ISSN 0267-7474

SCOTTISH SCHOOLS SCIENCE EQUIPMENT RESEARCH CENTRE

Bulletin No. 162

April 1989

Electronic Thermometers reviewed

A D D R E S S   L I S T

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

[After move do not use until notified : SSERC, 24 Bernard Terrace, Edinburgh EH8 9NX]

BDH Ltd.,Apparatus Division, PO Box 8, Dagenham, Essex RM8 1RY Tel.01-597 8821
(Scottish Distribution Depot 041-637 2333).

J.Bibby Science Products Ltd., Tilling Drive, Stone, Staffordshire ST15 0SA Tel.(0785) 812121.
(Distributors : BDH; Fisons; Harris, Orme Scientific etc.)

British Gas Education Service, PO Box 46, Hounslow, Middlesex TW4 6NF

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

Griffin & George, Bishop Meadow Road, Loughborough, Leicestershire LE11 0RG; Tel. 0509 233344.

Hanna Instruments - see Agents & Distributors e.g. U.K. Instruments, Whatman

Philip Harris Limited, Lynn Lane, Shenstone, Staffs. WS14 0EE; Tel. (0543) 480077.

Mackay & Lynn Ltd.,2 West Bryson Road, Edinburgh EH11 1EH Tel.031-337 9006.
- also at 17-18, Tait's Lane, Dundee DD2 1DZ Tel.(0382) 645145.

Maplin Electronic Supplies Ltd., PO Box 3, Rayleigh, Essex SS6 4LR

Mullard Ltd., Mullard House, Torrington Place, London WC1E 7HD Tel. 01-580 6633 (and through Scottish Distributors).

NCSB, University of Reading, London Road, Reading, Berks. RG1 5AG

cont. inside back cover

The Centre is an independent national advisory service, solely controlled and largely financed by Scottish Regional and Islands Councils as Education Authorities. It currently incorporates the Science Equipment Research Centre and the Scottish TVEI Joint Support Activity Project :

STERAC (Science and Technology Equipment Research and Advisory Centre).

ANNOUNCEMENT
Changes to the S.S.E.R.C. Service

In Bulletin 161 we announced the intended extension of the Centre's services to give support to technology education in addition to that already offered for the sciences. The observant will already have noted the changes to the footnote on the inner front cover for this issue. Bulletin 162 will go to technical education as well as science departments.

The dropping of the "science" in our corporate name does not mean that we will be formally extending the service to all subjects. We will have our hands full servicing those applied science and technology courses which we already see as immediate priorities additional to those we already have for the 'traditional' sciences.

Steering Arrangements

The previous Planning Committee has now been replaced by a Steering Group. We have clung to the idea of peer group evaluation in that the major part of the membership has been drawn from the ranks of practising teachers. Membership has been broadened by inclusion of representatives of technology education and computing interests but by removing double memberships for some categories the overall size of the group has been kept manageable. As before members come from a variety of airts and pairts across Scotland.

New Premises

Despite a number of initial difficulties our appointed contractors are now re-furbishing our new premises. We hope to be completing our move sometime in May of this year. We are not moving far, just across to the south side of the centre of Edinburgh. We will be all on one ground floor and, our regular visitors will be pleased to read, we will have more and less inconvenient car parking spaces.

Our new address is given on the inside front cover along with our existing location. You must not use our new postal address until we announce that it is safe for you to do so. You will be informed of our new telephone number in due course.

New Staff

The first appointment under the induction phase of the Joint Support Activity (JSA) arrangements was made at the turn of the year. This was at Project Officer level where we appointed a biologist. Mr.Derek J. MacLaughlan joined us in January from the Anderson High School, Lerwick, Zetland. Derek hails originally from Ayrshire and qualified at Paisley College of Technology before post-graduate training at Northern College (Dundee Campus). He has taken over a large share of the Director's specialist biological workload so freeing him to manage the JSA Project.

Two other appointments have been made but the appointees will not be in post until late Spring/early Summer. The new posts are both at Senior Project Officer level. One postholder will specialise in equipment for technology courses such as Technological Studies the other will bring further expertise into the Centre on the use of information technology equipment and electronics for science and technology courses.

Mr Daniel Burns, currently teacher of Technical Education at Larbert High in Central Region has been appointed to the first post and Mr Clive Semmens presently a teacher of computing and Depute Co-ordinator of TVEI in Western Isles has been appointed to the second.

In addition to these three appointments we intend to recruit a small number of additional support staff.

Work Programme

The drawing up of a Work Programme for the session 1989/90 is the first task set for the new Steering Group. A needs analysis is currently underway the results of which the Group will consider in mid-April. Looking at some early returns suggests that the previous advisory, information and training services are likely to continue but be offered to a wider clientele. Once such matters have been decided we will keep you informed, through these columns, of proposed Centre activities for next session.

Introduction

We apologise for the length of this section of the Bulletin but, inevitably, a good deal of material has accumulated since last we went to press.

COSHH Regulations

By now many teachers and technicians may be vaguely aware of the "Control of Substances Hazardous to Health Regulations" - 'COSHH' for short. These regulations have already been laid before Parliament and will take effect as from October of this year with further requirements as from January 1990.

Keep the heid!

As with other statutory Health and Safety provisions in recent years a whole new industry has sprung up over COSHH. Consultants spawn conferences and courses. Pundits proliferate. On the flimsiest of evidence salesmen will offer you monitoring equipment with literature and a host of other COSHH cottage industry products. In the midst of all this frenetic activity it is as well to realise that whilst many of the provisions of COSHH will apply to schools the Regulations were not formulated with education specifically in mind. They are really aimed at employers who were not meeting the spirit of the Health & Safety etc. at Work Act and were not providing employees with sufficient information on, and protection against, hazardous substances used in their workplaces. Despite that original intention schools and colleges nonetheless will have to comply with COSHH.

What is still in some doubt is the exact form such compliance can take. Although some general HSE guidance has already been produced it attempts to cover, as do the Regulations, a wide range of activities and uses of substances. The HSE Education National Industry Group is preparing more specific guidance to assist interpretation of COSHH by schools and colleges, not only in science and technology but also in other fields. Such guidance is to be issued to Education Authorities as soon as possible.

Possible amelioration

We are privileged to have membership of an HSE Education Service Advisory Committee Working Group which among other things has been looking at and advising on some of the COSHH guidance. From our knowledge of the work of that group we are sure that there has already been a tendency for outsiders to exaggerate the likely effects of the Regulations on school science and technology.

