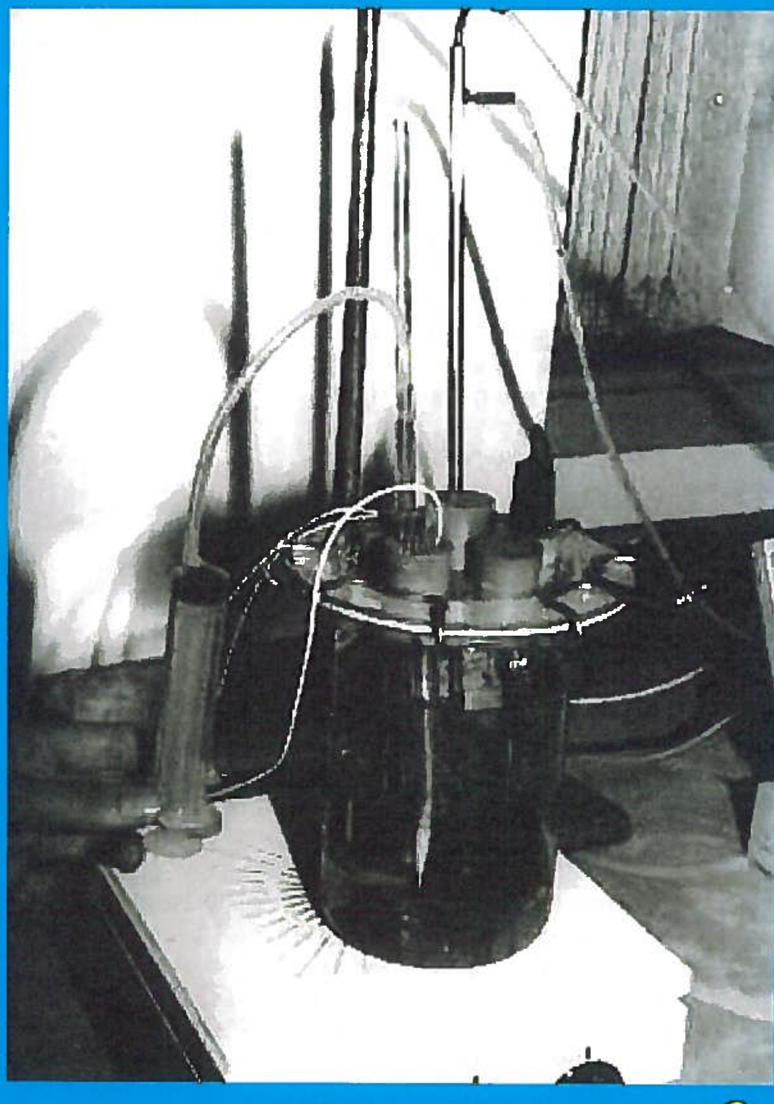
SCOTTISH SCHOOLS EQUIPMENT RESEARCH CENTRE



Bioreactors - an update

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NEWS AND COMMENT

Just one more to go?

The SSERC Board have agreed to a proposal from the Centre staff that Bulletin number 200 should be the last in this present format.

"Bulletin" has been more than somewhat of a misnomer for a long time. Our serial publication was so dubbed in the days when it had twelve pages. The first issue was published in the Autumn of 1965[1]. It was made up of six foolscap (!) leaves stapled at one corner. Produced for us by Edinburgh Corporation's printing department it used, for those educational times a new process, offset lithography. SSERC staff did the collation, stapling, envelope stuffing and *Addressograph* (now a museum piece of technology) stamping. All of this was done by hand. Bulletin time was a semi-social ritual and all the staff joined in. The one thing missing, looking back on it now, was a work song in the gaelic.

Only in 1981 did we go over to producing anything resembling a properly bound booklet. Since then it seems that, with each successive change of format or production method, the thing has got steadily bigger, less pithy, and harder to produce. Bulletin 200 in the Autumn of 2000, thirty five years on from the first issue, seems like a good point at which to take serious stock of SSERC's publications strategy.

More on the web

One result of the review of our paper based serial publication programmes will be a growing emphasis on electronic formats and on communication via our website(s). The 'Bulletin' title will still be published but cease to be such a misnomer. It will be more like the 5-14 Newsletter which we also publish. It is also likely that we shall begin the numbering again and publish, from the issue after the next, Volume 2 number 1. The Bulletin will contain news, announcements and pointers to other SSERC resources. These other resources are to be made available separately, both in print and electronic formats but with a distinct emphasis on the latter.

We are conscious that not everyone yet has suitable access to web based resources and we have heeded the results of an evaluation survey carried out some time ago. Teachers who responded to that made it very clear that they did not wish to see SSERC resources available solely on the Web. That is why we intend continuing with print, albeit in somewhat truncated form. At the same time, a greater emphasis on electronic formats is needed for science and technology education resources. The wider availability of such resources will provide powerful arguments for improved ICT provision in school departments outwith computer suites and similar centralised provision. We thus see the arrangements just described both as transitional and as being in the longer term interests of pupils, teachers and technicians.

[1]. *Footnote:* An electronic facsimile of Bulletin1 is mounted on our website - see the hotlink therein to "In the beginning . ."

No more NOFin' for now

In the last issue, we gave some information on the New Opportunities Fund (NOF) Training for teachers and librarians in ICT. Since publication of Bulletin 197, SSERC as lead body for the Scottish Science Consortium, has formally notified the NOF Board of its intention to withdraw from the NOF organised scheme for 'Approved Providers'. This decision was taken by the Board of SSERC Limited (the company and educational charity which governs the Centre's affairs). It was made on commercial and operational grounds and judged be in the best interests of the Company over the longer term.

'Sensation' - a new Science Centre

The *Dundee Science Centre* is on schedule and now nearing completion. Staff and exhibits, both highly interactive no doubt, should thus be installed in time for an opening in the early Summer. Eat your hearts out MSPs and Senor Miralles! An advertisement for the Centre appears on the outside rear cover of this Bulletin issue and there should also be a 'flyer' as one of the inserts.

Alice Hague, Sensation's Education Manager, was Education Officer at The Royal Society of Edinburgh before moving to the Dundee venture. Before that Alice worked at Techniquest in Cardiff. She is well-versed in science communication and public understanding issues.

We offer our very best wishes to Alice and her team, not only for a smooth run up to the opening but also for every success and, doubtless, much fun thereafter. Enjoy!

Lots to come

Sensation isn't the first and won't be the last of such centres and related projects. *Dynamic Earth* in Edinburgh - Scotland's very own Mini Dome (only of sorts, smaller yet perfectly formed) - has been very successful since launch. It has easily exceeded its self-imposed targets (sorry, didn't mean to curse) for visitor numbers. A centre devoted to invention and inventors has already opened in Irvine and the big yin, the *Glasgow Science Centre*, should be ready to open on its Pacific Quay site sometime in the first half of 2001.

Satrosphere in Aberdeen was effectively the founder of this Scottish science centre movement. We believe that it is currently in some difficulty over premises and trust that these will get sorted out. A long standing plan for a 'people-based' interactive science and technology centre in Edinburgh also has been recently dusted off and a number of outreach activities and festivals, for example Orkney and Shetland's distinctive approaches to such events could well be emulated and expanded. If only the formal science and technology curriculum was as rewarding, interesting or exciting.

* * *

SSERC Website

As indicated on page 1, we intend making more of our materials available via the internet. Currently a number of resources are posted on the "Members" section of the main STS/SSERC website at:

www.sserc.org.uk

Note that with effect from 1st July, 2000 the User-name for members and the password shall be changed. It will be necessary then for you Email us to obtain your own user name and password.

Downloads

A number of resources are available for downloading in 'native' formats for example:

Equipment Lists

Chemistry equipment lists include: A workbook in *Microsoft Excel* format covering Standard Grade through to CSYS and with linked spreadsheets for each of general lab items; chemicals, specialised chemistry equipment, ICT items and safety equipment. Each of these sheets is also available separately as a *ClarisWorks* file in either version 4.0 or 5.0 format. Only yet available in *Excel* format is a chemical stock control facility which can be downloaded as a template and adapted for the use of an individual chemistry department.

Similarly, an *Excel* workbook for biology equipment, restricted for now to Higher Still, is currently available for downloading. This has sheets for general items, ICT kit, safety equipment, materials of living origin, chemicals and biochemicals. A physics equipment list in a database/ spreadsheet format is in preparation. Meantime, there is a fairly comprehensive set of tables and links on ICT and other equipment for Physics, accessible from the Members' section. This is an interactive, hotlinked version of a briefing paper earlier circulated to advisers and others. It covers computer systems, interfaces, dataloggers and sensors for teacher and pupil usage as well as recommendations on software for graph plotting and statistical analysis. External links are provided out of the SSERC site to relevant websites of suppliers. Many of these links are specific to a particular piece of kit referenced in a table.

By such means we are able to direct you to up to the minute (we trust!) supplier information on prices and specifications etc. Similar techniques have been used to create links out of an interactive version of the colorimeter review which was originally, and more conventionally, published in SSERC Bulletin 198.

Health and Safety Policies

These are based closely on recommendations from the Education National Interest Group of the Health and Safety Commission. They too are downloadable (ugh!), the policy frameworks that is, from the site. They are available in any one of three formats : HTML (ie web type pages); *Microsoft Word* documents or in Rich Text Format (RTF). We could supply them as PDF files but that would defeat their purpose since they are intended to be edited and adapted to suit the specific circumstances of individual schools or departments.

Presently on the site are three such frameworks each in the three formats described above: Science Departmental Policy; a version for Technical (Technology) Departments and a Whole School (secondary) Health and Safety Policy Framework. These are all documents developed for and trialled in SSERC Health and Safety Management training courses. If need be, we could advise further on how to adapt and adopt these frameworks to meet the requirements of the Management of Health and Safety at Work Regulations.

Other resources

As staff time allows, past issues of SSERC Bulletins and other publications are being converted to interlinked web pages. A searchable index of many back issues is already available so that a particular article should be quickly traced, even if for now you then have to go hunting for the paper copy. Even more useful is the possibility of interlinking back issues so that related articles spread over several back numbers may be tied in the one to the other.

Endpiece

We trust that these notes have given a flavour of the potential for SSERC support mechanisms via the web. This certainly is what underpins our recent decision to move over from relatively bulky paper resources to more flexible, electronic formats.

If you already have access to the internet then do visit the site, see the possibilities for yourself and let us have your comments and suggestions.

* * *

Congratulations!

The members of ASE (Association for Science Education) Scotland are to be congratulated yet again for their wisdom in breaking with stereotyped convention in their choice of Chairperson. Last year they elected a Primary Head (Franca Reid). Franca has just remitted office to Pauline Anderson who is a technician at Earlston High in the Borders (to whom our commiserations?). Seriously we also wish Pauline an enjoyable and successful year in the ASE Scotland Chair.

* * *

Solder flux fume control

Until the results from some Health and Safety Executive (HSE) research programmes are published and guidance is issued by the HSE, it may be prudent to hang fire on investing on local exhaust ventilation (LEV) equipment for solder fume control.

Because the Health and Safety Executive (HSE) have set maximum exposure limits (MEL) on rosin-based colophony fume it would not be feasible for technical and legal reasons for schools to continue to work with solders containing natural rosin-based fluxes. This restriction includes modified rosin-based solders as well as rosin-based solders. Information and guidance on control measures were published by us last year [1]. Briefly, we recommended:

1. Be sceptical. Presume that fume from all solders is hazardous.
2. Substitute *Ecosol 105* (a rosin-free solder from Multicore) for rosin-based solders.
3. Do not inhale the flux fumes.
4. Use fume extraction equipment.

From discussions we have had with safety and managerial representatives of many Scottish councils, it is clear that the first three of these recommendations are each widely accepted and that councils have acted to implement them. However the fourth recommendation generally has not been implemented because it would be costly to do so. There is a belief that the case for installing local exhaust ventilation (LEV) for working with rosin-free solders is unproven.

The HSE are presently conducting two research programmes on solder fume. Results from this research, and guidance which we trust will follow, should provide firmer information on types of control measures required.

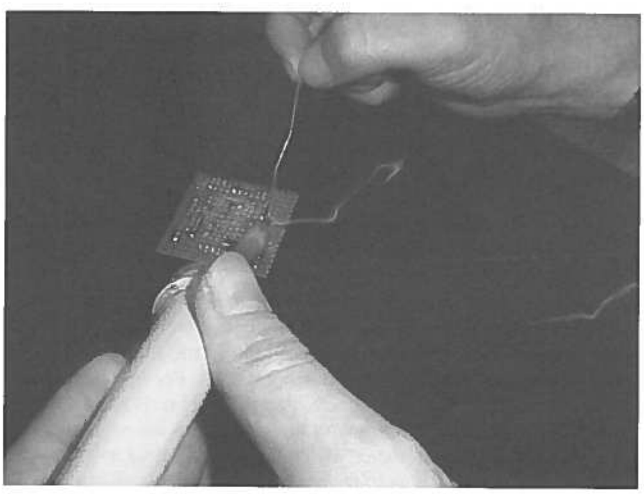

Figure 1 Solder fume rising from the workpiece.

Rosin free research programme: This research is complete. The report is at the draft stage and is to be prepared for publication in a scientific journal. The publication date would presumably be 2001. The researchers looked at a variety of solders to find what pyrolysis products were associated with each. The solders included : Rosin based types; modified rosin based and rosin- free solders

Modified rosin solders were found to produce resin acids. The risk from them can be assessed by the sampling method described in MDHS83 [3] for resin acids.

As with all types of solder, many pyrolysis products were identified from non-rosin solders. The composition was generally similar to that produced from modified rosin based solders. Formaldehydes were present. The products from one non-rosin solder had resin acids in it. (Resin acids are the identification marker used by MDHS83 for measuring the aerial concentration of rosin based solder flux fume.) Most of the substances found in the fume do not have OESs assigned. Some are classed as irritants.

On the basis of these findings, interim advice from the HSE is that employers should not assume that the pyrolysis products of rosin-free solder are harmless. Employers would have to assess the risk and put in place control measures.

Intermittent soldering research programme: The other HSE research is on assessing the risks from intermittent soldering. On the basis of its findings the HSE hope to be able to issue guidance to employers where there is intermittent soldering in their workplace. The guidance would include appropriate control measures and would advise on whether local exhaust ventilation should be installed.

Solder flux fume; Bulletin 196: SSERC: The HSE are undertaking a critical review of guidance published by SSERC in Bulletin 196. They have found one significant problem with the guidance, namely, that maximum exposure limits (MELs) do not apply to children. They would expect us to apply a lower limit than the MEL. For instance, in other fields of toxicology, an exposure level for children can be either one twentieth or one fortieth of an OEL for employees. We are presently awaiting a decision on this matter.

Summary: solder flux fume control

Because we are waiting for guidance from the HSE on their two research programmes and on exposure limits for children, it would seem prudent to hang fire on investing on expensive control measures at present. Interim control measures in Bulletins 186 [2] and 196 [1] not including LEV should be applied.

We are aware of one Scottish council that has agreed to install one Purex 2-Station Electric Solder Fume Tip Extraction System into each secondary school for usage by technicians. We understand that in that council's schools the time spent on soldering each day on average is about 30 minutes in each school.

Last year we had notification of one technician working in a secondary school who has become sensitised to solder flux fume.

References

1 *Solder flux fume* Bulletin 196 SSERC 1999

2 *Solder fume control* Bulletin 186 SSERC 1995

3 *Methods for the determination of hazardous substances Resin acids in rosin (colophony) solder flux fume* MDHS83 HSE 1997

Ionising Radiations Regulations 1999

A major revision of these Regulations, first introduced in 1985, has taken place. The changes of significance to schools and colleges are reported.

The Ionising Radiations Regulations are technical regulations made under the Health and Safety at Work Act for establishing safe working conditions in a workplace where radioactive materials are used. They apply to schools and insofar as they affect science teachers their main import is in setting controls over laboratory usage of radioactive sources.

The regulations were first introduced in 1985. A major revision has just taken place. The revised regulations are dated 1999, but came into force on 1 January 2000 [1]. The new regulations are much simpler than the old, and a little more relaxed. Specific changes to working arrangements in schools will include:

1. *Local rules:* No longer required. However this is of little practical significance because we obviously still need control measures, implying written procedures and the provision of information and instructions.
2. *Radiation Protection Supervisor (RPS):* No longer required because the level of risk from ionising radiations from educational sources is very low. Again this change is of little practical import because, under other sets of Regulations, someone (usually the PT Physics) has to manage overall health and safety arrangements for the subject and supervise employees who may be at risk.
3. *Radiation Protection Adviser (RPA):* Such a person (or body corporate) is now specifically required. An RPA must meet criteria of competence set by the HSE. Those criteria include either a professional qualification in radiological safety together with experience, or 15 years experience together with a record of work showing that the individual is suitably competent. It would seem that specialist staff at SSERC might meet the second of these criteria. The HSE inspectorate who enforce the regulations have indicated to us that the current SSERC physics specialist might reasonably be appointed as the RPA for every Scottish Council. Were that to happen, the inspector would be satisfied that this regulation was being met[1].
4. *ARP organisation:* The present arrangement in councils who have appointed an Adviser in Radiation Protection (ARP) should remain. It is useful to have local management to supervise the provision and procedures in schools, carry out or supervise the programme of leak testing and maintain records of stock.

The above changes are of little practical significance. As to working procedures in the laboratory, or how sources are stored, schools should continue to apply the health and safety arrangements laid down in the *Explanatory Notes* [2]. Leak testing is still required. An annual stock check should be made.

The *Explanatory Notes* shall have to be revised, not only because of the regulatory changes, but to take account also of the working experiences and changing conditions in

[1] Footnote :

There is a technical difficulty here in that all councils should currently have an RPA in post. The regulations allow for a 5 year period of grace for an unqualified post-holder to remain in office. Under the Adviser in Radiological Protection (ARP) scheme, such a person was not, technically, an RPA, but a competent person appointed under the Management of Health and Safety at Work Regulations. For any practical purpose, we see that distinction as a quibble. Having spoken to the HSE team who have rewritten the regulations, and to the local inspector who polices them, they seem satisfied with the way in which working procedures are arranged in Scottish schools.

schools over the 13 year period that the Notes have applied. A revision will be undertaken by SSERC and a new set of safety arrangements will eventually be published.

SSERC will seek to ensure that one of its specialist staff becomes professionally qualified as an RPA for the education sector. If this happens, councils will be notified and invited to appoint this person to be their RPA. A similar offer will be made to independent schools through SCIS.

Reference

1 *Work with Ionising Radiation : Ionising Radiation Regulations 1999 : Approved code of practice and guidance* L121 HSC 2000 ISBN 0 7171 1746 7.

2 *Protection against ionising radiation in science teaching Explanatory notes on local rules for teaching establishments (SED Category C only),* SSERC, 1987.

Protactinium generator

Most generators will by now have reached the end of their recommended working life. Harris generators may be used, subject to provisions, for a few more years. School-made generators should be rebottled.

Because of the risk of the capped or stoppered vessel leaking with age, the protactinium generator was given a ten year lifespan by SSERC in the *Explanatory Notes* written in 1987. Most generators in schools were purchased from Philip Harris (Fig. 1) in the period 1988-90. They have now reached the end of their arbitrarily set life. Some schools have a school-made generator based on a SSERC design. If your school has one of these, please look at the latter section of this Safety Note. An illustrated version will be mounted on our website in early course.

Replacement products

A replacement product is not currently available. Harris withdrew their generator about 5 years ago for redevelopment. We understand that their laboratory trials on an improved product have worked well, but that the delay in reintroducing the generator to their product range has been down to their flitting and to the fact that the radionuclide, uranyl nitrate, is hard to obtain. SSERC have given Harris the names of two suppliers of uranyl nitrate and they have assured us that they will now try to make the product available again.

As an interim measure, it is suggested that schools should continue to work with their old protactinium generator provided that there is no sign of leakage. If Harris are as good as their word, schools should be able to replace old generators within one or two years.

No school has reported leakage since the first batch distribution around 1988. About ten a year are sent to SSERC for disposal. Leakage has been noticed on only one out of perhaps twenty five sent for disposal. On this evidence, the advice to continue using 10 year old generators for a little while longer would seem to be reasonable.

A possible substitute source for radioactive decay is an isotope generator containing Cs-137. This source is made by Amersham and supplied to schools in Germany and elsewhere as part of a kit known as *AktivLab.* The kit is made by the Danish company Frederiksen and costs £1425 in the UK from AEA Technology.

