; £2.80.

Push-pull Follower: comprises low power *npn* and *pnp* transistors with emitters commoned and bases commoned; includes 1 kΩ protection resistor on base; £3.30.

Impulse sensor

Educational Electronics have introduced a new product for studying the variation of force with time during impact. Called *Force Time Grapher*, the apparatus comprises a set of electronic bathroom scales with LED display modified to link to a computer. Already prepared is a BBC version, product number 9220. A version for the Archimedes is promised. The apparatus and software, including notes on experimental ideas, costs £66.

From its specification, this apparatus would seem to let you plot force-time graphs, which is suggested in the Revised H Grade Physics syllabus.

Orbit Tellerium

This model, not to scale, of the Sun, Earth and Moon has been designed to demonstrate:

Sun's apparent motion across the sky

night and day

changing length of daylight

changing length and direction of shadows, both daily and annual sequences seasons

sundials and shadow sticks

phases of the Moon

eclipses of the Moon and the Sun

The Sun is modelled by a powerful lamp and parabolic reflector. The Earth is rotated about the Sun and about its polar axis by hand. The Moon is coupled to the Earth by gears and moves in response to the Earth being turned. The model is best viewed in a darkened room.

The model is available from several suppliers including Cochranes of Oxford, from whom it costs £140.

Another datalogger from Harris

The *DLPlus* can be used as a stand alone datalogger, or linked to a computer. If used independently from a computer, the *DLPLus* is programmed from its own keypad and data is presented on its LCD display in either alphanumeric or graphical mode. Data files can be downloaded to computer for analysis with *Datadisc Plus* software. If used directly with a computer, the *DLPlus* then becomes a real time interface. Intersample times can be set from a minimum of 61 µs to a maximum of greater than two hours. There are four analogue inputs. These are compatible with both Harris sensor ranges - *Blue Box* and *First Sense*. The latter range is automatically recognised by *DLPlus*. Both are automatically calibrated.

To get the full specification, please consult Philip Harris. The *DLPlus* catalogue number is T19500/6 and costs £318, to which should be added the cost of a computer connecting lead. This has to be specified for BBC, Archimedes, IBM compatible, Nimbus or Apple Mac. Please also consult Harris for the version of *Datadisc* required to operate the *DLPlus* files.

Harmony software

Harmony write software which is designed to collect experimental data, analyse it and compare the findings with mathematical models. There is a generalised version of wide application throughout physical science, and a specialised version for a set of radioactivity experiments including the half-life of protactinium.

Unilab now retail Harmony software. The order codes are 532.006 for *Simple GM Interface and Software* (£87.84, inclusive of apparatus) and 532.090 for *Experiments and Models* (£35).

Motion QED

If you're not yet into computing, or if you're wanting out of computing, or if you're just wanting another way of measuring time, speed and acceleration, this new apparatus from Unilab (532.050) may be of interest. It is a microprocessor controlled timer, which should be linked to light gates, switches, or similar inputs. The facilities it offers are:

Event timer: measures the time of occurrence of up to eight consecutive events from which frequency, speed, momentum or acceleration may be derived.

Interval timing: up to four succesive light gate interruptions may be timed.

Speed: Up to four speeds may be measured.

Gap timer: Unlike Interval Timing, only the leading edge of an obstruction is recognised. In other words, timing is triggered by consecutive logic transitions of the same sense.

Average speed: Offers one reading based on the Gap Timing mode.

Acceleration: Up to two accelerations may be measured.

An LCD display on the *QED* presents instructions and readings. The price of the apparatus is £85.14.

Model houses

We understand that the small Edinburgh company, School Science Service, are no longer manufacturing model houses for use in studying heat loss and insulation.

New drivers for Alpha

The *High Power Driver* (223.046) has been designed to be used with digital boards in the Unilab Alpha range. It can satisfactorily drive loads at up to 8 A for prolonged periods. Because it can switch digitally at high frequency, it is suited to pulse width modulation. This can be used to control the temperature of heaters, or the speed of motors. The price of the board is £11.33.