Monitoring of exposure and health surveillance

These can be required under Regulations 10 and 11 of COSHH. It looks likely that these, the two most potentially onerous provisions of COSHH, will not usually have to be met in schools and colleges establishments.

The first is a requirement - where necessary - to monitor, for specific types of harmful substance, the atmosphere in the workplace. "Where necessary" usually means where the nature of the hazard is such that the required control measures cannot be relied upon absolutely and thus exposures must be monitored. Because this will rarely, if ever, be the case in schools and because exposure times and maximum amounts in school labs typically are both relatively low then monitoring is unlikely to be nécessary. For much the same reasons regular health checks and the maintenance of detailed records for specific chemically related problems, both potentially onerous for the school system, are expected to be unnecessary.

Unavoidable duties

Whilst in the light of the special circumstances of education enforcement of COSHH should not prove unduly burdensome, EAs and independent (opted-out?) school governors as employers will have a duty to:

-continue to enforce prohibitions on the use of certain substances (e.g. some known carcinogens) already existing in current safety laws (Regulation 4);

- arrange for the carrying out of risk assessments where the use of any hazardous substance (including micro-organisms) is proposed (Regulation 6);

- provide, inspect and maintain any necessary control measures (Regulations 7,8 & 9) and

- provide necessary information and training (Regulation 12)

Each of these aspects is further commented upon below.

Prohibitions

This merely carries forward the provisions of extant safety legislation so there is likely be no substantive effect on school practices.

Risk assessments

An assessment of risk is required before any substance defined by the Regulations as "hazardous to health" is used. The definition of "hazardous" used in COSHH includes, any micro-organism; or any chemical which comes, from a supplier, labelled "very toxic"; "harmful"; "corrosive" or "irritant". Obviously many such substances are routinely handled by teachers, technicians and pupils. Risk assessments are required before any such handling be it for storage, in dispensing or diluting, in use or for disposal.

'Standard' activities

The HSE has yet to publish definitive statements as to what would constitute acceptable assessments in the situations already indicated. Our understanding is that what may often be required is a careful, structured consideration of the hazards likely to arise and of the precautions and protection measures to be adopted. Such an assessment may not have to be written down, especially if routine commonplace activities are involved. It has however to be carried out - even if as a sort of mental checklist routine. It does not always have to be formal and need not be so carried out each and every time that operation is performed. Re-assessment will be required in the event of a notified change in the degree of risk associated with a substance or operations involving it.

Although the assessments themselves need not be written down, the conclusions (or summaries of the results of several assessments) will often have to be confirmed or communicated in writing to employees. This requirement arises mainly under Regulation 12.

For standard, well kent, practical activities many employers and employees will rely for their assessments on advice and information already published and of established authority. We would expect that the publications of ASE (eg "Topics in Safety" 2nd Ed.), ourselves and of our sister organisation CLEAPSS would be seen as being in that category.

Projects and novel activities

Where practical activities involve unfamiliar substances or novel contexts and techniques then a risk assessment may well have to be formalised. It may also have to involve a system of referral which could extend from consultation with a relevant subject specialist within a school, reference to an external panel of experienced senior teachers or indeed to agencies like ourselves.

Control Measures

Regulation 7 requires an employer to prevent or adequately control the exposure of employees to substances hazardous to health. In all cases prevention or control of exposure should be achieved, whenever reasonably practicable, by measures other than personal protective equipment. In other words procedural or process controls including scale of operation and methods of containment are preferred.

The results of a risk assessment may well suggest the need for such control measures and Regulation 8 requires every employer who provides any such control measure to ensure that it is properly used and that every employee makes full and proper use of that control measure.

What does all that mean in the context of schools and non-advanced FE? For substances harmful by inhalation "control measures" under Regulation 7 could imply the use of a fume cupboard or artificial ventilation. Under Regulation 8 the employer has the responsibility to ensure that fume cupboards and any forced ventilation devices are operative to the required standard. The requirement under COSHH is for an inspection every 14 months. For simple systems this is likely to mean an annual check, to an agreed procedure, by a school or college or resource services technician.

Other hazards

At this point it is worth digressing slightly from the strict requirements of the Regulations. Note that COSHH is only concerned with substances hazardous to health. Such substances are often chronic rather than acute in their effect. A procedure may involve a substance with such chronic harmful effects but which also carries, for example, an explosion hazard. In theory COSHH does not cover the explosion risk - even though that could certainly and acutely harm your health! In practice no sensible person would assess the chronic health risk without also assessing factors such as flammability, explosion etc. Sensible control measures adopted under COSHH would also take account of other hazards and the need to control these also under other provisions of the Health and Safety etc. at Work Act.

Information, training etc.

Regulation 12 requires that suitable and sufficient information, instruction and training must be given on risks to health and on the precautions to be taken. Anyone carrying out any tasks under COSHH on behalf of an employer must also have the necessary information, instruction and training to do the job properly.

We regard this relatively short article as a contribution to the "information" bit. We shall, if and as necessary, be supplementing any HSE literature with guidance directed more specifically at school laboratories and technology rooms. One possible area for such assistance would be more detail on those substances and materials (including wood and other dusts) for which risk assessments are required. Provision of exemplar assessments would be another.

We consider that we have already made something of a contribution with the "HAZCON" sections in our Standard Grade Chemistry Practical Guides. As other demands on our time allow we may also be able to contribute to the training programmes of Scottish EAs.

Endpiece

It is likely that COSHH will make little difference to science and technology teachers who had earlier adopted a systematic and conscientious approach to the handling and use of hazardous substances.

The Regulations are largely just a spelling out and formalisation of the sensible approach already required for good, professional practice and indeed by the Health and Safety at Work Act itself. The only folk with real cause for concern are any employers with a less than professional approach to safety management or any employee with a cavalier approach to the handling of hazardous substances.

References

1. "Control of Substances Hazardous to Health Regulations" SI 1988 No.1657, HMSO.

2. "Summary of the Control of Substances Hazardous to Health (COSHH) Regulations 1989". An abstract of the "launch speech" by Dr.Cullen, HSE, in "Caution Magazine"

3. "Schools and COSHH", Tawney D.A., Director CLEAPSS, "Education in Chemistry" March 1989.