Figure 1 Philip Harris Protactinium Generator with cap upright in normal storage position.

The same source is also available from PASCO, called the *Isotope Generator Kit* (product number SN-7995) at £238. Cs-137 is not an approved school source for use by schools in the UK. Before it could be used here the Scottish Office would have to be assured that it is reasonably safe to work with in schools. Only then might it become an approved source.

Renewing the container

If your school has a 10 year old, school-made, protactinium generator, the time has now come for it to be rebottled. The type of container to use is an Azlon, translucent, polypropylene, flask, 50 ml, Azlon type FDF 018 (Fig. 2). These are stocked by McKay & Lynn at £5.20. Their product number is FL800-22.

The rebottling should be carried out by a science teacher. It should not be delegated to a technician. The work should be done over a drip tray which has been lined with absorbent paper. The person carrying out the procedure should wear eye protection, a labcoat and gloves. For a fuller description of safety arrangements, please refer to '*Preparation of the protactinium generator*' (*SSERC Explanatory Notes*, pp42-45) [1] and '*Stoppering the flask*' [2].

The procedure is:

1. Unstopper the flask of the old generator.
2. Decant the contents into a new flask.
3. Top up with pentyl ethanoate.
4. Stopper the flask and check that it is not leaking (see second reference [2]).

We recently issued this advice to a school and was pleased to hear from them that the procedure had been found to be straightforward. The teacher observed that there had been a small residue left in the old flask after its contents had been decanted. Fearing to lose some of the goodness of the brew, he transferred some liquid back into the old flask, swirled it about to capture the residue and decanted to the new. This cleared the old flask. The teacher also commented on the usefulness of the article on stoppering the flask – he would not have realised its significance had attention not been drawn to it. The old flask and its stopper should be cleaned by leaving overnight in a secure location in a bucket containing water and detergent. Suitable detergents are *Decon-90* or *Lipsol* at a concentration of 5% detergent to 95% water. The following day the teacher wearing labcoat and gloves should rinse out the bucket and flask with water several times.

Disposal

The flask should be sealed in a polythene bag and disposed of as ordinary refuse. The bucket should be left in the sink used for the disposal and water run into it and the sink for at least 15 min.

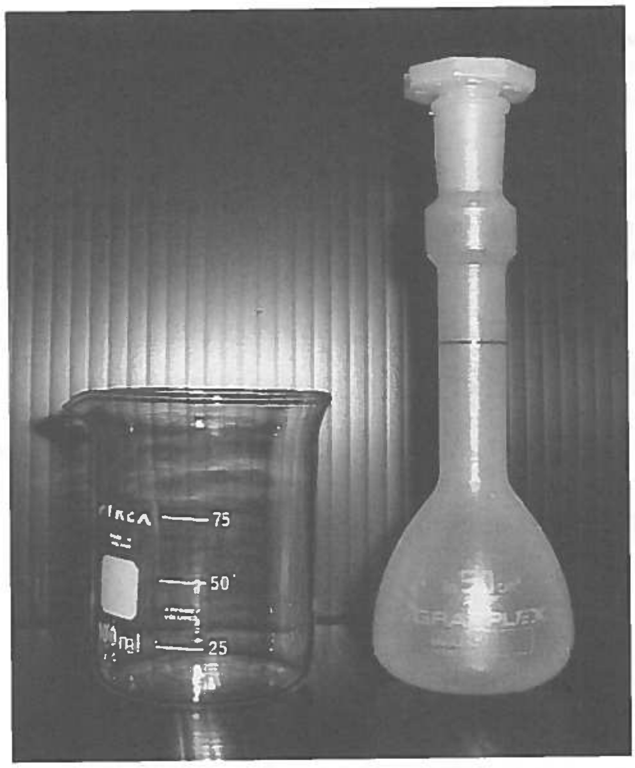

Figure 2 A 50 ml Azlon flask of the type suitable for a school-made protactinium generator.

References

1. *Preparation of the protactinium generator Appendix IV Protection against ionising radiation in science teaching Explanatory notes on local rules for teaching establishments (SED Category C only)*, SSERC, 1987, pp 42-44.
2. *The protactinium generator - Stoppering the flask*, Bulletin 160, SSERC 1988.

False nails - fire hazards in the lab?

An article published in a fairly recent issue of the Journal of Chemical Education [1] reports on a study of the flammability and ignition times of press-on artificial nails and nail tips. A summary of this article was given in the Laboratory Hazards Bulletin [2].

The study found that using a Bunsen burner, the average ignition time of false nails was 0.8 s with 87% of the samples igniting in ≤1 s. When birthday candles were used as the ignition source, 58% of the artificial nails or nail tips ignited in ≤1 s with an average ignition time of 1.1 s. All of the samples so tested burned completely and often produced droplets of flaming polymer.

New nails, as well as samples that had been filled, polished and, or, aged were tested and it was found that the presence of polyacrylate filler or nail varnish had little effect on the flammability of the samples.

References

1. *Synthetic finger nails as a fire hazard in the chemistry laboratory* Vanover, W. G.; Woods, J. L.; Allin, S. B. *Journal of Chemical Education*, November 1999, 76, 11.
2. *Synthetic finger nails as a fire hazard in the chemistry laboratory*, Fires & Explosions, Laboratory Hazards Bulletin, Royal Society of Chemistry February 2000, Items 69-112.

Revised Management Regulations

These regulations [1] place duties on employers and employees with respect to the management of health and safety at work. The need for the original 1992 regulations to be updated has come about for several reasons. Firstly the law required to be clarified. Secondly it had become untidy by incorporating changes relating to new or expectant mothers at work, young persons at work [2] and new workplace fire precautions. The revision allows the HSC to integrate these three changes into the regulations. Thirdly it brings them into line with HSE's changed policy on ACoPs. "What are ACoPs?", many of you will ask. *ACoP* stands for *Approved Code of Practice.* The HSC now publish commentary on each regulation of which about 70% has ACoP status and the remaining 30% is guidance. Employers are legally bound either to follow ACoPs, or to adopt other practices which are at least equally safe. HSE guidance has a lower legal status, but should generally be followed.

The remainder of this review describes where the law has been clarified.

The very long and complex regulation 3 on the duties placed on employers to carry out a risk assessment has had its ACoP and guidance revised to tally with advice given in the well known HSE leaflet *Five Steps to Risk Assessment.* This should make it easier to comply with the ACoP.

The original ACoP to regulation 3 ended with preventive and protective measures to be taken. To reinforce their importance, these have been extracted from regulation 3 to stand separately as regulation 4. Expressed tersely as a set of nine general principles of prevention, they are now more readily assimilated.

The new regulation 21 makes it explicit that employers cannot discharge their obligations in ensuring the health and safety of workers through enlisting the support of competent persons or services, nor by workers' obligations in respect of health and safety. In other words, the buck rests always with the employer.

On health and safety assistance (new regulation 7), employers should first seek to appoint designated workers from the workforce in preference to a competent person not in their employment. Only if no such person is available should an employer buy in competence. This is a common sense approach.

References

1 *Management of health and safety at work, Management of Health and Safety at Work Regulations 1999,* Approved Code of Practice and Guidance, L21, HSC, 2000, ISBN 0 7176 2488 9.

2 *Young Persons Regulations,* Bulletin 193, SSERC, 1998.

Educational use of *E.coli*

Recent incidents involving the problematic strain, known as *O157,* of the bacterium *Escherichia coli* have raised questions as to this species continued usage in school and college microbiology. We have had a number of enquiries on this topic, and judge that it might be timeous to seek to clarify the current position on the educational applications of this organism. In considering the advisability of such usage, it is important to remember that only two specific strains of *E.coli* are in the listings drawn up and agreed upon jointly by a range of UK bodies with specialist interests and expertise in this area. The two strains in question are the general purpose strain *K12,* and the strain *B* which is susceptible to the *T4* type bacteriophage. Both of these strains are somewhat debilitated and thus suited to educational applications.

That there have been specific instances in education - with incidents and infections reported from farm visits, and food sales at school fairs - as well as in the wider public, from *E.coli O157,* strengthens rather than weakens the case for retention of the educational applications of *E.coli.*

The epithet *coli* indicates that it is a species of the genus *Escherichia.* In practice, the term 'species' in microbiological classification is a broad one to say the least. Two bacterial cultures with similar cell shape and arrangement, colony appearance and general biochemical features may belong to the same species but differ sufficiently in details of biochemistry as to be considered distinct strains of that species. In practice, the strain rather than 'species' is the key to predicting something of the detailed behaviour of the organism.

Strains of *Escherichia coli* are ubiquitous in the guts of mammals, including those of humans, and elsewhere in the environment. Most are harmless so long as they stay put and many are positively beneficial, possibly indispensable, in the organisms which 'host' them. It's when they turn up in places they didn't ought to be (such as in our food) or mutate into virulent strains, such as gave rise to *O157* in the first place, that there's likely to be trouble.

Retaining the use of the *E.coli K12* and *B* strains in teaching [1, 2] allows us to raise, in proper and natural contexts, these types of issues and questions. It lets us point out that, such is the business of microbial taxonomy, to compare *E.coli K12* to *E.coli O157* is almost to liken your average, domestic moggie to a man-eating tiger.

References

1. *Switched-on genes,* Technical Article, Bulletin 192, SSERC Autumn 1997.
2. *DNA from bacterial cells,* Technical Article, Bulletin 189, SSERC, Autumn 1996.

Note: For a list of microorganisms see Bulletin 194, either the paper copy thereof or the interactive version on the SSERC website.

Acknowledgement

Thanks are due to Dr John M.Grainger of NCBE and MISAC for commenting on the original draft of this note and for suggesting several helpful amendments.

Thermistor Circuits with a PC

Adaptations to an earlier application of thermistors with Acorn BBC computer equipment are described. Circuitry for detecting minor changes in human skin temperature is modified to allow the use of devices interfaced with PC platforms.

In the newer course materials for Higher Human Biology, issued as part of the Higher Still Development Programme [1], there is a reference to a SSERC Bulletin article [2]. The article includes a description of circuitry with thermistors used to detect and record minor changes in human skin temperature in response to rapid heat loss. That original Bulletin article refers to using the thermistor circuits with Acorn/BBC microcomputers. Many science departments now have gone over to PC platforms. The notes below were prepared for a school which had already used the circuits with Acorn machines but wanted to convert the application to PC usage.

Software and hardware

Any PC interface or datalogger with a 1 V voltage input may be used including *Alba* (DJB Microtech), *EasySense* or *Sense & Control* (Data Harvest), *LogIT* (Griffin), *System SM* (Harris), the *500 Interface* (PASCO) and the *CBL 2* (Texas Instruments) with appropriate software (*Alba*, *Insight*, *Datadisc Pro*, or *Data Studio*, etc.).

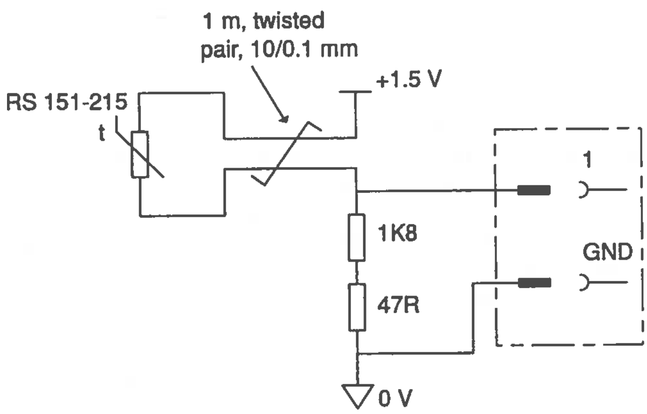

Figure 1 Basic thermistor circuitry for physiological applications. Modified form of circuit diagram which originally appeared as Figure 6 in Bulletin 175.

The circuit (Fig. 1) linearizes the voltage output for temperatures lying between 20 °C and 40 °C. At these two extremes the outputs are about 500 mV and 800 mV respectively, giving a sensitivity of 15 mV per degree Celsius. Outwith this range the performance is non-linear and the circuit should not be used.

Top views of a working circuit on stripboard are shown in Figure 2 and Figure 3.

Note that, because this is a DIY sensor then your software won't 'recognize' it. You shall have to calibrate it yourself so as to display temperature units rather than voltage. You can use another thermometer as your secondary standard. Calibration against two known points would suffice (say 20 °C and 40 °C).

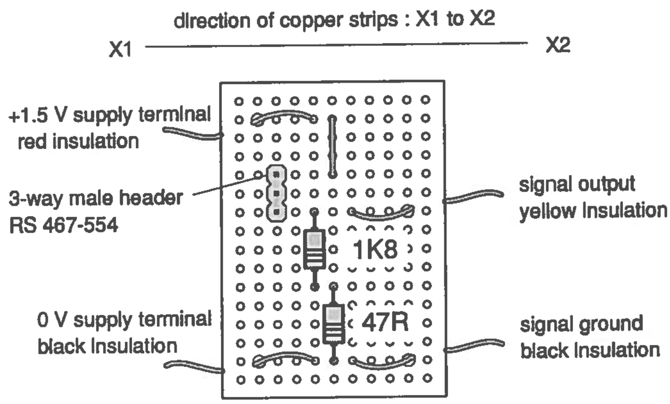

Figure 2 Diagrammatic thermistor circuit layout on stripboard.

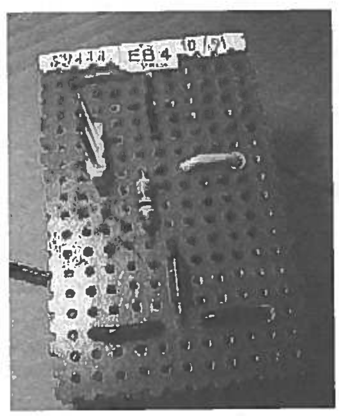

Figure 3 Photograph of thermistor circuit layout on stripboard

The accuracy of the system depends on at least four factors - the electronics, the calibration, the interface and how it's used. Electronically, the circuit is very linear, to at least ± 0.1 °C. Perhaps the most accurate calibration instrument to hand would be a 300 mm mercury-in-glass thermometer. With that, the uncertainty of any reading might be ± 0.3 °C. Regarding the interface, the input range should be 0 V to 1 V. If less, some of the signal may be missed. If more, the uncertainty increases. With many modern interfaces on a 1 V range, the resolution is likely to be 0.5 mV, giving an uncertainty four times greater at ± 2 mV. Combining all these effects, the uncertainty of the output might be ± 0.4 °C - not bad value for about £2 in parts.

References

1. *The Continuation of Life (H) : Regulation Mechanisms,* Technical Guide T14.5, HSDU, SCCC, August 1998.
2. *Biology and human biology : Thermistor Applications,* Technical Article, Bulletin 175, SSERC, October 1992.

(A version of ref. 2 is currently mounted on the SSERC website.)

Adapting Unilab light gates for a PASCO *Interface*

It was recently observed in the Bulletin that light gates are notoriously difficult to design for reliable operation in all circumstances. For example the range of light gates produced by Unilab do not operate a PASCO *500 Interface* when connected to one of its digital inputs. Some extra circuitry is needed to adapt the light gates and interface them to the interface. The adaptation is really quite simple and inexpensive, requiring just a MOSFET, a couple of resistors and a jack plug (Fig. 1).

The modification works with three versions of light gate: item 414.032, pre 1990, whose sensor consists of a single phototransistor; item 414.032, post 1990, with the same phototransistor and a protective diode and resistor; and 414.033, the currently available model.

With the 10 kΩ pull-up resistor between the red terminal on the light gate and +5 V from an external supply, the voltage levels on the red terminal are +5.0 V (dark) and +1.5 V (light). The MOSFET cleans up and inverts the signal, which now becomes 0.0 V (dark) and +5.0 V (light). This now corresponds with the signal from one of PASCO's own photogates.

The MOSFET IRF520N is more powerful than need be, but was chosen because its threshold voltage is above 2 V and because it has been used in other applications. It is stocked by Rapid (47-0284 at 45p) and RS (254-0853 at 73p).

Power for the circuit is drawn from the +5 V outlet on the PASCO *500 Interface* through a quarter inch stereo jack plug (RS 485-748 at 65p each, minimum quantity 10).

The rise and fall times have been measured with a PASCO *Voltage Sensor* connected to the PASCO *500 Interface*. The sample rate was 10,000 a second. Falling and rising edge times were 0.3 ms and 0.2 ms respectively. This performance is considered to be remarkably good.

The circuit was tested with a PASCO *Picket Fence* ME-9377A freefalling through the light gate. From the sample velocity time graph published on page 11 in this issue under the heading '*Data Studio*' it can be seen that the straight line through the six data points is a perfect linear fit. Its gradient is 9.76 m s^{-2}. Repeated measurements gave values lying between 9.75 m s^{-2} and 9.85 m s^{-2}. This is highly satisfactory.

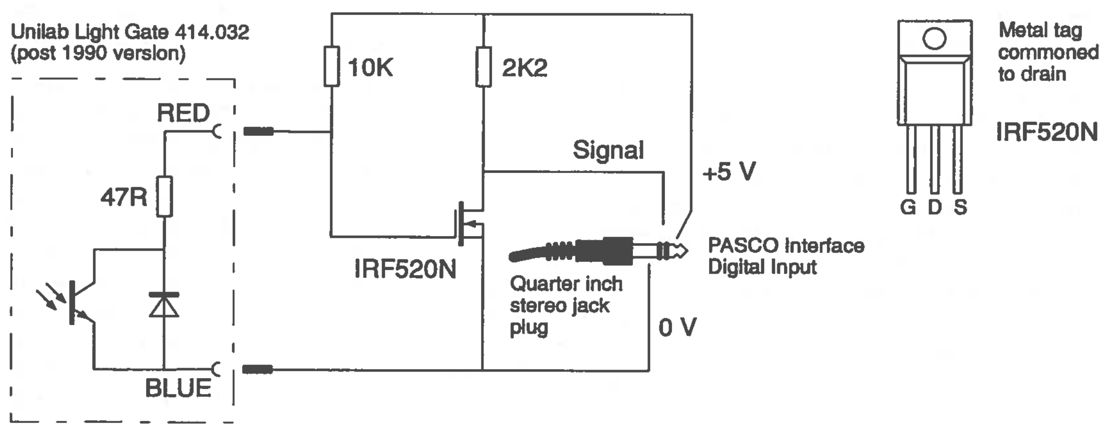

Figure 1 Circuit for adapting Unilab light gates (414.032 and 414.033) to operate a PASCO 500 Interface. Details within the pecked box relate to the post 1990 version of 414.032.

Publications

Experimental practice

A beginner's guide to uncertainty of measurement
Stephanie Bell, National Physical Laboratory, 1999, 30 pages, £25 (one free copy supplied to any school on application to NPL).

A measurement result is only complete if it is accompanied by a statement of the uncertainty in the measurement. This guide introduces the subject of measurement uncertainty - a subject which has radically altered in the last decade. Essential reading for teachers of engineering or physics.

Signs, symbols & systematics
ASE, 2000, ISBN 0 86357 312 6, 158 pages, £20.00.

A compendium of useful information for science teachers. Contains sections on SI unit definitions, physical quantities, symbols and units, constants and data relating to physics, chemistry, materials, biology, earth sciences and safety, electrical circuit symbols, chemical nomenclature (inorganic and organic), Latin and Greek components of words, a glossary and minefield of scientific terms (e.g. distinguishing between *energy transfers* and *transformations*), the use of algebra and mathematical topics. Will become indispensable!

The resourceful physics teacher
Keith Gibbs, Institute of Physics Publishing, 1999, ISBN 0 7503 0581 9, 230 pages, £14.25.

A compilation of more than 600 demonstration experiments and ideas for pupils in physics.

For a list of recent publications on health and safety, please turn to Page 33.

ICT NOTES - SOFTWARE REVIEW

Data Studio

Data Studio is the first of a new generation of software for use in data logging and analysis. It sets a very high standard for graphical presentation and analytical tools, which perhaps no rival package currently can emulate. Whilst most of the program is intuitive in operation, parts of it are not. Is this an Achilles heel, bringing condemnation on a package which, in the main, is delightfully simple with which to work?

Data Studio is newly released software from PASCO Scientific for operating with their *Science Workshop* group of dataloggers and sensors. It is such a complex package that it would be tedious to attempt to review it in full. Instead we outline what it does, discuss to what extent it achieves its educational objectives and list some of its failures.