The *Bi-directional Analogue Driver* (223.045) is a device for controlling the speed and direction of motors. It requires a dual rail supply and can be operated off a potentiometer, or, more practically, an op-amp. It costs £9.20.

Both boards have been tested by the Centre. Reports on their performances are available.

SSERC, 24 Bernard Terrace, Edinburgh EH8 9NX; Tel. 031 668 4421. (**Please Note**: our Fax number - 031 667 9344)

Albert Browne Ltd.,Chancery House, Rosebury Road, Anstey, Leicester LE7 7EL; Tel. 0533 340730.

Allardyce Health Care Ltd., 6a Castle Street, Dundee DD1 3AA; Tel. 0382 28411 (warehouse) & 0382 22523 (shop).

A.S.E. Scottish Region, Annual Meeting Secretary, 118 Claremont, Alloa, Clacks. FK10 2EG.

The Association for Science Education, College Lane, Hatfield, Herts. AL10 9AA Tel. 0707 266532

British Gas plc, Service Engineering Department, 326 High Holburn, London WC1V 7PT Tel. 071 242 0789 Ext. 3274

Cochranes of Oxford Ltd.,Leafield, Witney, Oxford OX8 5NY; Tel. 099387 641.

Dixons Surgical Instruments Ltd., 1 Roman Court, Hurricaine Way, Wickford Business Park, Wickford, Essex SS11 8XB Tel. 0268 764614

Edinburgh Science Festival Ltd., 1 Broughton Market, Edinburgh EH3 6NU; Tel. 031 556 6446. For *Box Office Tel. 031 557 4296*.

Educational Electronics Ltd., Woburn Lodge, Waterloo Road, Linslade, Leighton Buzzard, Bedfordshire LU7 7NR; Tel. 0525 373666.

Farnell Electronic Components Limited, Canal Road, Leeds LS12 2TU; Tel. 0532 636311.

Griffin and George Limited, Bishop Meadow Road, Loughborough, Leicestershire LE11 0RG; Tel. 041 248 5680, or 0509 233344.

Philip Harris Education:

2 North Avenue, Clydebank Business Park, Clydebank, Glasgow G81 2DR; Tel. 041 952 9538;

Lynn Lane, Shenstone, Lichfield, Staffordshire WS14 0EE; Tel. 0543 480077.

Institution of Electrical Engineers, Schools Education & Liaison, Michael Faraday House, Six Hills Way, Stevenage, Herts. SG1 2AY Tel. 0438 313311.

Jencons (Scientific) Ltd., Cherrycourt Way Industrial Estate, Stanbridge Road, Leighton Buzzard, Bedfordshire, LU7 8UA; Tel. 0525 372010.

JJM Electronics, "The Hedges", Meft Road, Urquhart, Morayshire IV30 3LG

Kuhn Rikon (UK) Ltd., L.C.P. House, Pensnett Estate, Kingswinford DY6 7NA; Tel. 0384 400123.

Maplin Professional Supplies (MPS), PO Box 777, Rayleigh, Essex SS6 8LU Tel. 0702 552961 (enquiries) 0702 554171 (orders).

National Centre for Biotechnology Education (NCBE), Department of Microbiology, University of Reading, Whiteknights, PO Box 228, Reading RG6 2AJ; Tel. 0734 873743.