4. "Approved Code of Practice COSHH and Approved Code of Practice Control of Carcinogenic Substances" ISBN 0 11 885468 2, HMSO.

5. "COSHH assessments : A step-by-step guide to assessment and the skills needed for it"; ISBN 0 11 885469 0, HMSO.

6. "Introducing COSHH"; "Introducing Assessments" and "Hazard and risk explained" - all free leaflets from HSE offices.

* *

Gas taps - a reminder: anti-rotation devices

A year ago, in Bulletin 159, we drew the attention of readers to an official circular from the Scottish Education Department which was partly concerned with the safety of gas tap fittings. The background to that circular and both our and the Department's concern was a serious gas explosion in an English school which caused injury to six pupils and a teacher. The primary cause of the explosion was the partial unscrewing of a gas tap from its supply pipe. That had been made possible because of inadequate anti-rotation fittings on the taps.

We have now been notified of another related incident. We again would draw your attention to the need for inspection of anti-rotation provision on laboratory gas taps and for prompt remedial action where that is found to be necessary.

* *

Reports of Dangerous Occurences

Vacuum flask implosion

Description

We have received an account from a school of such an implosion during a calorimetry experiment. The apparatus was arranged as shown in the sketch below (Fig.1).

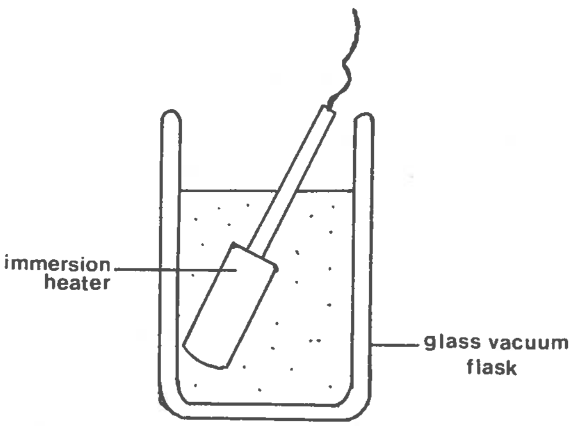

Fig.1

The heater in use was of a low voltage (12 V, 50 W) type from Philip Harris and was new. At the time of the incident it was being under-run at about 8 V.

What happened?

There was a loud bang with the room and the pupils being showered with fragments of glass. Fortunately there were no injuries. There was no damage to the immersion heater.

Probable cause

Investigation suggests that the cause was thermal shock to the glass and fracture of the inner wall of the flask because either:

-the heater touched the inside wall of the flask or

-a too steep thermal gradient was developed within the contents of the flask.

Recommendations

There seems no good reason to ban this experiment as such but:

-there is a need for a jig or clamp to hold the heater and ensure that it cannot contact the inner wall of the flask and

-either safety screens should be used or the vaccuum flask should be contained within a larger outer vessel or box to contain fragments from any implosion that might nonetheless occur.

Explosion in a flask

Description

This time the piece of apparatus was a round-bottomed flask fitted with electrodes and used for the sparking of air to show the combination of nitrogen and oxygen in air. Water is then added to the resulting nitrogen dioxide and tested to show the formation of an acid.

Because the flask had to be used dry, and because there was little time between classes, it had been rinsed out with ethanol and the solvent left to evaporate.

What happened?

As in the implosion incident already reported, with the apparatus in use as described there was a loud bang and the flask shattered. Interestingly, the electrode gap was being adjusted at the time and the EHT supply was switched off.

Probable cause

Despite time being allowed for evaporation of the ethanol there was indeed a small residue of solvent in the flask which mixed with the air to form an explosive mixture. A discharge from the supply (from a reservoir or other capacitor) gave a spark or there was some other source of ignition which led to an explosion.

Recommendations

Staff should be reminded of the general proscription on the use of flammable solvents for drying glassware for use in activities involving a source of ignition. Where the demonstration is to be repeated and there is insufficient time for the natural or heat assisted, air-drying of glassware; then spare dry flasks should be to hand.

Implosion in a lamp - carbon filament type

This note is also the result of a notification of an incident in a school. Like the other incidents it involved a bang with broken and flying glass. It is of particular interest because it highlights differences between carbon filament lamps, used for certain physics activities, and lamps of the more usual tungsten filament type.

Background

Carbon filament, unlike tungsten filament lamps are vacuum lamps. There is a pressure difference of one atmosphere between the inside and outside of the envelope. There is therefore always some risk of implosion and these lamps have in consequence to be treated with respect.

There are several mechanisms whereby such a lamp can implode:

<u>Current surge</u>

Vacuum lamps in general are far less likely to be damaged by a surge in current than are gas lamps such as the common tungsten filament lamp. This is thus unlikely to be a cause of failure. Indeed there are tales from the early days of electrical lighting, when these lamps were ubiquitous, of them seemingly to run forever. Such is the price of progress!

If then, they are apparently immune to supply surges it is known that they can occasionally arc with the arc acting as a short circuit across the filament. Were this to occur the whole lamp can overheat and the envelope implode. Osram GEC, now we believe the sole British manufacturer of this type of lamp, are obviously aware of the problem. To prevent catastrophic failure through arcing they fit an internal fuse within the inner glass casing of their lamps. Lamps sold by Griffin and George and Philip Harris are made by Osram and ought now therefore to have such protection. Old, or imported, stock may however not be so protected by fusing.

<u>Ageing of the glass</u>

The strength of glass is known to degrade with time. If at any time the surface of the envelope has been scratched it will be further weakened.

<u>Water on the envelope</u>

If a drop or drops of water were to fall on the envelope the resulting thermal shock may fracture the glass. Because of the relatively cooler envelope of a vacuum lamp the risk from this source is somewhat less than with gas filled lamps such as tungsten types.

<u>Falling from the socket</u>

Where the lamp is suspended and a fitting loose then it may fall and fracture. Accident reports identify this as a common source of failure. Witnesses to such accidents are apparently deluded into thinking the lamp imploded in situ in its socket, whereas it actually fell out and imploded on impact.

Recommendations

1. Use the type of lamp that has a fuse. The fuse is recognisable as a whiteish bead on one of the electrodes inside the inner glass casing (see Fig.2). If your stock includes lamps which do not have fuses you should seriously consider replacing them.