It attempts to greatly simplify the operation of a *Science Workshop* computer interface or datalogger , while offering a large number of ways of presenting the results, making use, as necessary, of powerful analytical tools. Much of the software is delightfully simple to use. In fact the core of the program is intuitive. The user informs the system which sensor is to be used, opens a window for a graph, table, large digital readout, or all of these, starts capturing data, and finds that it is being presented with superb clarity.

The example velocity time graph (Fig. 1) illustrates the high resolution, graphical display. There are many clever ways, mostly intuitive, of manipulating the graph – for example, moving the axes, or origin, changing the scale, adding error bars, finding the gradient, or fitting a line through either part or all of the points. The smart cursor has more to it than is at first obvious. Not only does it provide *x,y* values, it has a *Smart Tool* for giving the increment to any other part of the graph. This is such a powerful aid for teaching how to interpret graphs and drawing forth information that might otherwise have lain hidden.

Because the *Science Workshop* sensors can be relied upon to provide accurate information, and because the information is presented in SI units, the data has a ring of confidence about it. It is trustworthy. In the example of a changing velocity of a freely falling object, the gradient of the velocity-time graph should be close to 9.8 m s^{-1} / s, which in fact it is. If working with velocity, the standard derived quantities are position, acceleration and momentum. These are provided as default functions, allowing the user to flip from one function to another, or to display up to three simultaneously.

All of these operations we have described are intuitive. Although the facilities are complex, the operation is simple. It sets a blisteringly hot example for rival products to match.

Yet all is not perfect. There are significant snags.

One relates to the keyboard entry type of experiment where one of the variables is detected automatically by a sensor while values of the other are entered from the keyboard. In setting up this type of experiment, windows open called *Sampling Options* and *Data Properties* where it is unclear how to proceed. If that hurdle is cleared, and the Keyboard icon is dragged onto the Table window, the table columns are *x* against *time*, not *x* against *y* as might have been expected. If variable *y* is dragged and dropped in the table, there are then four columns: *x* and *time*, and *y* and *time*. The variable *time* then has to be switched off, giving the requisite *x* against *y* two column table. Strangely this is the proper way for preparing this procedure. Worse has still to come, which will not be gone into here. Suffice to say that setting up and performing this class of experiment is unbelievably cack handed and most certainly not intuitive.

Another awkward step is in labelling columns for keyboard data entry. We should explain that, in common with many other datalogging programs, *Data Studio* has a facility for graphing data that has been collected manually. Nearly all of this procedure is intuitive. The core of it is brilliant. The start-up screen has a blank, two column table at the top left hand side, which would be the place to start by intuition. To the right of the table and occupying more than half of the screen is a blank graph. If numbers are entered into the table, matching data points appear simultaneously on the graph and the axes are scaled automatically. To repeat, this is simply brilliant. The snag is, neither tables nor axes can be labelled with their physical quantities and units by unconscious dexterity. We won't go into how its done, but to find out how, and the generally helpful *Help* facility omits to explain, a helpful man in technical support in California gave us the details. It's quite simple when you know how, but not obvious.

There is a rider to this tale. A teacher 'phoned us recently raving about *Data Studio's* graphing facility (raving praise, not raving mad). Having been informed that all of his pupils now routinely use *Data Studio* to plot graphs, the teacher was asked if they were able to label the axes. "No bother", he said, "they just do ....." and he went on to tell of a completely different way of doing this – something we would never of dreamed of in a month of Sundays.

So there you have it. Most of *Data Studio* is brilliantly intuitive, but a few bits aren't, but even when it isn't, it is the experience of one school that neither the students nor the teacher had been upset because, having found out how the task could be done, had learned what to do and were happily applying it.

What the telephone report also made clear is that the program is being widely used by students in a department whose facilities include several computers and PASCO interfaces.

Our own view is that this package would be immensely useful also in a teacher demonstration with a notebook computer and computer projector. In the hands of a skilled teacher, the powerful graphics and analytical tools should enable many points to be taught which by conventional means would be difficult to illustrate.

As we said, it is not perfect, but it is pretty near heaven, and nearer than most of us have ever been!

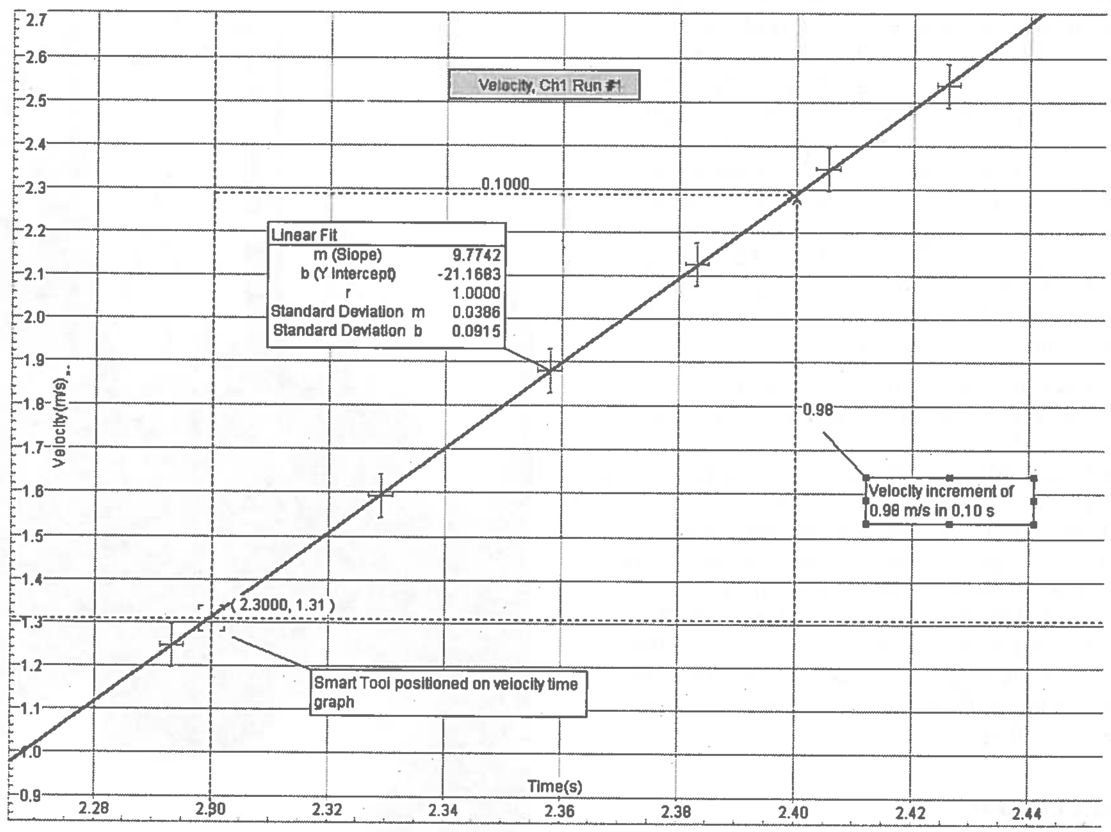

Figure 1 *Data Studio* graph of velocity versus time made with a *Picket Fence* ME-9377A freefalling through a modified Unilab light gate. The *Smart Tool* shows the difference between points, helping to explain how the gradient, time derivative, or acceleration is obtained.

SUMMARY

Prices: *Data Studio* Software, Single copy CI-6870 £79

As above Site licence CI-6871 £359

A single copy of *Data Studio* is supplied at no additional charge with every PASCO *Science Workshop* interface.

Producer: PASCO Scientific **UK Supplier:** Instruments Direct

Operating system: Windows 95/98 or Windows NT 4.0 Macintosh System 7.5 or higher

Main facilities include:

- Independent set-up of interface to collect and analyse data
- Library file of 284 Data Studio experiments for Biology, Chemistry, Physics, etc.
- Graphical analysis package on data entered by keyboard or imported electronically.

BIOLOGY NOTES

Bioreactors - an update

Ongoing activity, part of the SAPS Scotland Biotechnology Education Project, is reported. An overview of the aims of this initiative and its curricular contexts is provided and some possibilities for the future indicated.

This June, it will exactly be ten years since we last ran any major pieces, in the Bulletin, on bioreactors and fermentation technologies. In 1990, we began a three part series on "Fermenters" [1,2,3]. Part I dealt with general principles and went on to review commercially available, educational bioreactor equipment; Part II looked at the practical implementation of a number of published ideas for DIY bioreactors and Part III tried to extend the DIY scene into the tricky territory of continuous fermentation. We sought, foolishly as it now seems, the holy grail of the 'chemostat'. Interestingly, full scale systems for continuous fermentation remain relatively rare on the commercial scene even now.

The hope was that bioreactor design and use might encourage realistic, cross-curricular, investigative and project work in science and technology departments. For wholly understandable reasons, that proved to be an idea somewhat before its time. Over the past three years or so the climate for such innovative work has improved slightly. Here we report on some of the work carried out, as part of the SAPS Scotland Biotechnology Education Project, in Quest International's labs at Menstrie[1], Dollar Academy, the High School of Stirling and here in SSERC. Related work at the National Centre for Biotechnology Education (NCBE) in Reading and at University College London is touched upon.

Design criteria

The initial brief for this new phase of activity was arrived at in discussion with research and development and management staff at Quest[1]. Three groups of criteria were used:

Curriculum : The original context was Certificate of Sixth Year Studies Project Work in biology and chemistry. Analysis of likely curricular requirements was the starting point for the original 1997 design brief to which the CSYS biology and chemistry students involved in the project have since worked. Recent changes in biology curricula, part of the Higher Still Development Programme, at Intermediate 2, Higher and soon at Advanced Higher, mean that a better climate for this kind of work is on the way (See tabulation in Appendix).

Costs : Commercial bioreactors were available on the educational market in a variety of forms. Some are still. With few exceptions, by school standards, they are very expensive. Their other disadvantage is that when the datalogging and control functions are expensively in place, packaged in a box, and all of the software routines are provided, much of the rationale for a project may disappear. Opportunities to encourage creativity, and core skills such as problem solving and teamwork may be badly undermined.

1. Quest International is now a subsidiary of ICI.

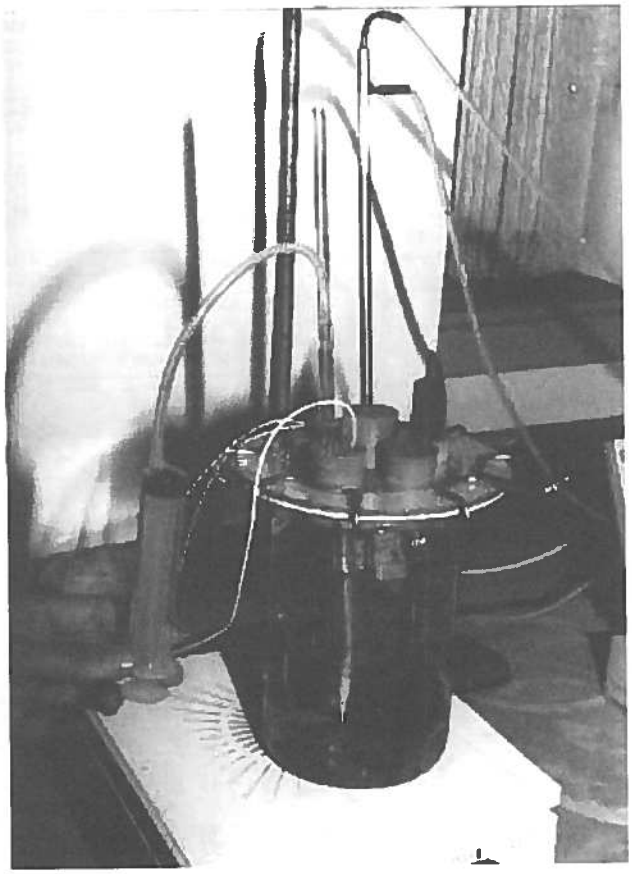

Figure 1 Original 'Quest' bioreactor vessel set up for an investigation on autolysis of yeast.

For this project, a hybrid approach was adopted. Commercial pieces of kit were used where that made sense but, so too were DIY devices. This was done so that problem solving skills might be nurtured and costs kept under control. For example, although a commercially available vessel was used for the early prototype, the lid with its ports for sensor probes, air intake and exit etc was homemade. Similarly, use was made of a mixed bag of sensors, datalogger and control devices. Most of these were already in the school being used for other purposes. Care was taken to increase the odds in favour of other schools, which might not have a specific item or device, being able to substitute other components into the system.

Constraints : These were many - in addition to that of cost just described. For example, in the business of setting a maximum volume for the vessel, it was necessary to avoid making it so big that significant difficulties and safety issues arose in sterilising, and aseptically transferring, large batches of media (with costs thereof an obvious complicating factor).

The other major constraint was that of time. Students were being asked to devote quite a lot of effort to these activities. It was necessary that such expenditure of time be duly recognised in some way. It was decided to approach the fermenter project as a double award activity. Whilst the overall activity remained one investigation, it was written up as two Sixth Year Studies project reports, each with different emphases, one submission for biology and the other for chemistry. Through the good offices of the Northern SATRO, which administers the funds, support was secured from a Nuffield Foundation scheme and students also submitted their work for CREST Awards.

The projects began originally as placements in the laboratories of a bio-industrial plant (a yeast production with a downstream processing and derivatives facility in Menstrie). There were thus some wider educational objectives, in addition to getting good grades at CSYS. The intention was to teach students something also about R&D project management techniques, about budgets, priorities, cut-off points and deadlines. The design brief and specifications attempted also to cover these other, broader aspects.

Phase one activities

For these the vessel shown in Figure 1 (opposite) was used in various guises. The initial design and build was carried out by two students on placement in the Quest labs. A commercially available, glass 'pot' with a notional capacity of ca. 800 cm³ was used for the vessel. The glass pot has a flange around the top and this is used to support a polycarbonate plate as a lid. The lid has several holes drilled in it to take sensor probes, heater cables, and filtered air-lines etc. A stainless steel spring clip holds the plate or lid in place.

The early development work was done in Quest during the Summer of 1997 and thereafter the vessel was used in SYS biology and chemistry projects by Mairi Wilson (Dollar Academy) and Hannah Bayes (High School of Stirling). There were three main areas of investigation:

- *autolysis of yeast cells;*
- *anaerobic batch and*
- *aerobic batch fermentations.*

Autolysis

This is the basis of yeast extract production. Yeast suspensions are subjected to controlled, raised temperatures and salt treatments. In these conditions the cells first plasmolyse then die. Disruption of the cell membranes and walls leads to the formation of complex breakdown products the composition of which depends upon the temperature conditions and salt regime.

The autolysis products flood out of the yeast cells. They enter the surrounding medium from which they can be recovered for further processing into food flavourings and other products. As these autolysis products accumulate, the pH of the medium, unless otherwise controlled, falls noticeably (see Figure 2). The soluble fraction of the total contents of the medium (ie the residue left after filtration and evaporation to dryness) rises markedly. As the autolysis proceeds, so in samples of culture the proportion of viable cell to dead cell counts falls away. All of these parameters are amenable to study and measurement by students.

This category of investigations also includes technological problems such as those met in controlling and monitoring temperature and pH in the vessel. The students utilised the *LogIT* datalogger and the related *SwitchIT* control device with *Multilink* software. The use of these specific devices is not critical however and other makes and models which schools hold may well lend themselves to such applications. In any event, since the original project, *LogIT* has been superseded by *Datameter* 1000. (cont./)

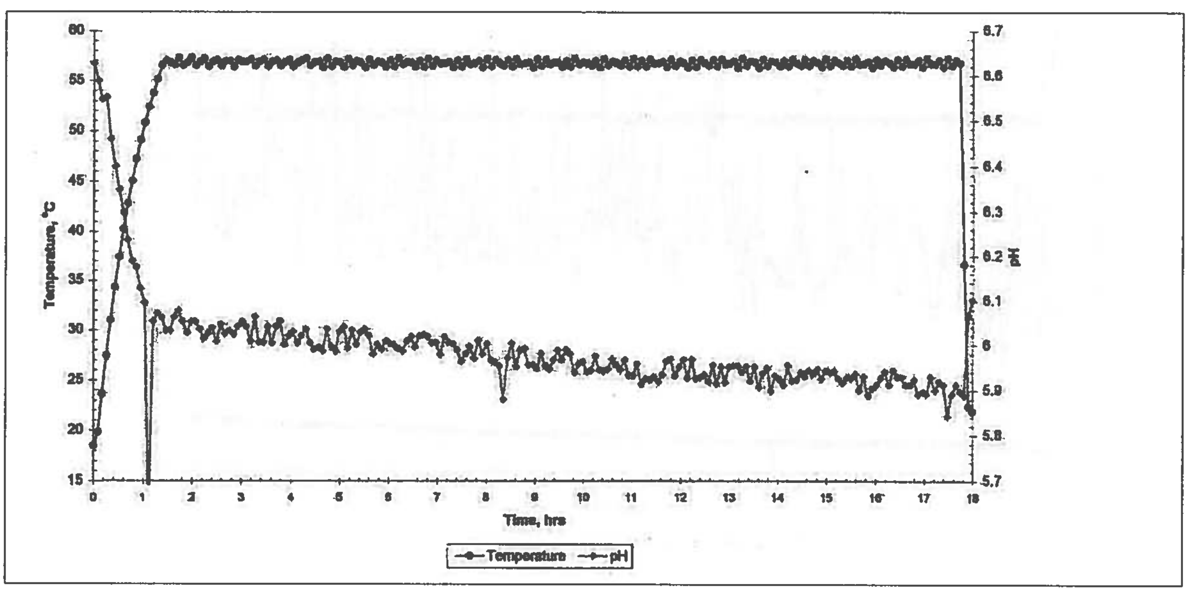

Figure 2 Plots of temperature and pH versus time in an investigation on the autolysis of yeast.

Autolysis cont.

In addition to the work carried out with the fermenter itself, the activities provide opportunities to practice a range of basic microbiological techniques. For example:

- *vital staining of* Saccharomyces *cells with methylene blue to monitor cell viability at various stages of the process;*
- *microscope techniques and cell counts using a haemocytometer and*
- *gravimetric analyses in monitoring the levels of the soluble fraction.*

Batch fermentations

Both anaerobic and aerobic fermentation were studied. The major interest lay in monitoring changes in yeast cell numbers (as cell densities) and in estimating levels of ethanol production.

Temperature was controlled using a temperature sensor feeding a signal to the *LogIT* datalogger coupled to a *SwitchIT* control device connected to a heater circuit. By such means vessel temperature could be controlled within a degree or two of 30 °C. The control of pH was an optional extra. The progress of fermentation was monitored either with pH allowed to fall as fermentation proceeded or when it was controlled by a feedback loop with the addition of alkali. The students learned the practical need for two separate power arrangements, one for the instrumentation and the other to switch any appreciable current loads. Failure to make such arrangements leads to noisy signal lines, unreliable control circuits, possible overload problems and sundry other difficulties.

Samples were withdrawn at intervals and cell counts carried out. Ethanol levels were measured using gas chromatography facilities at Quest. This latter measure was, and remains, recognised as a problem at this level and a number of attempts have since been made to find alternative techniques more accessible to schools. To date none of these has proved wholly satisfactory.

The pH control technique devised by the students was interesting and effective. They realised that low voltage solenoid valves, resistant to corrosion by alkali, are both expensive and difficult to source. They therefore set up an air lift pump for the alkali line and controlled the flow by controlling the airstream from an aquarium pump. For this a much cheaper solenoid operated air valve proved sufficient and the technique avoided its contamination by the corrosive, alkaline liquid. In the aerobic batches an oxygen sensor was added to the instrumentation system.

A copy of a printout of a fairly typical trace for an aerated batch process with the pH control system in place is shown in Figure 3 below. Note the fairly close control over both temperature and pH. Dissolved oxygen levels, however, do apparently fluctuate widely but closer examination reveals two interesting features of the oxygen data. Firstly, with active aeration via a filtered airline the culture is seemingly supersaturated from the beginning (probably due to air bubbles entrapped at the electrode membrane). Secondly, the apparent wide fluctations are partly due to scaling and partly because of hysteresis in the oxygen measuring system. After the first seven or eight hours the oxygen level oscillates about a nominal level of 220% saturation. In stirred systems used later in the project oxygen levels were lower and the signals steadier.