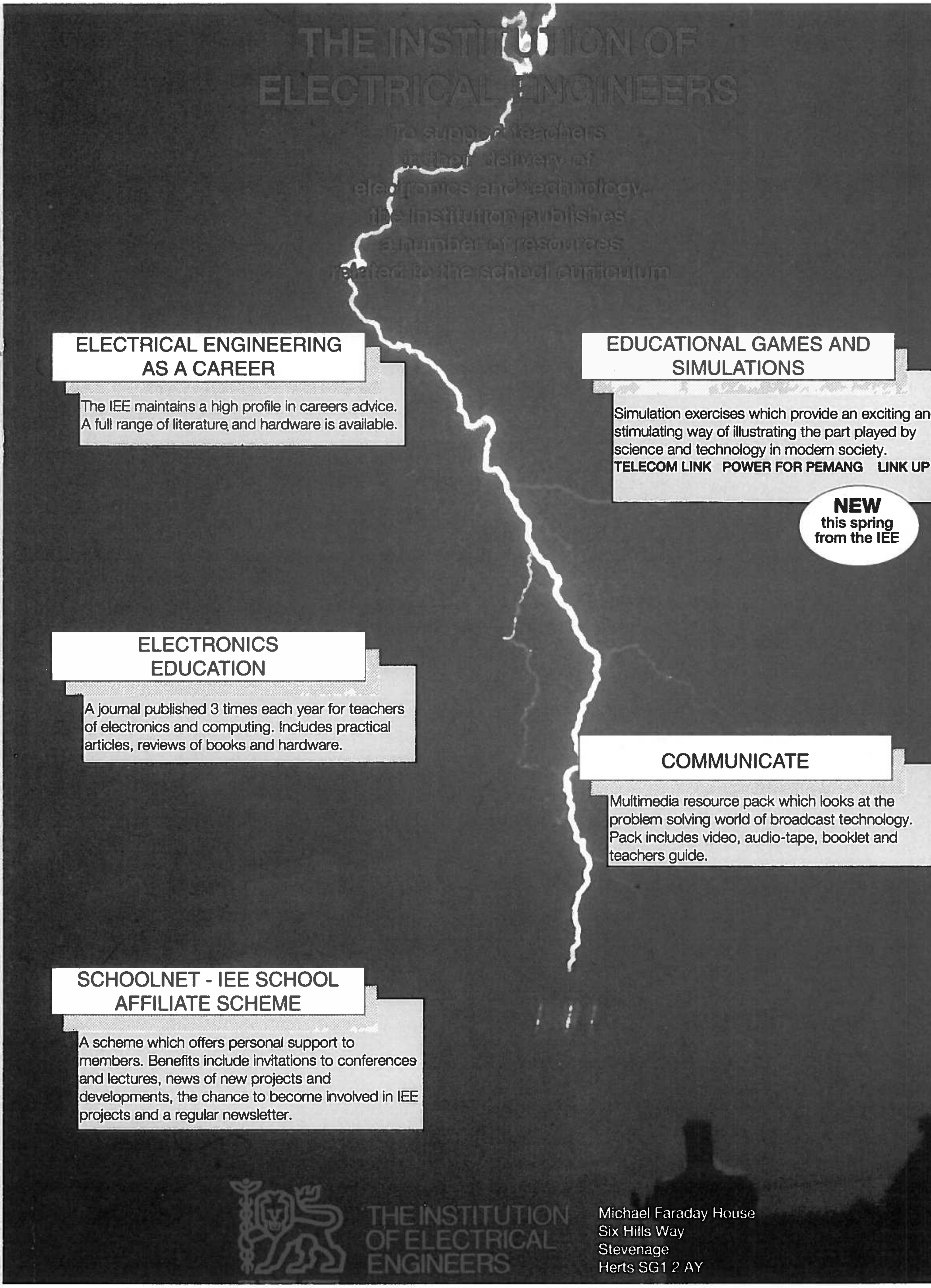
RS Components Limited, PO Box 99, Corby, Northamptonshire NN17 9RS; Tel. 0536 201201.

Scottish Examination Board, Ironmills Road, Dalkeith Midlothian EH22 1LE Tel. 031 663 6601.

SCCC, Gardyne Road, Broughty Ferry, Dundee DD5 1NY; Tel. 0382 455053.

Unilab Limited, The Science Park, Hutton Street, Blackburn, Lancashire BB1 3BT; Tel. 0254 681222.

Verospeed, Boyatt Wood, Eastleigh, Hants. SO5 4ZY; Tel. 0703 644555 (sales), 0703 641111 (admin. & technical enquiries).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A journal published 3 times each year for teachers of electronics and computing. Includes practical articles, reviews of books and hardware.
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SCHOOLNET - IEE SCHOOL AFFILIATE SCHEME
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