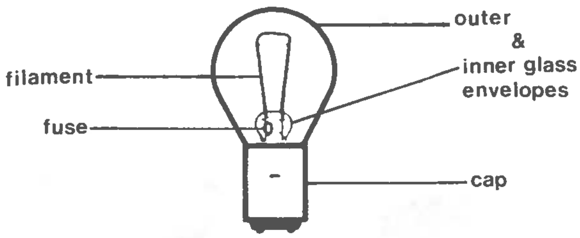

Fig.2. Fused lamp

2. Replace old stock as a matter of course. Twenty years should be the maximum permitted age of stock.

3. Replace any lamps with scratches on the glass envelope.

4. Warn pupils of the danger in handling a vacuum lamp and of the risk of implosion.

5. Instruct pupils to wear eye protection when using such lamps.

6. Do not use carbon filament lamps at all unless necessary for technical reasons. In schools this would seem to restrict usage mainly to work with the pinhole camera where a diminished real image is required.

We did swither somewhat before deciding on the advice under point 5. Given the accident history however, there seems little choice but to recommend the use of eye protection. There is a forseeable risk of injury to the eyes and thus protection is required under the relevant Regulations.

More on lamps

ES fittings - spectrum lamps

We have had, very recently, notice of an accident involving a sodium lamp with an Edison Screw fitting. Because the matter is still under consideration in the EA concerned we are unable to give a lot of detail on the accident itself. We would however bring to your attention the need to ensure that such lamps are wired with the correct polarity. The outer, female thread of the fitting must be wired to the neutral and the centre cap to the live side of the supply. A number of incorrectly wired lamps have been found in use in schools.

As an additional and necessary defence against incorrect wiring the fitting itself should be of the type with a protective skirt extending down over the 'shoulder' of the lamp. The skirt should be arranged such that when the lamp is screwed fully home and makes electrical contact no metal associated with the male screw on the lamp is exposed.

Such lamps are frequently used by senior pupils, usually for CSYS projects. It should be noted that discharge lamps require a high 'striking' voltage and draw large currents at switch-on until the gas in the envelope ionises. This explains the need for a supply incorporating a transformer and capacitor and underlines the need to ensure that fittings are correctly wired and protected.

We have instigated discussions with commercial suppliers of these lamps and fittings and will report further, if necessary, in a future Bulletin.

* *

Pupils wiring plugs

It would appear that some teachers may be issuing pupils with a length of two core and earth (3-core) mains cable to which has been attached at one end three 4 mm banana plugs. The pupils are then required to connect to the other end of the cable a 13 A three-pin mains plug. Once so connected the assembly is taken to the teacher, who inserts the cable into a home-built, low voltage, test box giving an indication of whether the wiring is correct or faulty.

Several designs for such a test box are believed to be in circulation. The general features of such designs are shown in Fig.3. below.

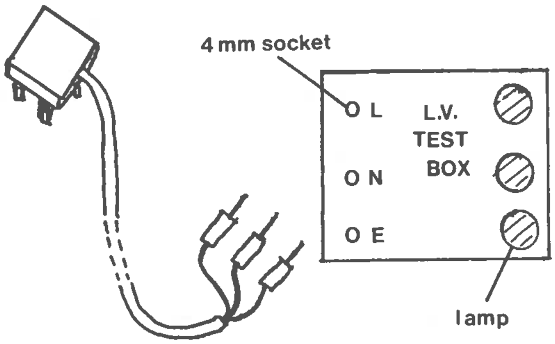

Fig.3

The risks from using such a technique are obvious. Through misuse or misunderstanding a pupil may either plug such a cable into a 13 A mains socket and receive a shock or apply 240 V to the test box which could also result in a shock. This technique for testing the wiring of mains plugs goes against good practice in that it mixes fittings meant for quite separate high and low voltage applications. It should be prohibited.

Permitted access to mains

In our "Standard Grade Physics Technical Guides - Volume One" (Section 1:Unit 2 page 54) we describe a pupil activity where the powering of a pupil wired mains device - an extension socket - is denoted optional and dependent on the passing of a visual inspection by the teacher.

Whilst we believe the activity, as described, is acceptable we have received an excellent suggestion for an improvement which makes it almost fail-safe. The method came from the Technician Service in Glasgow Division and uses in-line connectors one of which remains under the control of the teacher.

The activity is the wiring by the pupil of a 13 A extension socket. The pupil is supplied with an extension socket and a length of 3-core mains cable to one end of which is already wired the 'male' section of an in-line connector of the type used to power many modern garden tools (e.g. Farnell LCP 53B at £1-53 see Fig.4).

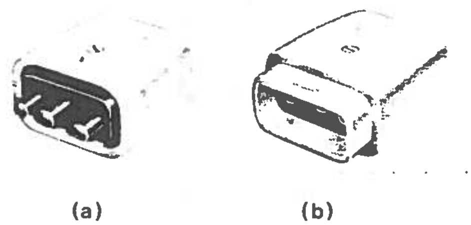

Fig.4. In-line lead connectors (a) Male (b) Female

The teacher retains a specialised lead with a 13 A mains plug at one end and the 'female' section of an in-line connector at the other. The pupil wires the extension socket to the cable with the 'male' connector. That work is then checked by the teacher and only when he or she is satisfied is the pupil given the lead with the 'female' connector and the 13 A plug. The method thus parallels good practice in industry in using a "permission to work" procedure. Pupils cannot connect their test piece to the mains supply without the specialised connecting lead and the teacher has control over final connection to the mains.

Teaching staff are to be reminded of the need to decommission the pupils' extension socket/cable assemblies on completion of the activity so that they cannot be put to use by anyone else but re-used for further pupil activities.

Measuring mains

On page 61 of the same Physics Technical Guide is a teacher demonstration (again designated as optional) of the use of an attenuator probe and an ocilloscope to measure mains voltage. The suggestion therein is to use a safe-bloc with a single, short, protruding length of brown mains core as a test point. Again we are grateful to the Glasgow Resource Services Technicians for a suggested improvement to the safety of the method.

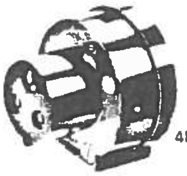

Fig.5

As for the pupil activity on the wiring of an extension socket, the suggestion is to use a special connector - this time a 'female', non-reversible socket (e.g. RS 489-497 £2-04, see Fig.5).