The results for anaerobic and aerobic fermentations were of interest and confirmed much of the basic biology studied elsewhere in the CSYS course. Cell numbers in the anaerobic process increased by only about 2.5 times over the numbers per cm^3 in the original overall culture volume. In the aerobic process, they went up more than threefold over roughly similar times. In contrast, the final ethanol levels in the anaerobic batch were 5.5% v:v whilst only reaching 1.75% in the aerobic process.

Other work included early attempts to model 'fed-batch' fermentations where substrate is added - 'topped up' - to keep the process going.

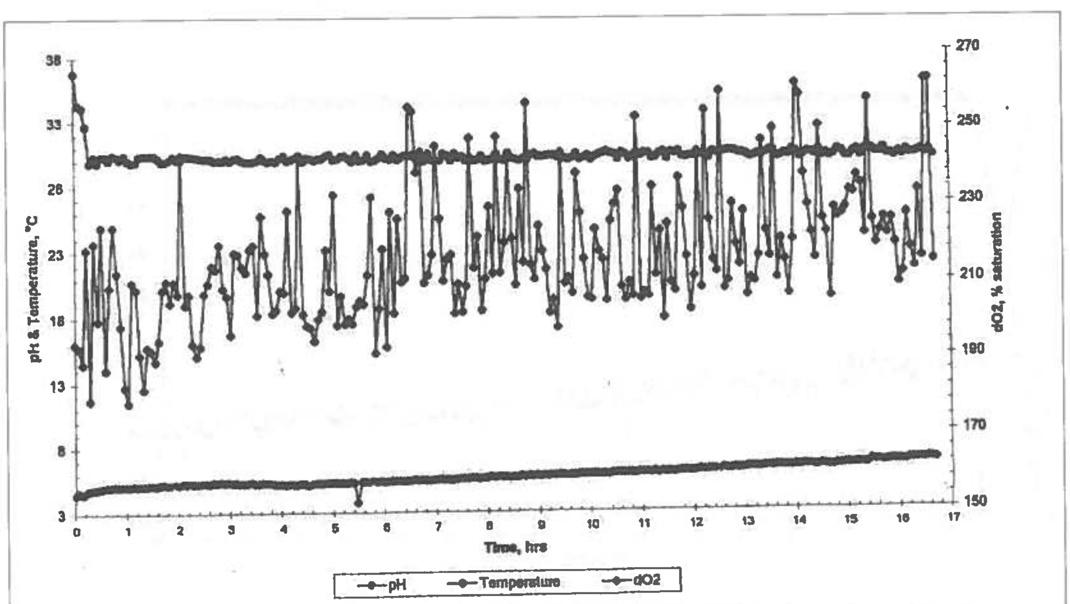

Figure 3 Plots of temperature, pH and dissolved oxygen levels during an aerated batch fermentation. (Temperature and pH - top and bottom traces controlled via LogIT/SwitchIT loops).

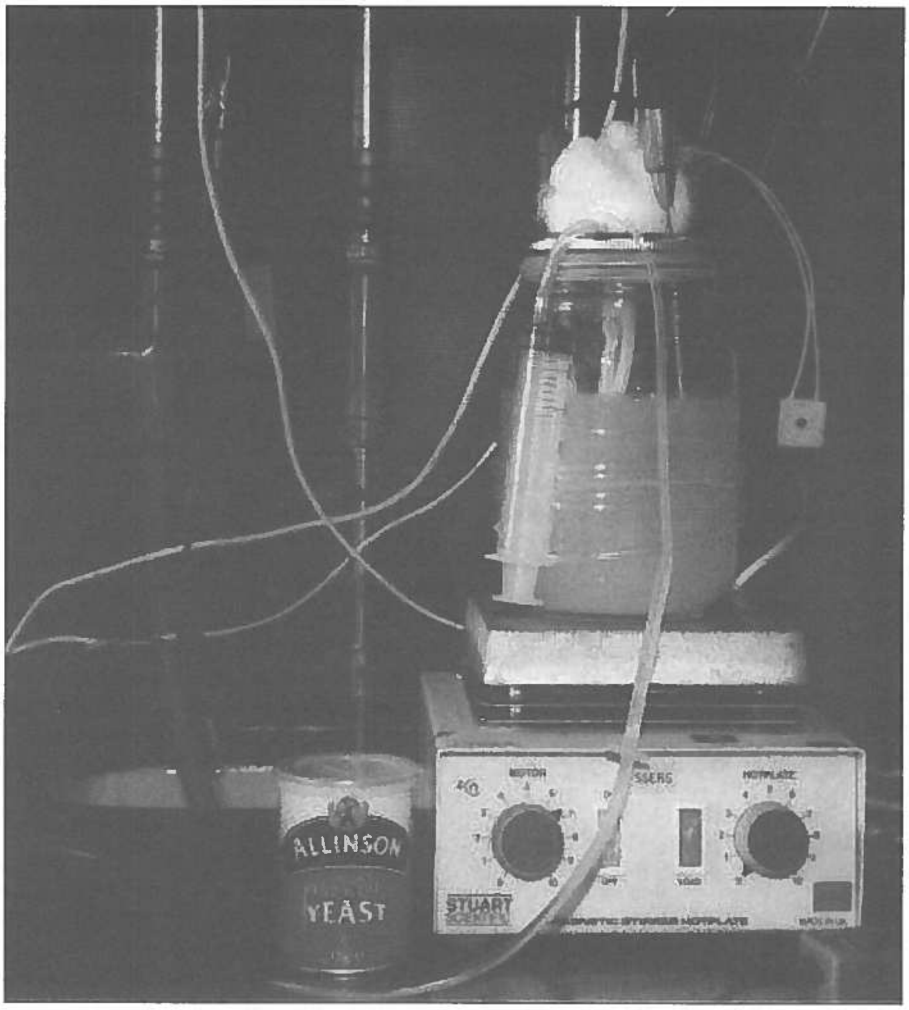

Figure 4 Bioreactor based on a Kilner jar - hybrid set-up with elements of both the original 'Quest' design and the UCL system.

Following on the industrial placements, CSYS projects in biology and chemistry were successfully completed by both students in their respective schools. In the following Summer break (1998) further work on the 'Quest' version of the bioreactor was carried out at SSERC by one of the students (Mairi Wilson, now reading Medicine at Dundee University). Other sixth year students then based projects on the system in the following session and in the Summer of last year Mairi returned to SSERC on vacation employment to carry out further work on fermentations. This marked the beginning of a new phase of the development.

Phase two activities

The original bioreactor designs had been exhibited at both the 1998 and 1999 Biotechnology Summer Schools held in Edinburgh University. There they had generated renewed interest in fermenter technologies as vehicles for learning and teaching. By 1999, another Dollar student, Guy Mozolowski, had shown a keen interest in the project. At about that time SSERC and the SAPS Scotland Biotechnology Education Project had been made aware of another educational bioreactor initiative based at University College London (UCL).

The UCL bioreactor system

The UCL project is slightly unusual in that it is intended largely for sixth year students doing A level mathematics and physics, rather than for biologists. This is an initiative involving both the Biochemical Engineering Society and TEP (the Gatsby Funded *Technology Enhancement Project*) as well as the relevant department(s) at UCL.

The UCL bioreactor uses a Kilner jar as the basic vessel, with a bespoke lid insert. This insert has ports for sensor probes, and inlet/outlet lines, much the same as those in the Quest vessel closure. What is markedly different on the UCL model is an electrically powered, top mounted, stirrer motor. This motor is fitted with a torque arm and other accessories. Attached to the underside of the lid are anodised aluminium inserts to act as baffles. The UCL system thus lends itself to investigations into rotational mechanics, motor characteristics and fluidics. It is a powerful educational model, set in a biological context, but one which allows exploration of basic ideas in maths, physics and engineering. In that sense, it is akin to the *Fermenter Case Study* used by SSERC several years ago as an industrial context for Technological Studies at the Higher Grade.

cont./

Hybrid designs

The original Quest bioreactor was largely a technological vehicle and context for learning and teaching about biological concepts and industrial research and development project management. Nonetheless, students also learned (they had to) a good deal about solving problems in design, control techniques and instrumentation. The UCL vessel, on the other hand, is more of a biological context for learning and teaching in maths and technology. It is firmly rooted in the physical sciences. As a result each of the designs is a compromise, as perhaps is every design. For example, in the Quest vessel emphasis on measuring biologically important parameters has meant a plethora of ports in the lid for sensors, airlines and sampling points. In the UCL design the motor assembly with its large shaft bearing leaves much less room for sensor ports and other apertures. To set against that, the UCL vessel has a smaller volume than the original Quest model. This eases problems of ensuring sterility of media and lowers running costs.

In addressing the needs of Scottish biology courses, an obvious ploy was to combine elements of each design as appropriate. The idea of using a Kilner jar and its lid ring, as the closure has been adopted in a hybrid system which also retains a lid insert with lots of ports. In the latest prototypes the bulky top-mounted motor system has been replaced by a plastic disc or 'spinner' as a means of agitating vessel contents where stirring rather than aeration is to be used as a means of mixing. This is so as to keep the organism in optimal contact with the liquid growth medium.

Additional investigations

Over part of the Summer of 1999 Mairi Wilson returned to SSERC and extended the work she had already done on bioreactors. In particular, she carried out a series of trials and investigations into diauxic growth of yeast.

The growth of individual organisms and that of populations, including collections of microbial cells not unusually follows a pattern of 'lag', 'log' and steady state. These together produce the classic 'S' shaped or sigmoid growth curve. In diauxic growth, the sigmoid shape occurs twice (literally - "double growth"). Such double 'S' growth curves occur when fermentations are carried out with certain mixed substrates. In a simple model, the mixture may be two sugars such as glucose and lactose. The organism may preferentially utilise the glucose until that is used up and then switch over to using the lactose. There will then be a second lag phase whilst lactose is broken down into glucose and galactose and cell division and culture growth begins again.

A number of attempts were made to model this type of growth with yeast in the bioreactor. Various parameters were used in order to track substrate utilisation in both anaerobic and aerobic fermentations. Variables examined included dissolved oxygen levels, carbon dioxide production and cell counts. After considerable trial and error recipes for suitable substrate mixtures with appropriate glucose and lactose concentrations were established. Later runs produced some promising results with marked double growth curves. This work is now being further developed by other CSYS students.

Where next?

The SAPS Scotland Biotechnology Education Project Steering Committee has set up a Task Group to take these activities forward to the next stage - that of wider dissemination. One major step will be revision of earlier analyses of compatability of available educational bioreactors with curricular needs - both current and in the short to medium term future. A curriculum analysis and matching exercise is to be carried out from 5-14 Environmental Studies right through to Advanced Higher level. The appended text box opposite shows the results of preliminary attempts at such a matching exercise for component biology courses in the Higher Still programme.

Meantime, a further four SYS students at the Quest Biotechnology Lab in Dollar are using bioreactors for their biology and chemistry projects. Two are using smaller scale (500 cm^3) bioreactors of a design from the National Centre for Biotechnology Education (NCBE) at Reading University [4] and two are using hybrid Quest/UCL designs of the type referred to above. The results of some of this work will again be shown as part of the Biotechnology Summer School in Edinburgh. This year, however there is also to be a formal needs analysis exercise and an evening discussion session for both biologists and chemists. It is hoped that the combination of the curriculum matching exercise and the 'market research' with teachers will lead to the specification of a range of suitable bioreactor equipment for use in a number of different courses.

One of the tasks carried out by Mairi Wilson at SSERC was the compilation of a list of fermenter parts and ancillary equipment useful for the kinds of projects and investigations described here. If none of the parts are held in a school then the total cost for a system built from scratch is high, at about £800. Quite a lot of of these components are however to be found already in schools or may be sourced relatively cheaply locally. Others are somewhat specialised and are scattered throughout and between science education suppliers' catalogues. One medium term aim is to produce a cohesive list of such items for entry as a page, or pages, in a designated section of the catalogues of specialist science supply firms. Some companies have already expressed both an interest and a willingness to cooperate in such an exercise.

References

1. *Fermenters - Part I, Categories of fermentation apparatus for use in schools,* SSERC, June 1990,Bulletin 166, 29.
2. *Fermenters - Part II, DIY fermenters,* SSERC, September 1990, Bulletin 167, 28.
3. *Fermenters - Part III, Modelling continuous fermentation,* SSERC, December 1990, Bulletin 168, 18.
4. *Practical Fermentation,* SSERC, 1999, Bulletin 198, 29.

   (A short review of an NCBE resource describing fourteen investigations on fermentation. Available from NCBE at £15.00 per pack of 5 Student Guides and two Technical Guides).

Acknowledgements

We are most grateful to the following for their active collaboration in, and contributions to, the joint development work reviewed herein: Dr Jim Hay and staff at Quest; Mairi Wilson and her fellow CSYS students Hannah Bayes and Guy Mozolowski; Marjorie Smith of SAPS Biotechnology Scotland and Dollar Academy; Bill Beveridge Chemistry Department at Dollar; Dr Ian Bardrick (at that time seconded to Biochemistry in UCL), Kath Crawford, Stevenson College, Professor Ian Sutherland at the Institute of Cellular and Molecular Biology at Edinburgh University, not least - Ian Buchanan, Marjorie Hamilton and Graeme Paterson all of STS at SSERC for much technical support.

Appendix : Bioreactors : Learning Activities

A. Trialled in various forms at Quest, Dollar, Stirling High and SSERC :

Viability of yeast at different stages of the yeast extraction process; flavour development in yeast extract production

Use of microbes to produce enzymes – manipulation, fermentation, recovery of product

Effects of different substrates of the growth of *Kluveromyces lactis* and *Saccharomyces cerevisae*

Biochemistry of micro-organisms and growth curves with different substrates

Respiration rates in yeast and measurements of growth using cell counts and dilution plating

B. Extant or emerging possibilities in Scottish curricula:

Intermediate 2 Biology:

Produce yoghurts using diffferent milks and aseptic conditions

Grow yeast in liquid culture and on agar

Use yeast to show alcohol production

Set up experiments to show flavour development in yeast

Measure BOD of yeast samples

Plan and design an investigation into anaerobic respiration in yeast

Measure the growth of a contained population e.g. yeast culture or *Chlorella* culture

Intermediate 2 Biotechnology:

Microscopic examination of yeast using vital stains

Investigate the limiting factors of photosynthesis using a *Chlorella* culture

Investigate the growth and or productivity of a *Chlorella* culture under different light conditions

Investigate the effects of mineral deficiency in *Chlorella* culture

Investigate the effects of nutrient enrichment on the growth of yeast cultures

Test end products of yeast and *Lactobacilli* fermentations

Measure the rate of decay of malt extract by the loss of weight in a yeast culture

Loop transfer of micro-organisms: solid to solid; solid to liquid; liquid to solid; liquid to liquid

Stain cultures of fungi and bacteria with for example methylene blue and carbol fuschin

Monitor the growth of *K.lactis* on whey to illustrate growth of biomass from waste material

Monitor changes in temperature and pH in a model silage silo

Investigate the effect of aeration on fungal growth in liquid medium

Investigate the growth rate of a yeast culture

Demonstrate the use of immobilised yeast in fermentation

Higher Biotechology:

Media preparation

Sterilise instruments, equipment and media by autoclaving, checking sterilisation.

Prepare and use disinfectants for bench swabbing, surface sterilisation and disposal

Examine the effects of temperature/pH/glucose concentration on the growth of a named organism

Obtain and present information on growth curves of industrial processes

Set up a small scale laboratory fermenter and monitor and control various conditions such as pH and temperature

Autolyse yeast and test viability at different stages in a downstream process

Test for the presence of specific micro-organisms using a range of diagnostic tests

Enumerating micro-organisms

Gas law experiments: Part 3

Methods and apparatus for showing Boyle's law.

If apparatus for showing Boyle's law is any good, then it should be capable of showing direct proportionality between pressure and inverse volume. This is the litmus test for assessing and comparing different apparatus and methods.

Secondly it should give pupils a feel for the springiness of air, under rarefaction as well as compression.

Thirdly it should be patently obvious what is happening.

The first method to be written about below was carried out with a PASCO pressure sensor linked through a *500 Interface* to a PC running on *Data Studio*. It illustrates the test procedure and explains how different experimental methods and apparatus are compared.

PASCO Pressure Sensor - Absolute (0 to 700 kPa) : CI-6532A : £119

An absolute pressure sensor is one that reads the actual pressure rather than a pressure difference relative to atmospheric. When its inlet port is open to the atmosphere, it reads atmospheric pressure. The range of this sensor is 0 kPa to 700 kPa, or seven atmospheres, and the resolution is 0.5 kPa. The 95% uncertainty in a reading is perhaps ± 2 kPa, but this we have not measured. From experimentation, it would seem to be no larger than that figure. This technical specification shows that its range is really too large for this application, resulting in a loss of sensitivity. In spite of this defect, it turns out to be very suitable for Boyle's law methods and can give splendid results.

The sensor is used with a PASCO interface. The lower specification model known as the *500 Interface* is quite adequate. The tests were conducted with new software, *Data Studio*. Running *Data Studio*, values of pressure are sensed automatically while values of volume are entered by the keyboard.

Other parts supplied with the pressure sensor are a 20 ml plastic syringe, 1/8 inch inner diameter polyurethane tubing and a set of quick release connectors (Fig. 1). The calibrated syringe acts as the variable volume air chamber. Setting up and dismantling can be done in a matter of seconds.

The method used was to disconnect the syringe, set the piston midway at the 10 ml mark, and reconnect to the sensor. At this position of the piston the pressure was at atmospheric. The piston was then drawn out to the 20 ml mark, rarefying the air, and the computer was instructed to begin logging values of pressure and volume. Sets of readings were obtained by 2 ml steps down to a minimum volume of 4 ml.

The graph of results (Fig. 2) shows that proportionality does not exist between pressure and inverse volume. The straight line through the points was obtained by the line drawing routine in *Data Studio* that gives a linear fit. Clearly the relationship is neither linear, nor proportional.

A source of error is easy to see, being the volume of the tubing connecting the syringe to the sensor. Taking into account a length of tubing hidden inside the pressure sensor box (Fig. 1), the volume of air between the electronic sensor and syringe is reckoned to be 1.4 ± 0.2 ml. If values of volume are corrected for this systematic error, the relationship between pressure and inverse volume is seen to be proportional (Fig. 3).

Commenting on the quality of the method, it is patently worse than the method with traditional Boyle's law apparatus of the type presently sold by Philip Harris. The Harris apparatus gives results that are questionably adequate (see below) whereas the uncorrected PASCO results are much poorer. But yet the beauty of the PASCO method is being able to

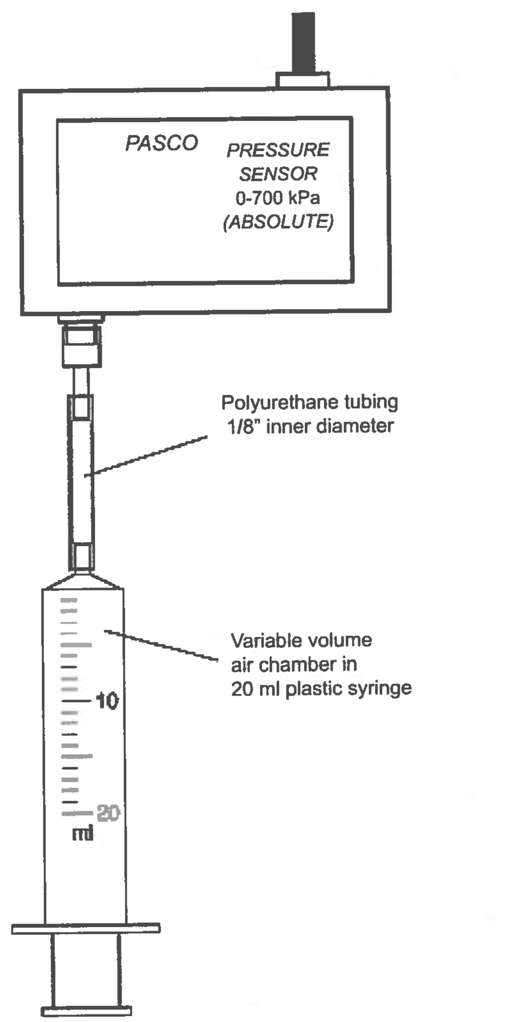

Figure 1 Boyle's law apparatus with 20 ml plastic syringe and pressure sensor.