The live terminal in this connector is wired to a short length of brown wire the other end of which is then connected to the live terminal of a safe-bloc. The teacher demonstrates the measurement of the mains voltage using the attenuated probe recommended in the Guide, accessing the mains at the special socket. This method has the advantage of shielding the mains test point so that only active misuse would lead to an accident.

* * * * *

THERMISTORS

Simple means of getting accurate temperature data

Abstract

If a thermistor is wired to a series resistor to make a potential divider network then by careful choice of resistor it is possible to design a system which has a linear transfer function between the incoming temperature signal and the outgoing voltage signal. This technique is explained and illustrated. A computer listing is given to take out some of the mathematical sweat.

Description

Thermistors are resistive sensors whose resistance is temperature dependent. They are widely used in temperature measurement. As explained in the Instrumentation Notes of Bulletin 161, and elsewhere, the electrical signal drawn from almost any type of sensor is nowadays a voltage. In Bulletins 141 and 150 we published circuits containing thermistors. These were out-of-balance bridge networks, which are quite difficult to analyse and work with. Their main practical difficulty lies in the output signal across the bridge being unrelated to earth potential. It is thus quite awkward taking a signal from such a bridge circuit and applying it to a computer interface or data logger whose inputs are referenced to ground.

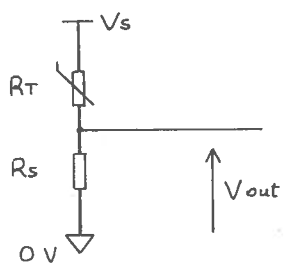

Fig.1 - Circuit to convert temperature into voltage

A much simpler arrangement is by connecting a resistor Rs in series to the thermistor thus making a potential divider. An output signal in the form of a voltage is taken from the common node of the network (Fig.1). This output signal is referenced to ground and may therefore be applied directly to any standard interface or data logger.

A thermistor's resistance varies non-linearly with temperature. However the output signal can be bodged to be linear by a bit of mathematics. It will then be linear across only the temperature range you specify. If the limits of this range are T1 and T3, and if T2 is the temperature midway between, then these three points have to be constrained to fit on the straight line

$$Vout = kT + c \qquad (1)$$

where k is the gradient or sensitivity in V/ºC and c is the intercept on the V axis (Fig.2).

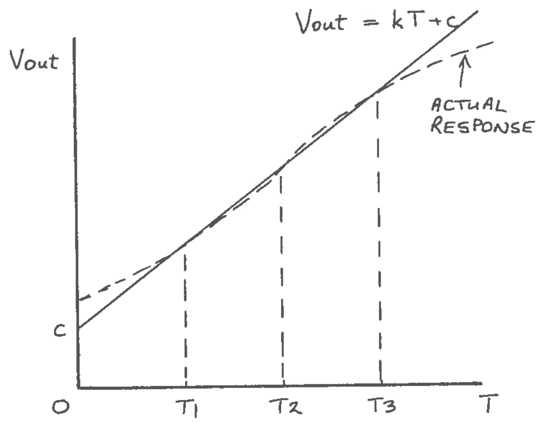

Fig.2 - Idealised transfer function temperature into voltage

The output signal Vout is also related to the resistance Rs and the resistances R1, R2 and R3 of the thermistor which correspond to temperatures T1, T2 and T3. If V1, V2 and V3 are the values of Vout at T1, T2 and T3 then

$$V1 = \frac{Vs.Rs}{Rs + R1} \qquad (2)$$

and similarly for V2 and V3.

By substituting (2) for Vout in (1) we can generate simultaneous equations (3) with three unknowns Rs, k and c. Only the equation for T1 is shown. The other two would be similar.

$$\frac{Vs.Rs}{Rs + R1} = k.T1 + c \qquad (3)$$

The solution for Rs is

$$Rs = \frac{R1.R2 + R2.R3 - 2.R3.R1}{R1 + R3 - 2.R2} \qquad (4)$$

By using this value of resistance in series with the thermistor the desired linearisation can be attained.

Thermistor resistances

Some types of thermistor such as the expensive R-T curve matched ones have tables published of resistance versus temperature in steps of 10°C. If using one of these the values of R1, R2 and R3 can be taken directly from the table and used with equation (4) to derive the value Rs of the series resistor. [A computer can be used to assist in this - see Listing 1 at the end of the article].

More commonly you are left to work out thermistor resistance values for yourself. To do this you need to use the following equation

$$R1 = R0.\exp(\beta/T1 - \beta/T0) \qquad (5)$$

where
- β = characteristic temperature constant (units in kelvin)
- T = thermistor temperature (units in kelvin)
- R0 = resistance at T0 (units in Ω)
- R1 = resistance at T1 (units in Ω)

It is usual for specifications to quote β and the resistance at 25°C.

Illustration of technique

Mullard manufacture a range of cheap bead thermistors, the 2322-642 series, which cost around 25p each. The linearisation technique is shown being applied to one of these. The temperature range being specified is 20°C to 40°C.

thermistor specification	β	=	4200 K
	R at 25°C	=	15000 Ω
	tolerance	=	5%
	power dissipation	=	8.5 mW/°C

Values of R1, R2 and R3 were calculated from equation (5).

T1	=	20°C	R1	=	19069 Ω
T2	=	30°C	R2	=	11893 Ω
T3	=	40°C	R3	=	7644 Ω

The resistance of the series resistor Rs was calculated from equation (4).

Rs = 8936 Ω

This resistor was built up from several standard fixed value resistors wired in series. The eventual circuit (Fig.3) was powered from a 1.5 V cell.

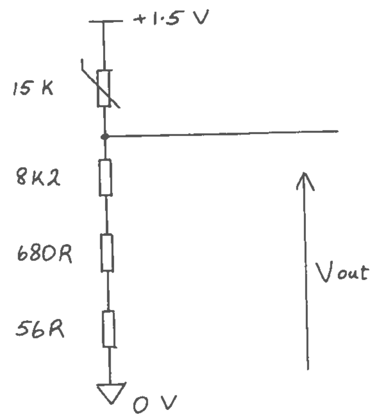

Fig.3 - Linearisation circuit for worked example

A check on the maximum power dissipated within the thermistor due to internal resistive heating showed that this is negligible.

maximum p.d. across thermistor (at 20°C) = 1.0 V

maximum resistive heating = V^2/R

= 50 µW

The circuit has been tried out and found to work as designed (Fig.4).

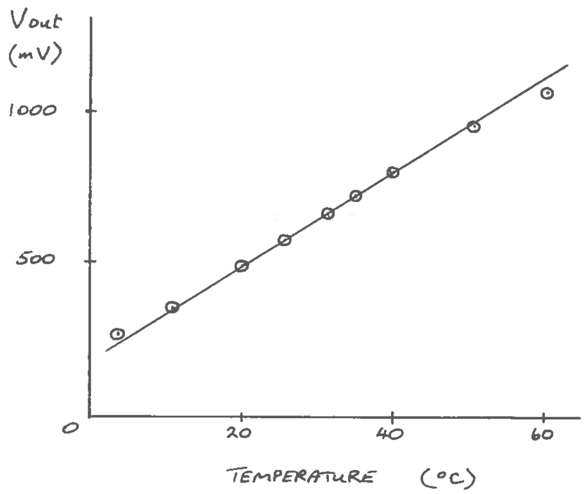

Fig.4 - Performance of worked example design

Notes on usage

1. Thermistors should be used in applications where a high sensitivity and small working range are required. You can expect to get a resolution of better than 0.1°C.

2. If accuracy, or miniaturisation, or speed of response, or combinations of these are wanted then use an R-T curve matched thermistor such as one of the series sold by RS Components (RS stock number 151-215, etc.). These at present cost nearly £4 each from RS.

The Centre has bought in a small stock of one of these in bulk and is able to offer it at £2.50 (item 641). The temperature tolerance of these is within 0.2°C and is exceptionally good. They can be linearised to better than 0.1°C by the method described herein.

3. If it is only the principle of operation that you want we recommend you buy a 25p thermistor such as the Mullard one just described. These too can be obtained from SSSERC (item 640).

4. One example of more demanding usage is in human physiological studies. Here it is suggested you would want features such as rapid speed of response, miniature size and high sensitivity. We recommend using an R-T curve matched thermistor in this instance. A suitable range would be 20°C to 40°C.

5. Linearisation can be done by computer processing - quite a different approach to that described here. With any reasonable value of series resistor Rs the signal Vout (Fig.1) should be input to a computer through an A-to-D converter. The value of Vout can then be processed by applying equations (2) and (5) to derive an actual value of temperature.

6. But staying with our analogue processing described herein the BBC Computer program (Listing 1) can be used to yield values of Rs for any temperature range.

```
  10 REM thermistor circuit design, SSSERC, 1988
  20 REM Rs is resistance of series resistor
  30 REM R1, R2 & R3 are thermistor resistances at T1, T2 & T3
  40 REM T2 is the mid-point temperature between T1 and T3; T1<T3
  50 REM B is the thermistor parameter beta
  60 INPUT"beta of thermistor ",B
  70 INPUT"resistance of thermistor at 25C ",R0
  80 T0 = 298.15
 100 INPUT"T1 ",T1: R1 = FNresistance(R0,T0,T1): PRINT"R1 = ",INT(R1+0.5)" ohms"
 110 INPUT"T2 ",T2: R2 = FNresistance(R0,T0,T2): PRINT"R2 = ",INT(R2+0.5)" ohms"
 120 INPUT"T3 ",T3: R3 = FNresistance(R0,T0,T3): PRINT"R3 = ",INT(R3+0.5)" ohms"
 130 Rs = (R2*R1 + R2*R3 - 2*R3*R1)/(R1 + R3 - 2*R2)
 140 PRINT"Rs is ";INT(Rs+0.5)" ohms"
1000 DEF FNresistance(R0,T0,T) = R0*EXP(B*(1/(T+273.15) - 1/T0))
```

Listing 1 - Calculation of series resistance Rs for any temperature range

Microbial fuel cell

Introduction

For some months we have been trying out such a cell based on ordinary baker's or brewer's yeast Saccharomyces cerevisae. We have been much impressed both by the performance of this device and the principles behind it. The cell we have been trialling was obtained from the National Centre for School Biotechnology (NCSB - further detail at the end of this article). One-offs of the cell are relatively inexpensive, easy to obtain and work well.

Basic principles

A microbial fuel cell depends for its operation upon the ability of bacteria and other micro-organisms such as yeast, to break down an organic substrate in processes providing a potential source for a useful electron flow.

The NCSB fuel cell design is based partly on devices developed by the Biotechnology Group at Queen Elizabeth College, London [1,2]. It is made largely from acrylic (Perspex) and consists of two chambers separated by a cation exchange membrane.

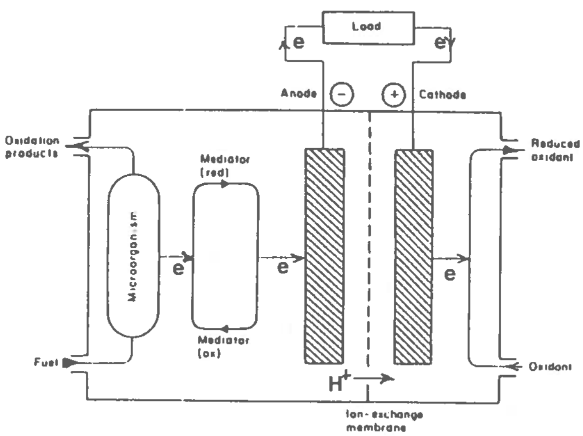

Fig.1 - Schematic diagram of microbial fuel cell

(After Roller et.al.)

One of the chambers contains the biological anode which is a micro-organism (baker's yeast in the NCSB fuel cell). The second chamber contains an oxidising cathode (potassium hexacyanoferrate (III) or air). Substances termed "mediators" couple sources of electrons within the micro-organism to the anode. These substances are often also called "redox mediators" (see Fig.1).

Mediator function

Cells will operate in the absence of such a mediator but will produce relatively little current when that relies on direct transfer of electrons from organism to electrode. Mediators improve the efficiency of the cell by increasing both the proportion of electrons transferred (the coulombic yield) and the rate of that electron transfer (the available current) [1].

The mediator in the NCSB cell is the common redox dye methylene blue. The dye is reduced at the anode, which is the organism and oxidised at the cathode. The rate of reduction of the dye is thus dependent on the reducing power of the organism which is in turn a measure of the organism's ability to support an electrical current in a microbial fuel cell.