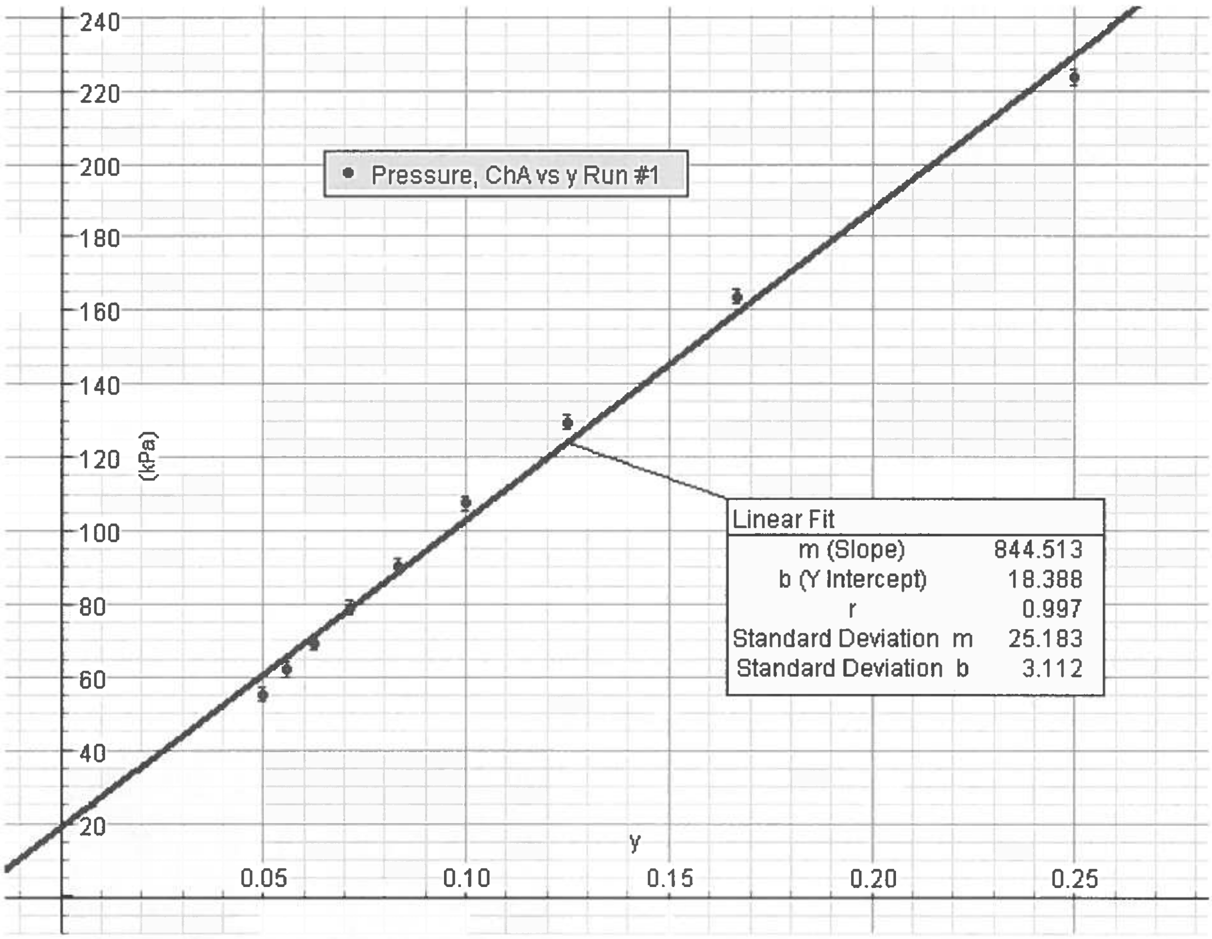

Figure 2 Uncorrected results showing that pressure is not proportional to inverse volume.

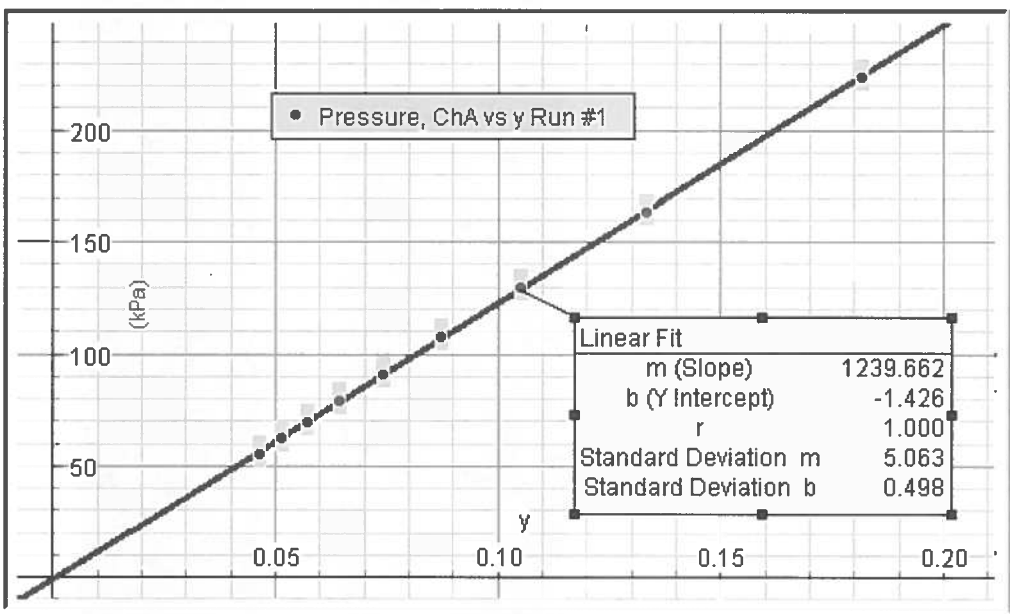

Figure 3

Corrected results showing proportionality.

analyse the results, spot the error, quantify it and apply a correction. This is good physics. It is mentally arresting. The fact that it ultimately yields a good result is very satisfying! It is of course made feasible by it being carried out with a computer.

Another good feature is the way that the operator of the syringe gets a tacit feel for air pressure. When the piston is withdrawn, you can feel that it wants to be sucked back into the cylinder, whereas when the air is compressed, you feel its springiness. By contrast you don't get any feel for Boyle's law with the traditional equipment. Indeed because the Bourdon gauge is separated from the trapped air by a column of fluid, it is far from clear just what the pressure gauge with traditional apparatus actually measures.

PASCO Gas Law Experimenter: SE-8011: £75

This kit is designed for use with a pressure sensor, such as the absolute sensor CI-6532A, computer and interface. It comprises an aluminium canister, 60 ml syringe with luer lock connection, tubing, connectors and valves. It may be used in several applications including Boyle's law, the pressure-temperature law, Dalton's law of partial pressure, Avogadro's principle and finding the average molecular speeds of gases.

Since the previous method was flawed because it had used a syringe whose capacity was only a few times that of its connecting tubing, a sensible progression would be to repeat the procedure, but with a larger syringe. The 60 ml syringe in the *Gas Law Experimenter* might seem to fit the bill. But with it, the uncorrected results resemble the ones with the 20 ml syringe. The non-linearity and non-proportionality between pressure and inverse volume is still significant - even with the shortest of tubes and the error minimised at 2 ml.

A big plus point with the larger syringe is that the springiness of air becomes much more tacit. Pupils will surely enjoy using it, and some may commit the experience to memory!

If there is time for just one attempt at Boyle's law with a pressure sensor, it should be done preferably with a 60ml syringe. Although there is still the tubing error to correct for, it does let students experience the springiness of air in a forceful way.

PASCO Heat Engine : TD-8572 : £278

As reported before, one of the main limitations of the apparatus is the leakage of air at the piston. Because air is as likely to leak into the chamber, under rarefaction, as out, under compression, a method which cycled between these two states was tried. The results were disappointing. In our opinion this apparatus is unsuitable for giving a quantitative demonstration of Boyle's law. However it does nicely show the springiness of air.

STE Boyle's Law Apparatus : £53.95

The apparatus is of traditional design (Fig. 4) with trapped air in a vertical, glass column. Air can be pumped into the base tank, pressurizing the system and forcing a coloured fluid to rise up the column, compressing the trapped air. A Bourdon gauge fitted to the tank records pressure. It is an absolute measuring meter, whose range is 0 - 400 kPa, reading to ± 2 kPa. The fluid is water coloured with fluorescein.

We understand that the apparatus is pressure tested twice. Once as a quality assurance test in manufacture and once on arrival at the STE warehouse. The perspex cage around the glass tube acts mainly for support, but partly for protection against the tube rupturing explosively.

The tank is fitted with a bicycle pump valve (Wood's type), easily replaced at low cost. A syringe is supplied for pressurizing the system, but either a cycle pump or footpump may be used instead.

The apparatus delivered to us for testing was in good working order and has performed well. However we have had an adverse report from a school on two sets of apparatus. Firstly, on delivery, both of the glass tubes were found to be curved, having popped out of their location holes. Secondly, a fungal growth appeared in the fluids some weeks after receipt. The apparatus was returned to STE and replaced with a second set, which also had a fungal growth. The school then cleaned them out and refilled with distilled water and fluorescein. Thereafter both sets appeared to be working.

Responding to this incident, we have been asssured by STE that these faults have been isolated to a small batch in a pre-production run and "the incidents of complaints about this product are incredibly small".

We suggested to STE that the extraordinary cheapness of their equipment may indicate that the quality is suspect. STE rejected this charge, stating, "the price should not reflect negatively on the quality as we endeavour to provide good quality in all our products".

Results with the apparatus are good. Two sets were taken. One with pressure increasing to 400 kPa. The other decreasing to 120 kPa. We found there to be

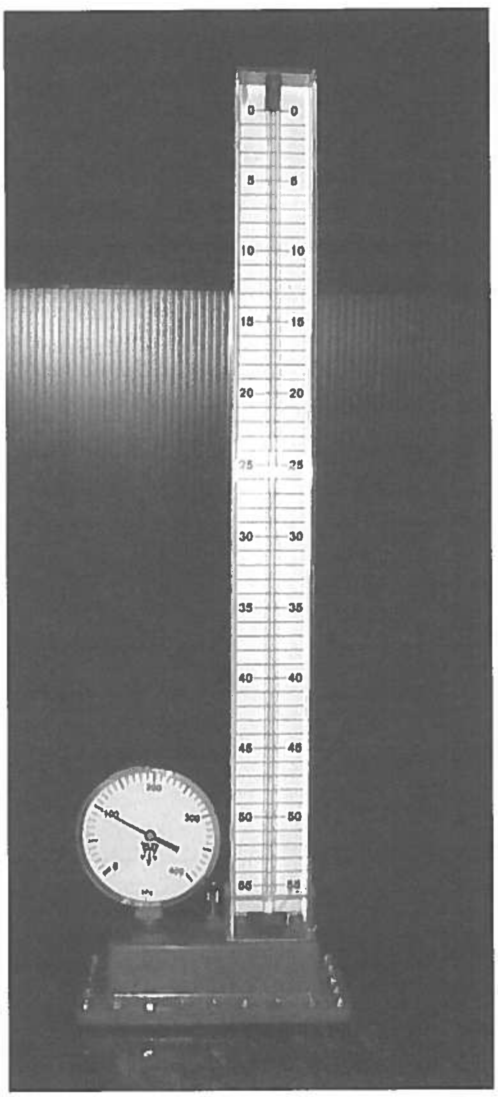

Figure 4 STE Boyle's Law Apparatus.

Suppliers: Griffin (XCR-465-P at £54.99),
Scientific & Chemical Supplies (XPG030.10 at £53.95).

excellent linearity between the values of pressure against inverse volume. The pressure axis intercept was 4 ± 4 kPa, indicating that the line might go through the origin, establishing a proportional relationship between p and $1/V$.

We were a little disappointed not to be able to withdraw air from the tank and work with pressures below atmospheric. By tilting the apparatus before taking a set of readings, it is possible to introduce the water column into the tube to take a reading at 100 kPa. However we know from correspondence with schools that some have not been able to set up the apparatus this way and were displeased at not being able to take a volume reading at atmospheric pressure.

There is a systematic error caused by the fluid column pressure. Because the error is directly proportional to the value of pressure, it does not affect the experimental results.

In summary, this apparatus gives good results, is inexpensive, has had production defects and, not being as robust as earlier designs, may not be as long lasting.

Philip Harris Boyle's Law Apparatus : £367.64

We can with confidence say that this apparatus is long lasting, knowing that lots of schools have a set, in working order, having purchased it in the 1960s. Not recalling any problems reported to us apart from one sticky valve, which was repairable, the apparatus would seem to be robust and perform well. But does it? We tested a sample which must have been well over 30 years old and were disappointed with the results. The graph of p versus $1/V$ was not as linear as we had expected (Fig. 5) and cuts pressure axis at 12 kPa. No uncertainty is given because of the discontinuity at 120 kPa.

We cannot fairly comment on the present Harris product because the equipment is very old. The pressure meter may have a non-linearity brought about by work hardening, or other problems with ageing.

We can write about problems with the method. There is an error caused by the fluid column pressure. Because of the size of the column height, the maximum discrepancy would be around 4 kPa, occurring with the system under high pressure. Neither the size nor direction of this slight effect agrees with the experimental results.

Another error is with the meniscus. Since the fluid is a dark oil, it is impossible to measure. It may be as large as 0.5 cm³. Applying a correction of this value does improve the linearity of p versus $1/V$. In fact the relationship becomes reasonably close to being proportional.

There are two other problems with the oily fluid. One is the oleaginous film left on the tube when the pressure is reduced. The other is its volatility. The effects of both of these can be seen from the following test. Pressure was reduced from 300 kPa to 100 kPa, causing the volume to expand and the fluid level to drop. Subsequently the fluid level was recorded over 30 hours. Its initial value was 58.5 cm³. The volume fell over 20 min to 56.8 cm³ as a result of oil creeping down the walls then slowly rose throughout the day to 58.0 cm³, caused by the room getting warmer. The following morning when the room was cooler the level had contracted to 57.3 cm³.

Assessing the significance of these effects is complex. The lack of proportionality may be caused by several factors.

Why does the STE apparatus, which is fairly similar, perform better? The following differences may be significant:

- with a clear fluid, the meniscus can be seen;
- the trapped air is cleaner because water is less volatile than oil;
- water does not coat the tube walls; and
- the fluid column pressure error is uni-directional and in proportion to air pressure.

In summary an aged version of the apparatus has been found to give results of doubtful worth. Related to the method are several defects whose effects are complex. The method does not provide children with a tacit feel for the springiness of air. Nor is it clear that the Bourdon gauge measures the pressure of the trapped air.

References

1 *Gas law experiments: Part 1* SSERC 1999 Bulletin 197 20-27.

2 *Gas law experiments: Part 2,* SSERC 1999 Bulletin 198, 6-10.

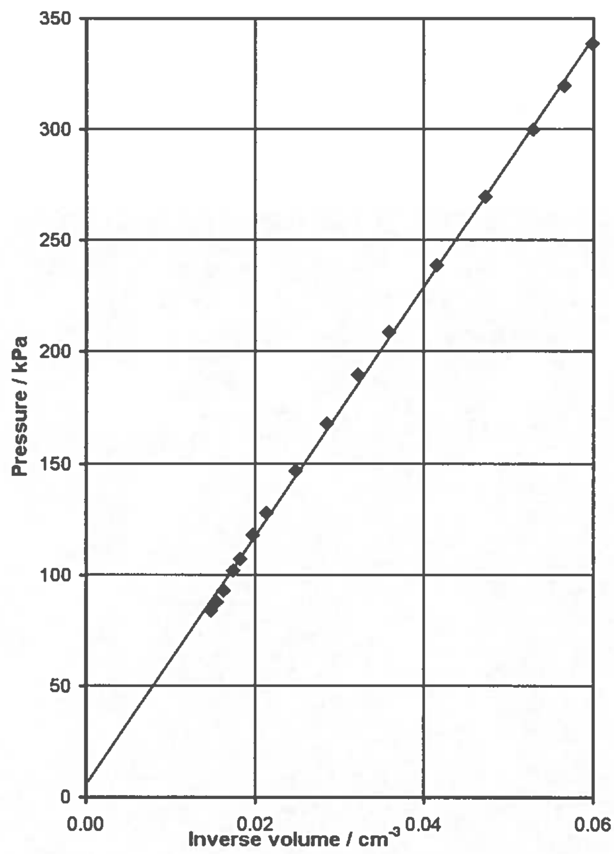

Figure 5 Graph of pressure versus inverse volume with aged Harris Boyle's Law Apparatus (*Excel* graph).

Microscale Vacuum Apparatus

New apparatus comprising a small bell jar and vacuum pump is reviewed. The report includes a description of using the apparatus to measure the density of air and to show Boyle's law.

This is an attractively designed kit made from modern materials for showing some of the simpler vacuum experiments. Having quite a low price, several may be bought for use by students. It was originally available only from a US supplier, Educational Innovations, at US$34.95 (order code VAC-10). This seemed quite an attractive price until adding US$19.35 for shipping. Therefore it is good to see that PASCO now stock the product because they have a UK agent, Instruments Direct, to soak up some of these delivery costs. PASCO have called the product their '*Student Bell Jar*' (order code SE-9790). The price, through their UK agent, is £33.

The polycarbonate bell jar stands 92 mm high on its base plate (Fig. 1). Its outer diameter is 70 mm, with a wall thickness of 4 mm. Because there is an O-ring between the bell jar and base plate, any slight deformities or minor scratches on the matching surfaces do not seem to matter. The fitment is effectively sealed.

The top of the bell jar has a quick-connect plastic fitting to which $^1/_8$ inch internal diameter polyurethane tubing is attached by light finger pressure. Two pieces of tubing are supplied, both of which have check valves. A 60 ml syringe is attached via a T-piece to evacuate the bell jar. It takes about ten draws of the piston to reduce pressure to about 12 kPa and a further twenty to reach 4 kPa. That is about the lowest pressure which can be reached.

Time (min)	Pressure (kPa)
0	3.9
30	8.8
60	13.2
90	17.6
120	22.5
150	26.4
180	30.3

Table 1 Increase in pressure with time due to leakage after depressurization with 30 strokes of the syringe to 3.9 kPa.

Our tests show that the bell jar can hold quite a good vacuum for an extended period (Table 1). In another trial the rate of leakage was about 30% slower. This would seem to show that the amount of finger pressure applied on tightening connections controls the leakage rate. The instructions warn not to overtighten joints. Thus a weakness of the system is that its performance does depend on finger control.

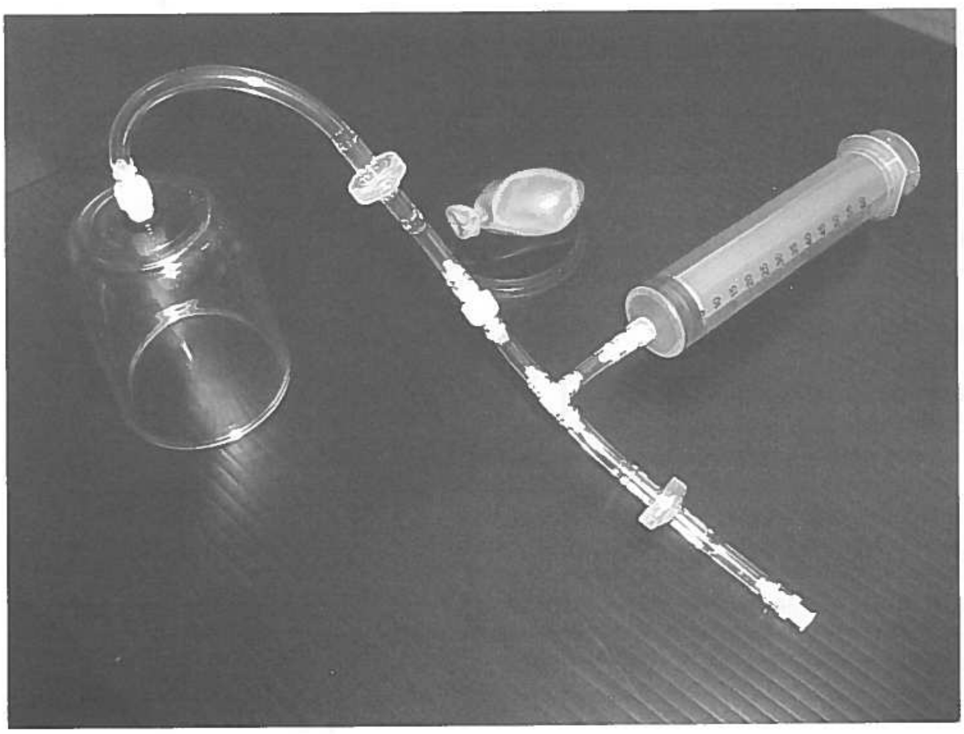

Figure 1 Photograph of Microscale Vacuum Apparatus showing bell jar attached by tubing to two check valves and 60 ml syringe. The base plate with balloon is to the right of the bell jar.