Source of current

Microbial fuel cells 'store' electrons released by the breakdown of substrates (the organism's food source). This is effected through reactive intermediate biochemical compounds such as NADH (the reduced form of β-nicotinamide adenine dinucleotide). This compound is (should be?) familiar to every senior biology student. Normal aerobic respiration would channel NADH through the chain of respiratory reactions, fuelling bio-synthetic processes in the cells of the organism. By excluding oxygen and making the fuel cell anaerobic we can cheat the system because the mediator can 'steal' electrons from the NADH. It is then oxidised at the "oxidising cathode" [1,2] transferring electrons to it and thence to any external circuit.

cont./

Use and performance

Setting up the NCSB fuel cell was a little tricky first time round but thereafter was straightforward enough. Certainly the performance of the cell more than justified the small amount of trouble it took to become familiar with the preparatory stages. The off-load voltage was typically several hundred millivolts. As with many biological systems there is an initial lag period but then the voltage builds up quite rapidly. It peaked at 750 mV or so. Currents, not suprisingly, are relatively small but typically are of the order of several milliamps.

This output is readily displayed on a digital multimeter and is even sufficient to drive a low-current motor (of the type we once sold for use with a lemon-cell but now, sadly, out of stock). With one of these precision motors the on-load voltage is about 250 mV with a current of 3 mA or so. Larger loads could be driven using combinations of fuel cells in microbial batteries.

Summary

This yeast based fuel cell is worthy of serious consideration by any school or FE college looking for a practical illustration of modern applied biology. Because it looks such a good vehicle for project work we have deliberately given detail sufficient only to whet appetites. We can offer Scottish teachers and technicians hints and tips based on our own practical experiences in setting up a cell, curing leaks etc. A fuller set of notes on such aspects is in preparation.

Sources of supply

One-off samples of a kit of parts with membrane material are available from:

NCSB,
University of Reading,
London Road,
Reading,
Berkshire
RG1 5AG

at a cost per cell of £15 (plus £1-50 p.& p.)

Staff at NCSB are quite rightly keen that schools should obtain only one sample to use as a model for the construction of further cells. There will then be scope for a cross-curricular approach with co-operation between science and technical or technology departments. The sample cell kit comes with sketches, information and recipes for making up the membrane and necessary reagents. Membrane material is included in the kit but chemicals (buffer, cyanoferrate, methylene blue etc.) are not.

Provided it is stored moist, the membrane may be re-used many times. It will be stained blue by the mediator but that does not effect its operation. Replacement membrane material is available from BDH (Cat.No.55165) and is somewhat pricey at £33.50 per 6 strips but that is sufficient for 24 cells. The chemicals and biochemicals required should be straightforward to obtain from the usual suppliers. One or two items may have to be ordered from specialists such as BDH or their agents.

The only other requirements are for common household things like 'J' cloths (used to mechanically protect the membrane) and rubber gloves for making gaskets to prevent weeping at the cell joints.

Acknowledgement

We are grateful to John Schollar of NCSB. So boundless is his enthusiasm for things biotechnological he effortlessly sold us a cell kit - straight off his exhibition stand. We are grateful also for his patience in answering all the minor queries which arose when we were first trying out the device.

References

1. Roller, S.D. et.al., 1984, "Electron-transfer coupling in Microbial Fuel Cells : Comparison of redox-mediator reduction rates and respiratory rates of bacteria". J.Chem.Tech. Biotechnol. 34B, 3-12.

2. Bennetto, P.,1987, "Microbes come to power", New Scientist, 16th April issue.

*   *   *   *   *

EQUIPMENT NOTES

Electronic thermometers tested

Up until about a couple of years ago electronic thermometers were uncommon and expensive. But all this has changed. There are now dozens of models of cheap digital thermometers on the market. How good are they? Are they accurate, reliable, and robust? Are they a good substitute for the tried and tested liquid-in-glass instrument, or do they offer no improvement in performance other than in ease of reading? These and other questions this report tries to answer.

What we have done is test more than twenty models of electronic thermometer, most with digital displays, but four with electrical outputs but no on-board display. Most are at the bottom end of the market, which was the criterion we used in deciding what to test. However this is but a sample of that part of the market - it is not the complete whole. As a measure of the state of flux, several of the models originally tested have since been withdrawn. They are not included in the summary table.

Other and new models which appear to be of use in schools will be tested and reported upon at a later date.

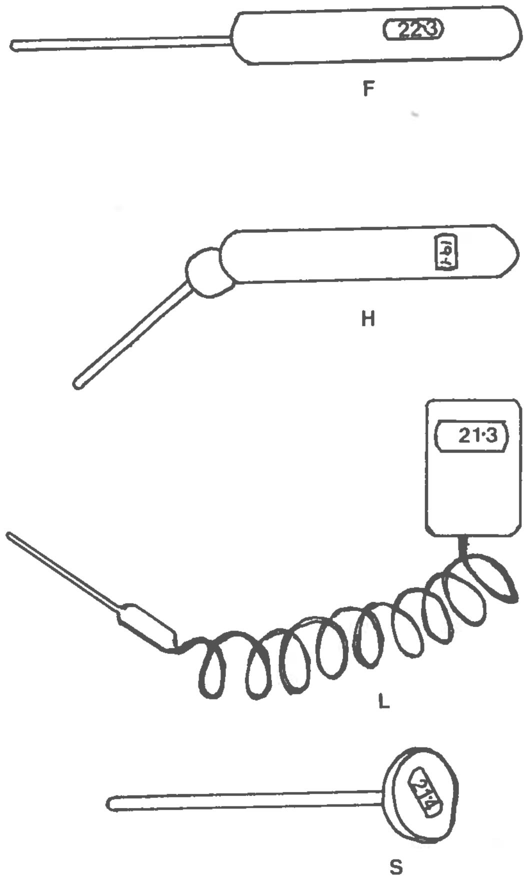

Fig.1 - Physical types

Physical design (see Fig.1)

- F fixed probe on body
- H hinged probe on body
- L probe on lead
- S spear type probe with dial indicator
- d probe detachable
- D display on instrument
- X electrical output, requires an external display

Range

If a thermometer has a range from -10°C to +110°C then it would be, in our opinion, a reasonable buy for schools as a general purpose instrument. Such a range should cover 98% of circumstances requiring the measurement of temperature. A wider range than this would be a bonus, but you would probably have to pay extra.