The apparatus is designed for use by students under supervision. Some of the simpler experiments which might be done, giving students a tacit feel for vacuum effects, include:

1. Observing that after one draw of the syringe, the bell jar is attached to the base plate.
2. Watching a slightly inflated balloon expand as the chamber is evacuated,
3. Seeing a similar effect with a marshmallow, or polystyrene chip.
4. Attaching a suction cap to the base plate and evacuating the chamber until the suction cap detaches.
5. Seeing that water can be made to boil when the surrounding air pressure is reduced.
6. Seeing that air has weight, because the mass of the bell jar and contents are reduced on evacuating the air.

Safety

Students must be informed of the hazards, instructed as to how to use the equipment and supervised while using it. Because there is a risk of an implosion, eye protection is needed. Pressurized electrical or electronic devices such as batteries or capacitors must not be placed in the bell jar. If a liquid is used in the bell jar, some of it is liable to be discharged as a mist. Because of this effect, only a very low hazard liquid such as water should be used. If the bell jar is placed against the skin and evacuated, severe injury might result. It should only be used with its base plate.

Density of air determination

The bell jar is weighed before and after evacuation on a balance with a resolution of 0.01 g. The difference in weighings is the mass of air displaced. If the air had been removed with thirty strokes of the pump, then the resulting pressure should be about 5 kPa. Therefore about 95% of the air had been pumped out. This can be confirmed by holding the bell jar under water and opening the inlet. When no further water enters the bell jar, it can be seen that the remaining trapped air occupies no more than perhaps 5% of the volume. The water volume in the bell jar should be determined with a measuring cylinder.

Some sample results are given. The mass difference after evacuation in one trial was 0.27 ± 0.02 g. The water volume which entered the chamber was 213 ± 2 ml, providing a value for the density of air of 1.27 ± 0.10 kg m^{-3} (95% confidence limit). This result is in agreement with the accepted value for the density of air.

The method would seem to be sound. It is known that after evacuation to about 4 kPa, air returns to the bell jar slowly such that the pressure might rise by about 1 kPa in 6 min (Table 1). This rate of leakage is negligible for the period needed to obtain about five weighings on a balance.

After using the apparatus for this experiment, the tubing should be dried before another determination of air density. Much of the water within it can be knocked or shaken out. Most of the remaining drops can be removed by reattaching the tube to the bell jar and evacuating the system a couple of times.

Boyle's law with a marshmallow

Because the cellular structure of the marshmallow contains trapped gas, when placed in a bell jar, the confection expands as the bell jar is evacuated. Provided that there is no release of trapped gas and the tension in the cell walls is relatively inconsiderable, the presumption is that the sweet expands volumetrically in inverse proportion with pressure. Were it to do so, it could be used to show Boyle's law (Fig. 2).

To try the idea, a marshmallow was placed in the bell jar of the Microscale Vacuum Apparatus. Three strips of graph paper with a millimetre grid were placed alongside the marshmallow to enable its height and basal and top diameters to be measured. A T-piece connection from a second Microscale Apparatus was connected to the bell jar neck. A PASCO Absolute Pressure Sensor CI-6532A was joined to the branch arm of this T-piece. The rest of the tubing with valves and syringe from the original Microscale Apparatus was connected to the other T-piece outlet to evacuate the air (Fig. 3). The sensor was connected through a 500 Interface to a laptop running *Data Studio*, which was set up to display pressure. The bell jar was gradually evacuated and values of diameters r_1 and r_2, height h (Fig. 4) and pressure p were jotted down.

After reducing the pressure in stages, at about 5 kPa pressure suddenly increased, showing that the cellular

(cont.p25)

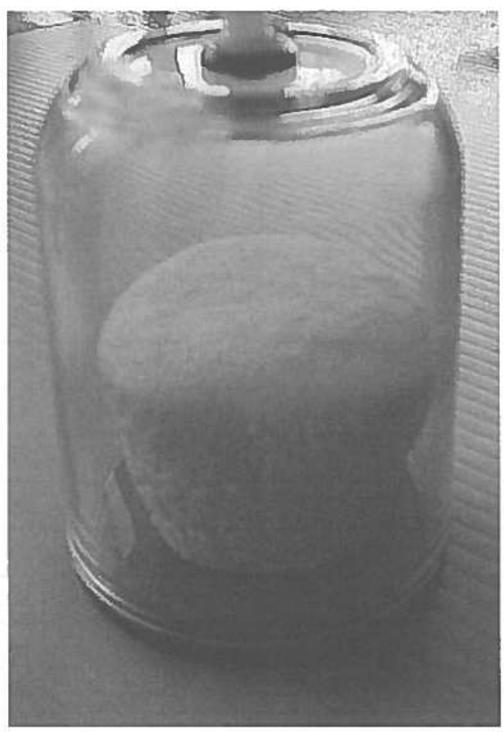

Figure 2 Photograph of swollen marshmallow in a partially evacuated bell jar.

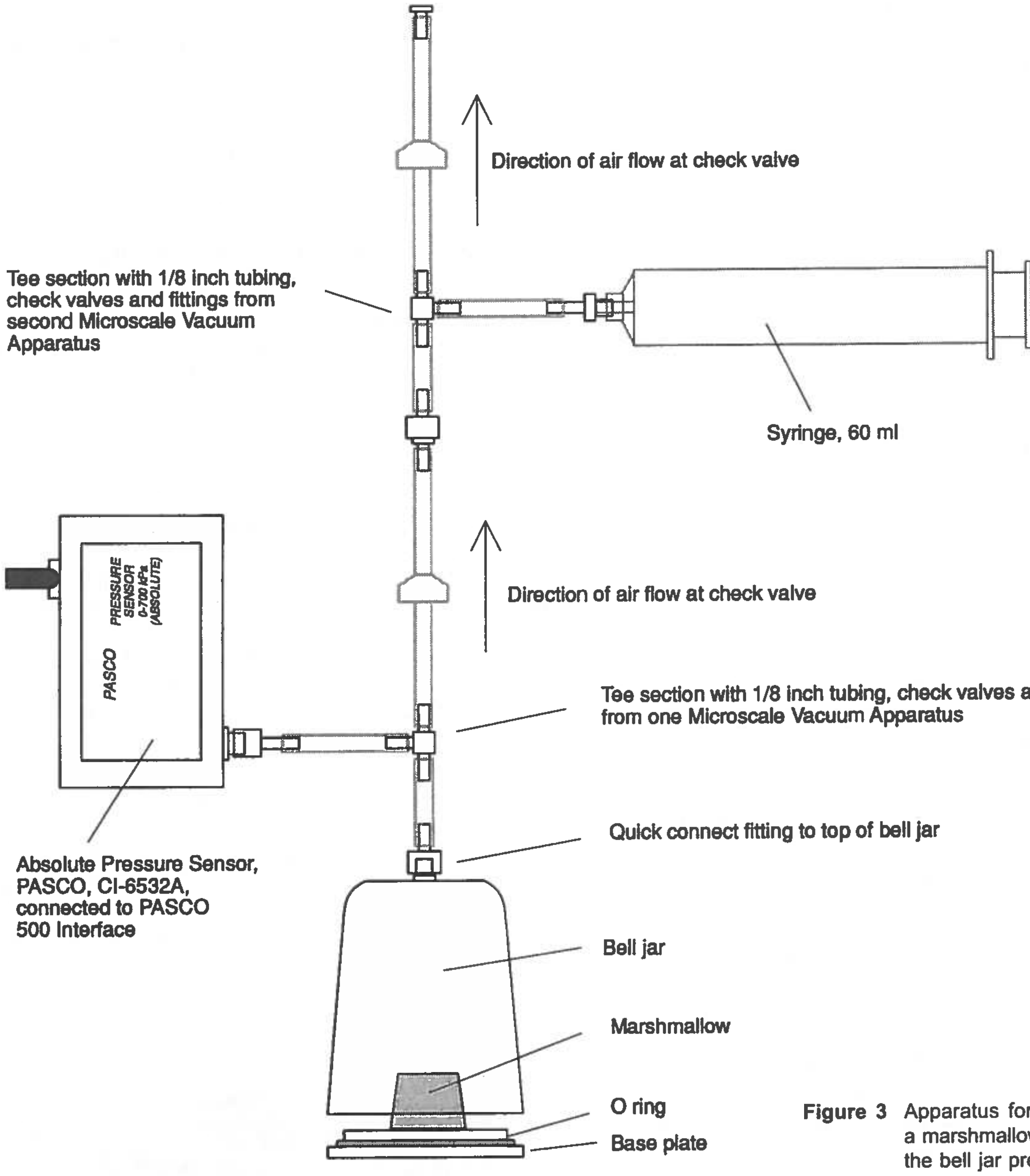

Figure 3 Apparatus for depressurizing a marshmallow and measuring the bell jar pressure.

Diameter $2r_2$ (mm)	Diameter $2r_1$ (mm)	Height h (mm)	Volume V (cm)	Pressure p (kPa)	pV (kPa cm³)	$1/V$ (cm⁻³)
28	21.5	22	11	100.6	1100	0.094
29	23	23	12	80.6	990	0.082
31.5	24	23	14	66.4	930	0.071
32	25.5	24	16	55.7	870	0.064
32	26	26	17	45.9	790	0.058
34	27.5	26.5	20	38.1	750	0.051
37	28.5	28	24	31.7	750	0.042
40	30	30	29	25.9	750	0.034
41.5	32	31.5	34	20.0	670	0.030
44	34	32.5	39	15.6	610	0.026

Table 2 Data obtained from depressurizing a marshmallow, including derived values V, pV and $1/V$.

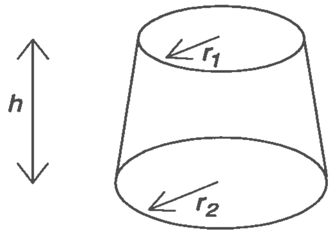

Figure 4 Simplified geometry of a marshmallow, which is presumed to be the volume V between two parallel, conic sections.

structure was cracking to release gas. This was the minimum pressure achieved. On the second attempt, the limiting pressure was about 10 kPa.

The results were analysed by the spreadsheet *Excel* (Table 2). To calculate the volume of a marshmallow, the shape was presumed to be the volume between two parallel sections of a cone[1]. Its volume V was derived from the volume of a cone ($V = {}^1/_3 Ah$) to be

$$V = {}^1/_3 \pi h\,(r_1^2 + r_1 r_2 + r_2^2)$$

The model for calculating V was incomplete because it failed to take account of the rounding of the edges between the side wall and top and bottom. Tabulated values of V are therefore overestimates. However since the error is likely to be proportional to volume, it may not be significant.

Interpreting the results (Fig. 5):

1. Volume increases as pressure falls, giving a qualitative demonstration of the pressure volume gas law.
2. The graph of p against $1/V$ has a discontinuity at 40 kPa. Above and below this pressure, the relationships are linear, but in aggregate they do not satisfactorily show proportionality.
3. The data at pressure above 40 kPa show a linear relationship between p against $1/V$ cutting the pressure axis at −35 kPa. This may indicate that the trapped gas within the marshmallow was pressurized at 35 kPa above atmospheric pressure before the experiment commenced. The cause of the pressurization is the elasticity of the cellular structure compressing gas within the cells.
4. The discontinuity at 40 kPa may be caused by the cell walls reaching their elastic limit and softening. Below this point the pressure volume relationship is fairly close to inverse proportionality.
5. At around 10 kPa, cell walls rupture, releasing gas.

In summary, placing a marshmallow in a bell jar and evacuating the air around it is a bit of fun. It doesn't clearly show Boyle's law, presumably because the physical processes within the marshmallow are fairly complex. However there would be an educational point in showing that Boyle's law does not hold and seeking plausible explanations. If using a Microscale bell jar, the investigation can be done by students.

Summary

With the *Microscale Vacuum Apparatus*, students can try out for themselves some of the simpler vacuum experiments, including making a rough determination of the density of air. The apparatus is well designed, of an attractive, modern appearance, simple to work with and reasonably priced. The risk of harm is low provided that the manufacturer's safety instructions are followed and that its usage is supervised. We recommend it.

[1] Our investigations showed that Tesco sell marshmallows with the requisite geometry.

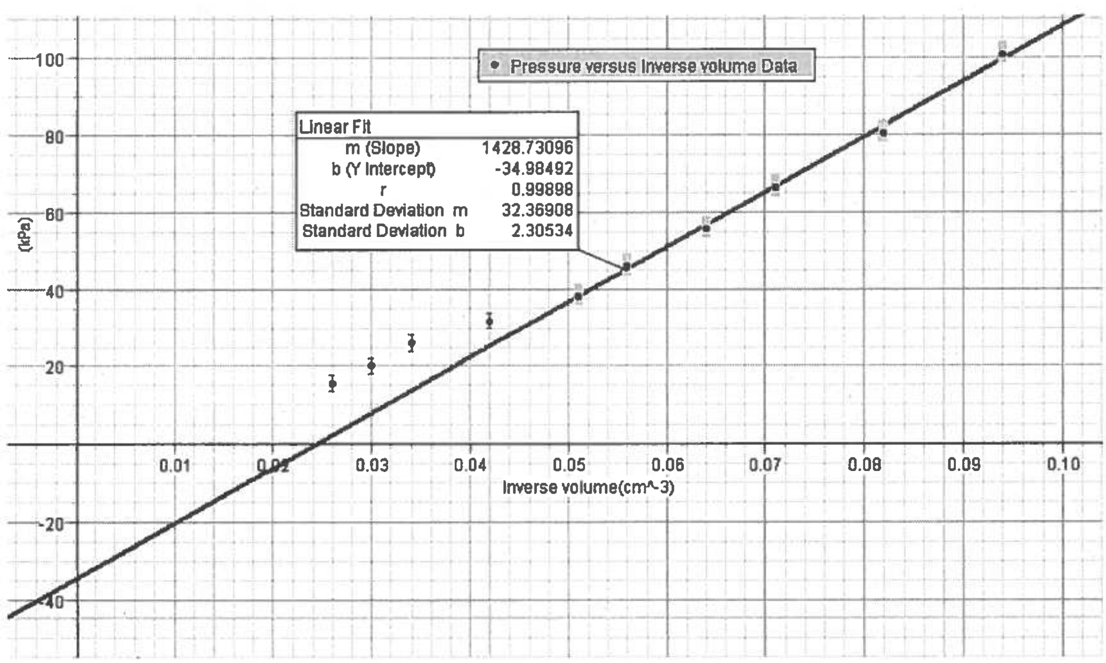

Figure 5 Graph of pressure versus the inverse volume of a marshmallow, $1/V$. The graph shows the 40 kPa discontinuity, rough proportionality for pressure below 40 kPa, and linearity above this limit. The graph was drawn with *Data Studio* from PASCO.

Enzymes – Hazards and Labelling

We've had a number of enquiries arising from the safety information provided by suppliers and manufacturers of enzymes. A particular issue raised has been that of how the information contained within Materials Safety Data Sheets (MSDSs) can be interpreted and used to label bottles containing dilute solutions of enzymes intended for student use.

As pointed out in a recent article on interpreting safety advice [1], if a substance is listed in the CHIP Approved Supply List [2] the hazard category and risk phrases assigned to that substance have been laid down for manufacturers and suppliers. In these cases there should be consistency between MSDSs. Where a substance is not included on the Approved Supply List the manufacturer or supplier must assign risk and safety phrases. This can lead to considerable differences in advice.

Of the enzymes that we have looked at, those included in the Approved Supply List are all assigned the symbol Xn (harmful, sensitising) with the risk phrase R42 (may cause sensitisation by inhalation) (Table 2). There are no concentration limits given with the classification and labelling information. However, in Schedule 3, part II of the Statutory Instruments [3], guidelines instruct that where a substance has been classified as sensitising and assigned the symbol Xn and the risk phrase R42 these should also be assigned to preparations of the substance where the concentration is ⊕ 1%.

We have used the data provided in the CHIP Approved Supply List along with information from other relevant sources to produce labelling advice for a number of enzymes commonly used in schools (Table 3).

Labelling information used in this article is defined in Table 1 above. For a complete list, please see *Hazardous Chemicals A Manual for Science Education* [4].

Explanation of Hazard Symbol, Risk and Safety Phrases		
Hazard symbols		
Symbol letter	Category of danger	Indication of danger
Xn	Sensitising	Harmful
Risk phrases		
Indication of particular risk		
R42	May cause sensitisation by inhalation	
Combination of particular risks		
R36/37/38	Irritating to eyes, respiritory system and skin	
Safety phrases		
Indication of safety precautions		
S(2)	Keep out of the reach of children	
S22	Do not breathe dust	
S24	Avoid contact with skin	
S26	In case of contact with eyes, rinse immediately with plenty of water and seek medical advice	
Combination of safety phrases		
36/37	Wear suitable protective clothing and gloves	

Table 1 Explanation of hazard symbol, risk and safety phrases.

When working with enzymes we recommend the following as good practice:

- Solid enzyme (powder or granules)

  Avoid enzyme dust in the air as repeated inhalation of dust may cause asthma or hay fever.

  Clean up any spillage at once as solid enzyme left lying may form dust. (Wet immediately and clean thoroughly.)

  To dispose, dissolve solid enzyme in water and discharge into the sewage system.

Enzyme	CHIP Approved Supply List (Fifth edition) Labelling information	Classification of preparation (other than gaseous)
Amylase	Xn R42 S(2), 22, 24, 36/37	Concentration >= 1% R42 obligatory
Cellulase	Xn R42 S(2), 22, 24, 36/37	Concentration >= 1% R42 obligatory
Pepsin	Xn R36/37/38, R42 S(2), 22, 24, 26, 36/37	Concentration >= 1% R42 obligatory
Proteas-es	Xn R36/37/38, 42 S(2), 22, 24, 26, 36/37	Concentration >= 1% R42 obligatory
Rennin	Xn R36/37/38, 42 S(2), 22, 24, 26, 36/37	Concentration >= 1% R42 obligatory
Trypsin	Xn R36/37/38, 42 S(2), 22, 24, 26, 36/37	Concentration >= 1% R42 obligatory

Table 2 Classification and labelling information for selected enzymes from Approved Supply List (Fifth edition).

Enzyme	Suggested labelling for preparations of concentration >= 1%
Amylase	Xn R42
Cellulase	Xn R42
Lactase (not listed in CHIP)	Xn R42
Lipase (not listed in CHIP)	Xn R42
Pepsin	Xn R42
Proteases	Xn R42
Rennin	Xn R42
Trypsin	Xn R42

Table 3 Suggested labelling of enzyme preparations in schools.

- Liquid enzyme

  Do not let liquid products dry, as there is a risk of dust formation. Repeated inhalation of dust may cause asthma or hay fever. Spillages should be washed into the sewer with water immediately.

  Liquid enzymes should not be sprayed. Spraying can produce an enzyme-containing aerosol which may increase the risk of inhalation of the enzyme. Repeated inhalation of enzyme containing aerosol may cause asthma or hay fever.

Avoid getting liquid or solid enzyme on either the skin or eyes. If this occurs quickly flood the affected area with tap water. If enzyme dust or aerosol is inhaled, rinse the mouth and throat and drink plenty of water. Contaminated clothing should be placed in water and then washed as usual. If after exposure symptoms develop in the respiratory passages, on the skin, in the eyes, or if you are in any way concerned, see a doctor immediately.

References

1. *Interpreting Safety Advice* SSERC 1999 Bulletin 197 3.
2. *CHIP Approved Supply List* (Fifth edition) HSC 1999 ISBN 0 7176 1725 4.
3. *The Chemicals (Hazard Information and Packaging for Supply) Regulations 1994* HMSO 1994 No.3247.
4. *Hazardous Chemicals A Manual for Science Education* SSERC 1997 a-5 to a-8.

Science Strategy Report

"Questions are hip! Answers are square!" A report issued in April of this year by the Science Strategy Review Group, a group appointed by the Scottish Executive, asks the sort of questions that should be asked were the Executive to put in place a national science strategy. It also reports on what additional mechanisms would be required to answer these questions and to implement such a strategy.

Questions asked within the section on education are:

- is further development in curriculum content required?
- is the existing emphasis on general education sufficient?
- is there adequate provision for those pupils wishing to specialise in science and pursue it in the tertiary education sector?
- how might a better physical infrastructure (laboratories and equipment) be provided? and
- what are the implications of this for the effectiveness of science teaching?

A copy of the report can be found on the web site: http://www.scotland.gov.uk/consultations/enterprise/ssrg/ssrg-01.asp

Pressure and depth in fluids

A revision of the HSDU version for showing the dependence of fluid pressure with depth and recommendations on suitable sensors.

The instruction in the HSDU Student Material [1] to work with an inverted thistle funnel with rubber diaphragm causes errors. The tension in the diaphragm exerts an appreciable downward thrust on the fluid causing the value of recorded pressure to lie between 10% to 20% too low. Secondly, if the diaphragm is stretched beyond its elastic limit, which is quite likely, the thrust exerted by it becomes non-linear and its behaviour ceases to be repeatable. Thirdly, if fluid penetrates the diaphragm seal, which is also quite likely, its sensitivity also changes. For these reasons a diaphragm should not be used. As for an upturned thistle funnel, the trouble with it is that, unless its stem is kept vertical, a portion of trapped air can be dislodged and bubble off, thus altering the system's sensitivity. Because this is probable, the use of open-ended, clear tubing is preferable.

The tubing and vessel holding the fluid must be transparent so that the fluid level is visible (Fig. 1). The depth is the difference between the fluid level in the tube and the surface of the reservoir. Tubing should be secured to a ruler to control its opening under the fluid and to measure its depth. Readings should be taken to the nearest millimetre.

The tubing types specified in the accompanying boxes are glass and polyurethane. If the bore diameter were to be very small, there is a risk that surface tension may affect the fluid level. Tubing with a diameter of 3.2 mm, or larger, gives good results.

Suitable vessels capable of holding a 200 mm depth of fluid include a 2 litre, tall form beaker and a 500 ml measuring cylinder.

Suitable sensors are:

1. Capsule element pressure gauge, 0 to 25 mbar, VDO.IMT type 1553 060 003, or
2. Low pressure sensor, gauge pressure, 0 to 10 kPa, PASCO type CI-6534A.

The first of these is sensitive to a change in water depth of 2 mm; the second to 0.5 mm.

Bourdon gauges are too insensitive for this experiment. The one with the highest sensitivity in one manufacturer's range has a resolution of 4 mbar, equivalent to a water depth of 40 mm.

Having a resolution of 0.5 kPa (50 mm of water), PASCO's *Absolute Pressure Sensor* CI-6532A, which can be used in gas law experiments, is also unsuitable in this application. Another use of the *Low Pressure Sensor* CI-6534A recommended here is recording respiration, giving the product added educational value.

CAPSULE ELEMENT GAUGE

Pressure gauge type :	Capsule element gauge
Manufacturer :	VDO.IMT
Part number:	1553 060 003
Range:	0 to 25 mbar, 1 mbar divisions
Accuracy:	1.6% of full scale, or ± 0.4 mbar (confidence limit not given – presumed to be 95%)
Gauge dia.:	63 mm
Reading uncertainty:	± 0.2 mbar
Supplier:	OEM Automatic Limited
Price:	£53.26 plus £8.50 post and packing
Comment:	Highly sensitive pressure gauge for low pressure ranges. Useful for water pressures at depths down to 250 mm. The scale is suitably large for accurate readings. The instrument uncertainty is low. It would be an ideal instrument for this experiment.
Zero adjustment:	Lift plastic cover off face. Screw adjustment to be found at bottom of dial.
Method:	Attach rubber tubing, 8 mm bore, 2 mm wall thickness, 12 mm o.d., 60 mm length, to gauge inlet. Attach other end to glass tube, 7 mm bore, 10 mm o.d., 350 mm length. Secure glass tube to 300 mm ruler with clear tape. Support the pressure gauge with a tall stand. Immerse the open end of the tube taking readings of the depth of tube and fluid level within tube. The effective fluid depth pressurizing the trapped air is the difference between these two levels.
Results:	Gradient = 0.101 ± 0.003 mbar mm^{-1} water (95% confidence limit)
Comment:	Should use an open, clear tube. Avoid releasing air from tube. This is unlikely with a tube, but quite likely with a thistle funnel, which therefore should not be used.

Reference

1 Physics: Mechanics and Properties of Matter (H) – Student Material Activity 18A *Pressure and depth in fluids* Higher Still Development Unit Autumn 1998

LOW PRESSURE SENSOR

Pressure gauge type :	Low Pressure Sensor
Manufacturer :	PASCO
Part number:	CI-6534A
Range:	0 to 10 kPa, gauge
Resolution:	0.005 kPa
Accuracy:	± 0.01 kPa (PASCO's specification) ± 0.02 kPa (SSERC's estimate) (95%)
Supplier:	Instruments Direct Limited
Price:	£99
Comment:	Highly sensitive electronic pressure sensor for low pressure ranges. It is a gauge type of pressure sensor, which implies that it reads relative to atmospheric pressure. Useful for water pressures at depths down to 1000 mm. The sensitivity is equivalent to 0.01 kPa per millimeter of water. That is, it can resolve to 0.5 mm of water depth. The instrument uncertainty is low. It would be an ideal instrument for this experiment.
Zero adjustment:	None. The sensor can register a small offset.
Method:	Connect the Pressure Sensor to the longer piece of plastic (polyurethane) tubing 3.2 mm i.d. supplied with the sensor. This tubing is 360 mm long. Fasten the tubing with clear tape to a 300 mm ruler such that its open end is at the 0 mm mark and suspend the apparatus from a tall clamp stand over the fluid. Immerse tube, taking sets of data at 20 mm stages of depth. Two ruler readings are required for every level: (1) depth of end of tube, and (2) value of fluid column within tube. The effective depth of fluid pressurizing the trapped air is the difference between these two readings.
Results:	Gradient = 0.0098 ± 0.0003 kPa mm^{-1} water (95% confidence limit)

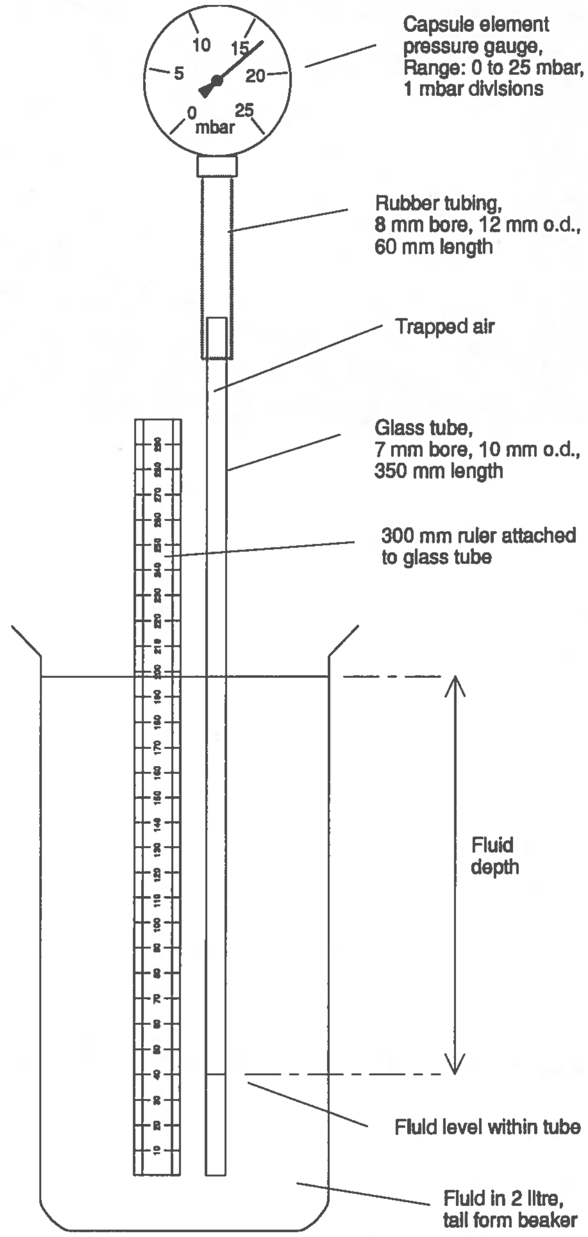

Figure 1 Capsule element gauge attached to 7 mm bore glass tube with 300 mm ruler.

Unilab 13 V Stepped Power Supply U022.102

Versions of this power supply (Fig. 1) manufactured before 1983 have a spurious, open circuit signal on the d.c. outlet caused by pickup. For instance, if the controls are set to 0 V and a digital multimeter is connected across the d.c. outlet to measure d.c. voltage, the reading is typically 7 V. But if a 10 kΩ load is connected across the outlet, the voltage signal decays to 10 mV, showing that the signal is insubstantial and caused by electromagnetic pickup.

The normal input impedance of a digital multimeter on its voltmeter setting is 10 MΩ. Because of this rather high impedance, the multimeter is quite an efficient detector of electromagnetic pickup. When

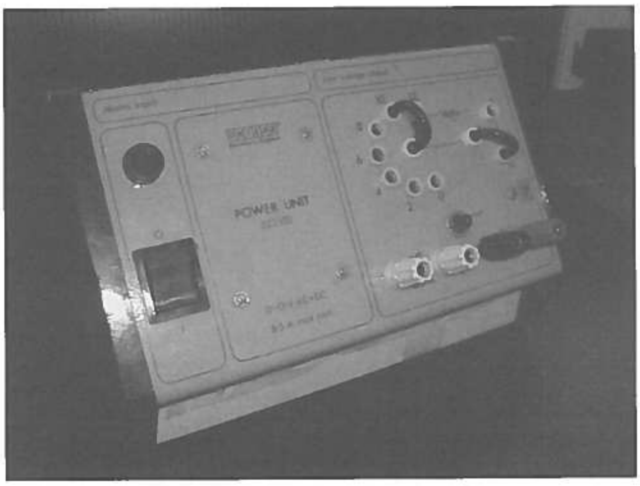

Figure 1 Unilab 13 V Stepped Power Supply U022.102.

the supply outlet is effectively loaded, even with a very small load of 10 kΩ, the signal more or less disappears.

The practical significance of the pickup signal is very slight, but not trivial, because it can cause confusion. We have checked several other models of power supply and find that on these other models there is either no pickup, or where there is, it is slight. The Unilab *Stepped Power Supply* 022.102 has by far and away the worst performance out of the group of power supplies tested.

Unilab have looked into the problem and agree with us that a 10 kΩ, ˘ W resistor should be connected across the d.c. outlet. The resistor should be connected internally by soldering to the socket outlets.

We understand from Unilab that all *Stepped Power Supplies* produced after 1982 have been fitted with such a resistor. The company are confident that electromagnetic emissions from this equipment are negligible.

Protection not foolproof

There are two protective devices on the *Stepped Power Supply*: a 1 A fuse on the primary supply line and an electromagnetic overcurrent device on the common a.c. outlet from the secondary coil. These devices do not protect against some forms of abuse.

The fuse mainly protects against the primary winding shorting. The other cut-out protects the transformer and bridge rectifier against the effects of an overload on either the a.c. or d.c. outlet. Other fault conditions against which the only protection is supervision include:

- Shorting together transformer outlets used by the J-link;
- Joining together the a.c. and d.c. outlets;
- Shorting the a.c. or d.c. outlets to the J-link outlets.

Several complaints have recently been made to SSERC about the transformer burning out. We are fairly sure that these resulted from mistakes or abuse of the equipment by children. Other than by replacing the units with other, more fully protected, power supplies, the only effective controls are instructing your pupils in how the equipment should be used, and supervising to see that the instructions are being followed.

Signal generators and capacitative loads

This report was triggered by a complaint from a teacher that the output voltage from a signal generator drops off with capacitative loading. Indeed it does, if the unit is overloaded. But provided that you do not overload the output, the voltage is stable.

Having never inspected this unit before, the tests were done on a Griffin *Signal Generator and Amplifier* XLB-540-010R, taking the chance to look at a new piece of equipment. Comparative tests were repeated on a Unilab *Signal Generator–Amplifier* 062.101. Its performance was similar to that of the Griffin unit.

The stability of the output voltage V_{out} against current I_{out} from the 4 Ω output was tested at 200 Hz and 500 Hz by loading with capacitors whose values were changed from 22 nF to 200 μF. Results are shown in Tables 1 and 2.

Frequency (Hz)	V_{out} (V)	Capacitive load (μF)	I_{out} (mA)	Load impedance (ohm)
200	2.02	0.022	0.062	
200	2.02	0.10	0.262	8000
200	2.02	0.47	1.28	
200	2.02	1.0	2.63	800
200	2.02	2.2	5.84	
200	2.02	10	20.7	80
200	2.00	33	76.7	24
200	1.89	100	190	8

Table 1 Dependence of output voltage V_{out} on capacitative load at 200 Hz with a Griffin *Signal Generator & Amplifier* XLB-540-010R.

Results and comment

At 200 Hz (Table 1) the voltage is stable provided that the current drawn is less than about 50 mA. This condition holds for capacitative loads up to 10 µF. At 500 Hz (Table 2) there is voltage stability for currents up to about 20 mA, that is for loads up to 2.2 µF.

The nominal output impedance is 4 Ω. The tests show that V_{out} is stable at 2 V provided that the load impedance is not less than about 80 Ω. That is, if the impedance of the external load is at least ten times greater than the internal impedance of the a.c. source, then the output voltage is stable.

These results indicate that signal generators can be used as a stable a.c. voltage source for showing that current through a capacitative load is directly proportional to the supply frequency provided that the supply is not overloaded. Because inexpensive multimeters of the sort typically found in schools have an upper frequency rating of 500 Hz on a.c. current and voltage ranges, the experimental frequency should be limited to 500 Hz. In practice they may perform satisfactorily to 1 kHz or above. The results at 500 Hz indicate that there should not be any signal degradation with a 1 µF load, and almost no degradation with a 10 µF load. Graphs of current versus frequency show the expected relationship, *viz.* proportionality, the results with a 1 µF capacitor being better than ones with a 10 µF capacitor.

Frequency (Hz)	V_{out} (V)	Capacitive load (µF)	I_{out} (mA)	Load impedance (ohm)
500	2.01	0.022	0.148	
500	2.01	0.10	0.651	3200
500	2.01	0.47	3.12	
500	2.01	1.0	6.55	320
500	2.01	2.2	14.41	145
500	1.99	10	49.5	32
500	1.86	33	172	9.7
500	1.43	100	360	3.2
500	0.85	200	450	1.6

Table 2 Dependence of output voltage V_{out} on capacitative load at 500 Hz with a Griffin *Signal Generator & Amplifier* XLB-540-010R.

In conclusion, the output voltage from both the Griffin and Unilab signal generators is very stable for a wide range of capacitative loads up to a certain limit, shown in the above tests. This limit depends on the internal impedance of the signal generator's output. The apparatus is suitable for showing standard a.c. relationships such as I against f (constant V, constant C), or I against C (constant V, constant f).

Diffraction gratings – Don't believe what it says!

A school has reported anomalous results with the *Educational Diffraction Grating*, a demonstration slide containing three gratings (Fig. 1). This product is made by Paton Hawksley. It is stocked by many suppliers and our catalogue records show that it has been available since the 1960s.

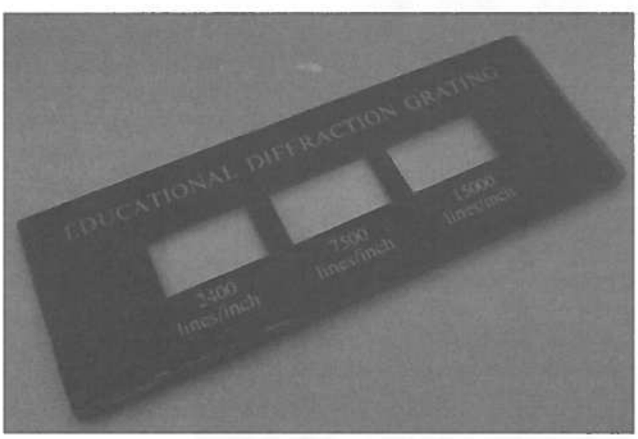

Figure 1 The original version of the *Educational Diffraction Grating* showing its imperial markings.

The problem came to light – sorry about the pun! – on finding that the annually conducted experiment to measure the wavelength of HeNe laser radiation consistently gave a value of around 600 nm. This made the teacher suspicious that there might be a systematic error. The source of the error was tracked down to a rounding off error in marking the grating. The one in use had been marked 100 lines/mm, but earlier versions of this grating had been marked in imperial units as 2400 lines/inch.

If the purpose of the experiment is turned around to determine the grating constant, where the wavelength is presumed known at 632.8 nm, the results are 2398 ± 26 lines/inch, or 94.4 ± 1.0 lines/mm, seeming to confirm the suspicion.

From information provided by Philip Harris, the product has undergone two changes. In its original

Present metric markings	Comments	Past imperial markings	Metric equivalent of imperial matrkings
600 lines/mm	Exact	15000 lines/inch	591 lines/mm
300 lines/mm	Rounded off from 7500 lines/inch	7500 lines/inch	295 lines/mm
100 lines/mm	Rounded off from 2500 lines/inch		98.4 lines/mm
	Previously rounded off from 2400 lines/inch	2400 lines/inch	94.5 lines/mm

Table 1 Information on the coarse, medium and fine gratings in the *Educational Diffraction Grating* set showing the rounding off errors in converting from imperial to metric.

version, it bore imperial markings. In its second version, using the same gratings, the markings were rounded off to the nearest metric equivalents. The third and present version bears the same metric markings as the second one, but the coarse grating has been replaced with one at 2500 lines/inch. These specifications are summarized in Table 1.

In summary, please be aware that gratings may have rounding off errors. The second version of the coarse grating rounded off to 100 lines/mm had the greatest error.

Acknowledgement

We are grateful to Alex Munro, PT Physics, Lossiemouth High School, for informing us of this problem.

Slime - What's that?

In Unit 2 of the Higher Still Arrangements for Chemistry is a five-word sentence which reads "Investigate the properties of 'slime' ".

A simple statement, but what is slime and why investigate it?

The term *slime* is used to describe a large number of materials that share similar properties. They all have a high viscosity, a resistance to flow dependent on the velocity of flow and a proportionate resistance to shearing forces. Slimes are Non-Newtonian fluids, that is they do not fit into one or another of Newton's laws of how true liquids behave. In particular, they expand under stress, which means that they exhibit some strange properties:

- If you poke a sample of slime gently your finger will slowly sink into it.
- If you punch a sample, it should resist.
- Slowly pull a sample and it will flow. You can even stretch it to form a thin film.
- Pull quickly and the slime breaks.
- When rolled into a ball and thrown onto a desk, it will bounce.

Figure 1 PVA slime.

With these types of properties, slimes are not only interesting materials to investigate, they are also lots of fun (Fig. 1).

Probably the most suitable slime to investigate in the school laboratory is polyvinyl alcohol (PVA) slime.

This is an interesting polymer that is formed when a solution of PVA is mixed with a solution of borax (see

http://www.sserc.org.uk/public/slime.htm

for a recipe).

Polyvinyl alcohol is used as a thickener, stabiliser and binder in various materials including cosmetics, cements and foodstuffs. Borax is a common cleaning agent. When aqueous solutions of PVA and borax are mixed, the borax forms cross-links between the PVA molecules and slime is produced.

There are lots of ways whereby properties of slime may be investigated. Here are some suggestions:

- When making slime, add the borax solution in small quantities and observe the changes after each addition. (These changes can be related to the increasing number of cross-links being formed.)
- Stretch a sample of slime slowly, then stretch the same sample quickly.
- Roll some slime into a ball and leave on a clean surface.
- Roll some slime into a ball and drop onto a hard clean surface.
- Compare slimes made from different volumes or concentrations of borax solutions.
- Compare warm and cold slime.

TECHNICIANS' NEWS

Modern Apprenticeships

A Scottish Framework for a Modern Apprenticeship for Laboratory Technicians in Education was launched in early May at the headquarters of the Convention of Scottish Local Authorities (CoSLA). This apprenticeship links into the Scottish Vocational Qualification system as described in earlier Bulletin issues. For information on Modern Apprenticeships in this particular sector the first point of contact is now the Local Government National Training Organisation (lgnto) - see Address List. Promotion of the educational technicians' apprenticeship framework however involves a wider partnership between the Science, Technology and Mathematics Council (ST+M) lgnto, CoSLA, Scottish Enterprise and Highlands & Islands Enterprise.

SSERC welcomes the involvement of CoSLA. ASE was the main instigator, a decade ago, and it has the interests of its technician members and the broader needs of science education at heart. It is not though an employers' organisation and was always going to struggle over the implementation of a system of vocational training. In the current climate such systems are employer led. CoSLA and the Local Government National Training Organisation are thus key partners in the process. The framework is heavily influenced, unsurprisingly, by practice south of the border. There are more unqualified or part qualified technicians in England and Wales. Here, both practice and problems are distinct and require different approaches and solutions. CoSLA, the lgnto and an ST+M Council representative are all based here in Scotland. There are, already, signs that the framework and the SVQ will evolve so as to more closely meet the needs of Scottish Education. Not the least of our problems is a lack of mobility in the service coupled with an ageing professional population. A more systematic approach to retraining for ICT support in particular and career development in general could well be the keys to progress here.

Publications

Health and safety

Management of health and safety at work, Management of Health and Safety at Work Regulations 1999
Approved Code of Practice and Guidance, L21, HSC, 2000, ISBN 0 7176 2488 9, 50 pages, £8.00.

There is a review of the revised regulations on page 7 of this issue of the Bulletin.

Guide to RIDDOR 1995 Guidance on regulations
L73, HSE, ISBN 0 7176 2431 5, £7.95.

This booklet replaces the old guide (0 7176 1012 8). It gives guidance on the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995.

Health and safety in engineering workshops
HSG129(rev), HSE, ISBN 0 7176 1717 3, £9.50.

This new edition takes into account recent changes in regulations (PUWER 1998 and LOLER 1998). There are also new sections on workshop machines and powder coatings, and a new appendix on work equipment risk assessment.

Fire safety - an employer's guide
Scottish Office, HSE, etc., ISBN 0 11 341229 0, £9.95.

Explains what the employer has to do to comply with the law relating to fire issues. It tells you how to carry out a fire risk assessment and identify the safeguards which you should have in your workplace, and contains guidelines on how to draw up an emergency plan.

Health & Safety on Work Experience: A Guide for Organisers
HSG199, HSE, ISBN 0 7176 1742 4, £6.50.

For anyone responsible for organising work experience for students in schools and colleges. It explains the duties of the organisers and gives a step-by-step guide.

Accommodation design

Science Accommodation in Secondary Schools: A Design Guide
Building Bulletin 80, Architects and Buildings Division, DfEE, ISBN 0 11 2710395, £18.95.

A new edition of this standard reference work is available from The Stationary Office.

Equipment Offers

Items are arranged by similarity of application, or for other reasons, and not by stock number sequence. Often the item number serves only for stock identification by us in making up orders. Newer stock items are underlined, so as to be more easily seen.

VAT : The prices quoted do not include VAT. However it is added to every customer's order. Local authority establishments will be able to reclaim this input VAT.

Postage : Postage and, where necessary, packing, will be charged for. It is therefore best not to send cash with an order, but wait for us to bill you. Official orders may be used.

Please try and ask for at least £10 worth of goods because the administrative costs of handling orders are significant.

Don't send cash with orders. We repeat, please do not send payment with your order. Wait until you receive our advice note upon which payment may be made. This saves unnecessary complications, e.g. when items are out of stock, failure to make provision for VAT, or if a delivery charge needs to be made. Items of equivalent value may be deducted from your order to balance any shortfall.

Motors

778 Stepper motor, Philips MB11, been stored in damp conditions but unused and retested. 4 phase, 12 V d.c., 100 mA per coil, 120 ohm coil per phase, step angle 7.5°, with 7 mm x 2 mm dia. output shaft. Dimensions 21 mm x 46 mm dia. on oval mounting plate with 2 fixing holes, diam. 3 mm, pitch 42 mm, at 56 mm centres. Circuit diagram supplied. £2.50

755 Pulley wheel kit comprising: - plastic pulley wheel, 30 mm dia., with deep V-notch to fit 4 mm dia. shaft, 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 shafts. Specially supplied to SSERC by Unilab. £1.25

848 Motor, 12 V d.c., no load current 2 A at 12 V and 1.5 A at 5 V. Min. no load starting voltage, 2 V, min no load running voltage 0.8 V. 64 X 37 mm dia., shaft, 11 X 3 mm dia. £2.50

614 Miniature motor, 3 V to 6 V d.c., no load current 220 mA at 9600 r.p.m. and 3 V, stall torque 110 mN m, dims. 30 mm x 24 mm dia., shaft 10 mm x 2 mm dia. 45p

593 Miniature motor, 1.5 V to 3 V d.c., no load current 350 mA at 14800 r.p.m. and 3 V, stall torque 50 mN m, dims. 25 mm x 21 mm dia., shaft 8 mm x 2 mm dia. 30p

739 Miniature motor, 1.5 V d.c., dimensions 23 mm x 15 mm dia., shaft 8 mm x 1.7 mm dia. 25p

621 Miniature motor, 1.5 V to 3 V d.c., open construction, ideal for demonstration, dimensions 19 x 9 x 18 mm, eight tooth pinion on output shaft. 25p

839 Motor, solar, 12 mm long by 25 mm dia., shaft 6 x 2mm dia. (see also Item 838 - solar cell) £1.70

773 Tachometer (ex equipment) £2.25

811 Worm and gear for use with miniature motors, 34 : 1 reduction ratio plastic worm and gear wheel. 35p

378 Encoder disk, 15 slots, stainless steel, 30 mm dia. with 4 mm dia. fixing hole. 80p

642 Encoder disk, 30 slots, stainless steel, 30 mm dia. with 4 mm dia. fixing hole. 80p

836 Motor mounts, plastic push-fit with self adhesive base pad, suitable for SSERC motors 593 & 614, pk of 10 £1.95

772 Encoder disk, 4-bit Gray code, stainless steel, 81.28 mm dia., 3 mm fixing hole, slots sized to register with components mounted on 0.1" stripboard. Applications: shaft position sensing, wind direction indicator. For related circuitry see Bulletin 146. £3.00

Precision motor stock

785 Precision motor with optical shaft encoder, 0.25 to 24 V d.c., no load current and speed 9 mA and 6,600 r.p.m. at 24 V, stall torque 23 mNm, 9 segments. Overall body length including shaft encoder 59 mm, dia. 23 mm with output shaft 20 x 3 mm dia. Back EMF constant 3.6 V/1000 r.p.m. Suggested application - tachogenerator. Data on shaft encoder section available on application. £15

787 Precision motor with attached gearbox, 0.15 to 12 V d.c. With a supply of 3 V, the no load current is 25 mA and the output shaft turns at ca. 20 r.p.m. Gearbox ratio 1 : 365. Overall body length including gearbox 43.5 mm and diameter 16 mm. Output shaft 6 x 3 mm dia. with flat side to maximum depth of 0.3 mm along outer 5 mm length of shaft. Application - any system where a very slow angular velocity is required. £15

Miscellaneous items

801 Propeller, 3 blade, to fit 2 mm shaft, 62 long. 35p
(Replaces Item 791 at lower cost).

792 Propeller kit with 10 hubs and 20 blades for making 2 or 3 bladed propellers. 130 mm diameter. Accepts either 2 mm or 3 mm shafts. £3.40

790 Buzzer, 3 V. 55p
827 Buzzer, 6 V. 55p

821 Reducer, 3 mm to 2 mm, enables gears, pulleys and wheels to be fitted to motor shaft, per 5 25p
867 Reducers, as above but 4mm to 2mm, pack of 5 25p
868 Ditto, 4 to 3mm 25p

846 Sound module, includes 'melody' chip and Piezo transducer. £1.00

710 Sonic switch and motor assembly. First sound starts the motor, a second reverses the direction of rotation, a third sound stops the motor. Driven by 4 AA cells (not supplied). 85p

715 Pressure gauge, ca. 40 mm o.d. case, 25 mm deep and 33 mm dia. dial reading 0 to 4 bar (i.e. above atmospheric). With rear fitting for 1/8" BSP. Suitable for use as indicator for pneumatic circuits in Technological Studies. 75p

165 Bimetallic strip, original type length 10 cm; high expansivity metal: Ni/Cr/Fe - 22/3/75 low expansivity metal: Ni/Fe - 36/64 (invar) 15p
166 Ditto, but 30 cm length. 40p

861 Bimetallic strip (new type - won't rust after exposure to Bunsen flame, hence higher price) 10 cm length. 30p
862 Ditto, but 30 cm length. 80p

758 Loudspeaker, 8 ohm, 0.5 W, 66 mm dia. 50p

771 Neodymium magnet, 13.5 mm dia. x 3.5 mm thick. £1.30

837 Ring magnet, 40 mm o.d., 22 mm i.d. 35p

815 Ceramic block magnets, random polarisation, 19 x 19 x 5 mm. 15p

823 Ceramic block magnets, poles at ends, 10 x 6 x 22 mm. 12p

824 Ceramic block magnets, poles on faces, 25 x 19 x 6 mm. 35p

825 Forehead temperature measuring strips 50p

745 Sub-miniature microphone insert (ex James Bond?), dia. 9 mm, overall depth 5 mm, solder pad connections. 40p

723 Microswitch, miniature, SPDT, lever operated. 40p

354 Reed switch, SPST, 46 mm long overall, fits RS reed operating coil Type 3. 10p

738 Relay, 6 V coil, DPDT, contacts rated 3 A, 24 V d.c. or 110 V a.c. 75p

875 Solenoid, 6 V, stroke length 3.5 mm, spring provided £3.75

774 Solenoid, 12 V, stroke length 30 mm, spring not provided. £2.25

742 Key switch, 8 pole changeover. 40p

382 Wafer switch, rotary, 6 pole, 8 way. 70p

688 Croc clip, miniature, insulated, red. 5p
759 Ditto, black. 5p

788 Crocodile clip leads, assorted colours, insulated croc. clip at each end, 360 mm long. £1.35

809 Wire ended lamp, 3 V 10p

741 LES lamp, 6 V. 15p
770 LES lamp, but 12 V. 15p
789 MES lamp, 3.5 V, 0.3 A 9p
690 MES lamp, 6 V, 150 mA. 9p
866 Lens-end lamps, MES, 1.2 V. Ideal where a concentrated beam of light is needed. Box of 100 £3.50

691 MES battenholder. 20p

692 Battery holder, C-type cell, holds 4 cells, PP3 outlet. 20p
730 Battery holder, AA-type cell, holds 4 cells, PP3 outlet. 20p
845 Battery holder, holds two C-type cells, PP3 outlet. 20p
835 Battery holder, AA-type cell, holds 2 cells, PP3 outlet. 15p
729 Battery connector, PP3 type, snap-on press-stud, also suitable for items 692 and 730. 5p

724 Dual in line (DIL) sockets, 8 way. 5p
760 DIL sockets, 14 way. 7p
826 DIL sockets, 16 way. 8p

808 Electrodes for making lemon or other fruit cells etc. 1 pair, comprising 1 of copper, 1 of zinc, each approx. 60 mm square, per pair 50p

716 3-core cable with heat resisting silicone rubber insulation, 0.75 mm^2 conductors, can be used to re-wire soldering irons as per Safety Notes, Bulletin 166. Per metre. £1.35

756 Silicone coated, braided glass sleeving, yellow, 2.5 mm dia., gives both heat and electrical insulation to conductors (e.g. for autoclave rewiring). Price per metre. 55p

714 Sign "Radioactive substance" to BS spec., 145 x 105 mm, semi-rigid plastic material. Suitable for labelling a radioactive materials store. With pictogram and legend. £2.70

763 Sign "DANGER, Electric shock risk" to BS spec., rigid plastic, 200 x 150 mm. £2.70

764 Sign "DANGER, Laser hazard" to BS spec., rigid plastic, 200 x 150 mm. £2.70

731 Re-usable cable ties, length 90 mm, width 2 mm, 50 per pack. 12p

752 Shandon chromatography solvent trough. £1.00

805 Condenser lens, bi-convex, 200 mm focal length, 75 mm dia. Crown glass. £12.50
806 Condenser lens, plano-convex, 150 mm focal length, 75 mm dia. Crown glass. £12.50

833 5¼" double density floppy disks, box of 10 60p

834 5¼" high density floppy disks, box of 10 60p

Components - resistors

420 resistors, 5% tolerance, ¼ W : Per 10. 6p
1R5, 4R7, 5R6, 6R8, 8R2, 10R, 15R, 22R, 33R, 47R, 56R, 68R, 82R, 100R, 120R, 150R, 180R, 220R, 270R, 330R, 390R, 470R, 560R, 680R, 820R, 1K0, 1K2, 1K5, 1K8, 2K2, 2K7, 3K3, 3K9, 4K7, 5K6, 6K8, 8K2, 10K, 12K, 15K, 18K, 22K, 27K, 33K, 39K, 47K, 56K, 68K, 82K, 100K, 150K, 220K, 330K, 390K, 470K, 680K, 1M0, 1M5, 2M2, 4M7, 10M.

421 DIL resistor networks, following values available: 62R. 1K0, 6K8, 10K, 20K, 150K. Per 10. 30p

BP100 Precision Helipots, Beckman, mainly 10 turn. 10p-50p

Components - capacitors

813 Capacitors, polystyrene: 4p
180 pF, 330 pF, 560 pF, 1000 pF, 2400 pF, 3000 pF, 3300 pF, 3900 pF & 4700 pF

695 Capacitors, tantalum, 15 μF 10 V, 47 μF 6.3 V. 1p

696 Capacitors, polycarbonate, 10 nF, 220 nF, 1 μF, 2.2 μF. 2p

697 Capacitor, polyester, 15 nF 63 V. 1p

698 Capacitors, electrolytic, 1 μF 25 V, 2.2 μF 63 V, 10 μF 35 V. 1p

358 Capacitor, electrolytic, 28 μF, 400 V. £1.00

Components - semiconductors

807 Teaching Chip Set, designed by Edinburgh University, Now with a new, comprehensive, 12 page datasheet. The new datasheet was published in December 1999. It is freely available on request. One is supplied per order. The 4 chip set comprises : Resistors; MOSFETS; Diodes and Optoelectronics, and Ring Oscillator. £6.00

Single replacement chips: £2.00 per chip:

871 Chip 1 - Resistors
872 Chip 2 - MOSFETS
873 Chip 3 - Diodes & Optoelectronics
874 Chip 4 - Ring oscillator

322 Germanium diodes 8p

701 Transistor, BC184, NPN Si, low power. 4p

702 Transistor, BC214, PNP Si, low power. 4p

717 Triac, Z0105DT, 0.8 A, low power. 5p

725 MC74HC139N dual 2 to 4 line decoders/multiplexers 5p

699 MC14015BCP dual 4-stage shift register. 5p

711 Voltage regulator, 6.2 V, 100 mA, pre-cut leads. 10p

Sensors

615 Thermocouple wire, Type K, 0.5 mm dia., 1 m of each type supplied: Chromel (Ni Cr) and Alumel (Ni Al); for making thermocouples, (Bulletins 158 and 165). £3.10

640 Disk thermistor, (substitute type) resistance of 15 kohm at 25°C, b = 4200 K. Means of accurate usage described in Bulletin 162. 30p

641 Precision R-T curve matched thermistor, resistance of 3000 ohm at 25°C, tolerance ±0.2°C, R-T characteristics supplied. Means of accurate usage described in Bulletin 162. Now stocked by RS.

718 Pyroelectric infrared sensor, single element, Philips RPY101, spectral response 6.5 µm to >14 µm, recommended blanking frequency range of 0.1 Hz to 20 Hz. The sensor is sealed in a low profile TO39 can with a window optically coated to filter out wavelengths below 6.5 µm. Data sheet supplied. For application see SG Physics Technical Guide, Vol.2, pp 34-5. 50p

504 Copper foil with conductive adhesive backing, makes pads for unscreened Kynar film to which connecting leads may be soldered. Priced per inch. 15p

506 Resistor, 1 gigohm, $^1/_4$ W. £1.40

Optical and optoelectronic devices

838 Solar cell, 100 x 60 mm, 3.75 V per cell max. £2.10

507 Optical fibre, plastic, single strand, 1 mm dia. Applications described in Bulletin 140 and SG Physics Technical Guide Vol.1. Priced per metre. 50p

508 LEDs, 3 mm, red. Price per 10. 50p
761 Ditto, yellow. Per 10. 60p
762 Ditto, green. Per 10. 60p

858 Flash bulb older type (getting difficult to source) for UV triggered reactions in chemistry. Pack of 5. 85p

Economy variable volume micropipettors

Of slimline profile, these micropipettors are fully autoclavable (121° C max.). They have a nominal accuracy of ± 1.75%. Supplied with spare O-ring and lubricant. Tip ejector swivels, thus pipettors are suitable for either left- or right handed users. Colour coded bodies for ease of identification. Supplied with two tips and stocks of spare tips available. Three sizes :

849 micropipettor, 1 cm³, range 100 to 1000 µl £16.00

850 micropipettor, 5 cm³, range 500 to 5000 µl £16.00

851 micropipettor, 10 cm³, range 1000 to 10,000 µl £16.00

Replacement tips in packs of 25 tips :

852 replacement tips for 1 cm³ micropipettor, pack. £1.50

853 replacement tips for 5 cm³ micropipettor, pack. £1.70

854 replacement tips for 10 cm³ micropipettor, pack. £2.15

Other biotechnology items for Higher Practicals:

859 Eppendorf tubes, 1.5 cm³, for use in TEP/SAPS/NCBE microcentrifuge, pack of 50 85p

860 Nylon mesh for protoplast isolation/fusion protocol, 70µm pore size, per 305 mm square. £7-00

Pipette fillers

863 0-2 cm³ pipette filler (Pi pump type), each £5.75

864 0-10 cm³ as above £5.75

865 0-25 cm³ as above £5.75

Gloves

869 Gloves blue latex*, extra strength, lightly powdered*, ambidextrous. *Small size only therefore suitable also for pupils.* *NOTE : Some individuals may be sensitised to the glove material and, or, the powder or become so. Pack of 50 (25 pairs, normally £9-£10 per box). £5.00

Items not for posting

The following items are only available to callers because of our difficulties in packing and posting glass items and chemicals. We will of course hold items for a reasonable period of time to enable you to arrange an uplift.

768 Sodium lamp, low pressure, 35 W. Notes on method of control available on application. 85p

810 Watch glasses, assorted sizes 20p

877 Volumetric flask, 50 cm³, Class B £1.30

878 Volumetric flask, 100 cm³, Class B £1.45

879 Petri dishes, glass, 52 x 20 mm, box of 18 £4.00

880 Petri dishes, glass, 63 x 18 mm, box of 18 £4.00

881 Petri dishes, glass, 100 x 15 mm, box of 18 £5.00

712 Smoke pellets. For testing local exhaust ventilation (LEV), fume cupboards and extractor fans : large, 50p, small, 40p

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User name and password as given in Bulletin 197. See page 2 of this issue for changes effective as from 1st July 2000.

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Unilab - see Philip Harris.

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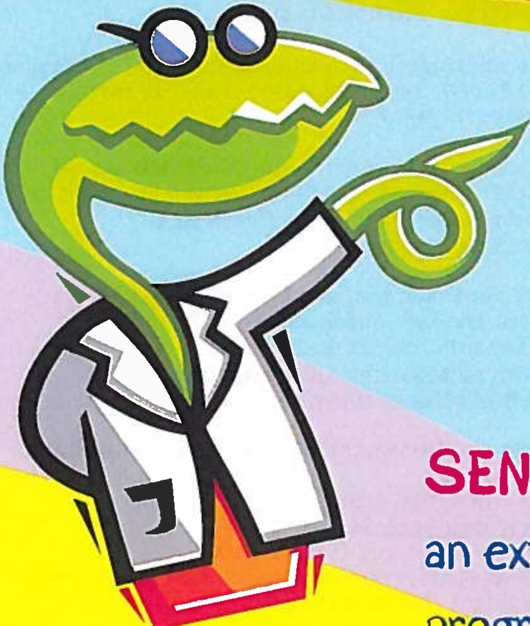

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