In general the cheaper the thermometer the more restricted the range. Instruments reading up to 200°C with a resolution of 0.1°C, or up to 1200°C, are not covered in this review. Instruments that do not cover our recommended basic range should be avoided. There are for instance several very cheap instruments with ranges such as -40°C to +40°C, or -20°C to +70°C. These would not in general be suitable for school laboratory use.

Notes on tests

Accuracy Most thermometers sampled had a resolution of 0.1°C and a specified accuracy which varied between ±0.3°C and ±1.0°C. Our tests show that eight of the twenty, or only 40% of the sample, were accurate to within 1.0°C. Five had errors in excess of 2.0°C. Eight met their specification on accuracy, but six did not, which as a percentage is quite an eyestretcher. Six others had no specification as to accuracy.

< 0.6°C	= good	0.6-1.1°C	= fair
1.2-1.8°C	= middling to poorish		
1.9-2.4°C	= poor	> 2.4°C	= very poor

Response time This was obtained by fully immersing the probe, originally at room temperature, in a bath of warm water. Eight of the sample took 20 s or less to read to within 0.1°C of their final equilibrated readings. Another five took up to 40 s to equilibrate. The remainder took longer. If you don't want pupils idling around, in this instance through no fault of their own, every time digital thermometers are used, consider this factor before buying.

< 11 s	= good	11-20 s	= fair
21-40 s	= slow	41-60 s	= very slow
> 60 s	= extremely slow		

Sampling period In some instruments this was 10 s or more and partly accounts for the slow response times found. Some have switchable sampling periods, such as 10 s and 1 s (denoted as 10/1 in table). But several of these switches were almost impossible to operate through being recessed. Those with this defect are marked '*' in the summary table.

Depth of immersion test Many of the probes were 100 mm or longer overall. Where appropriate, dependent on length of probe, the probe was immersed in warm water to depths of 20 mm, 50 mm and 100 mm. Two thirds of the sample showed differences between the 20 and 50 mm marks of less than either 0.5°C, or, for instruments with a 1°C resolution, 1°C. Six instruments showed significant differences.

The criteria below are for differences between 20 mm and 50 mm depths of immersion.

< 0.2°C	= good	0.2-0.5 or 1 digit	= fair
0.6-1.5	= middling	1.6-4.0	= poor
> 4.0	= very poor		

Thermal inertia or capacity The probe should have a low thermal capacity in order not to appreciably affect the temperature of the substance being sensed. This was assessed by mass of probe.

< 5 g	= good	5-9 g	= fair
10-14 g	= middling	15-19 g	= poor
> 19 g	= very poor		

Chemical resistance of probe The probe was immersed in several potentially corrosive chemical solutions, being copper sulphate, nitric acid and brine. A possible heating effect was looked for. The probe was inspected for signs of damage. The test solutions were inspected for signs of change.

Physical robustness The probe, connector and, where appropriate, probe lead were examined for signs of wear and tear, or weakness.

Battery life estimate This is estimated at 70% of the specified battery charge in amp-hours divided by the average measured current drawn by the instrument. About half the sample had batteries that did not have on-off switches. Such instruments presumably use very low power, CMOS circuitry. Currents drawn by these instruments were usually less than 5 μA. Most were designed so that their batteries would seem to have an expected lifespan of three or more years. But not all were. Instruments that did have on-off switches were found to draw very much higher currents. Typically, these currents were of the order of several milliamps. Were such an instrument to be run continuously its expected battery life would be of the order of a hundred or so hours. Their batteries thus have potentially a very short lifespan because of the risk of them being stored switched on. Only one such instrument had an auto-shutdown. We think that any instrument that uses high current components that require an on-off switch should have this feature.

cont./

For instruments with switches:

< 50h	very poor	50-149h	poor
150-300 h	fair	>300 h	good

'auto' = auto-shutdown (This is given a higher rating in the table)

For instruments without switches:

< 0.5 y	very poor	0.6-1.5 y	poor
1.6-3 y	fair	3-5 y	good
> 5 y	very good		

Summary Table

In the tables a space row is used to separate different instruments. However if an instrument is retailed by two different suppliers then these firms are run together in adjacent rows. For instance the ELTH thermometer which is manufactured by the Italian company Hanna is available from both UK Instruments, who call it by its maker s name, and Whatman, who call it 'Temp-u-Sensor'.

The following code is used:

A instrument also contains light meter in lux
B instrument is being redesigned to reduce current consumption
C contains internal and external sensors and 12 h clock
E catalogue specification is inaccurate; the range is not +20 to +110, but is indeed -10 to +110
G contains upper and lower temperature alarms
* sampling rate switch difficult to operate
n.a. not applicable

Best buy?

Digital displays The following instruments cover the basic range of -10 C to +110°C and have good to middling accuracy ratings:

TemPen (Bibby,Harris)	ESMI Mk2 (British Gas)
THV-120-010B (Griffin)	THV-200K (Griffin)
650-419 (RS)	0900.0125 (Testoterm)

and just missing out on accuracy:

ELTH (UK Instruments, or Whatman)

Test results are based on only one sample of each instrument. We cannot be certain that any instrument tested is typical. It may be the oyster with the pearl, or it may be the bad apple in the basket. Readers should qualify our test report advice with this knowledge of the restricted basis of our sampling.

Of the above list the sole instrument with no adverse findings in the first round of testing was:

650-419 from **RS Components** at £14.50.

This instrument thus came out tops in our original test programme. To judge whether this was chance or typical occurrence two more of these instruments have since been tested. We are pleased to report that in all three instruments the error never exceeded 0.5 °C. However some minor points of concern arose:

1. The three instrument probes were subjected to an additional test - prolonged immersion in condensing steam. One of the three developed a reading error, indicating possible water penetration either between the steel tip and plastic handle or the handle and cable. It therefore appears that the probes of these instruments may not be reliably sealed. The reading error greatly reduced after a 24 hour drying out period.

2. The hinged battery lid is probably insufficiently robust for pupil usage. As a temporary expedient we would recommend that it be taped over with plastic tape as a token that it should not normally be opened.

3. There is risk that the hinged battery lid may compress the cable twixt probe and instrument. We would thus recommend that the cable should not be stored inside the battery compartment.

Despite these minor shortcomings the RS Thermometer is still our recommended first choice.

Temperature sensors Of the group tested that have electrical outputs rather than digital displays the best buy would seem to be the MEP semiconductor temperature sensor from Griffin (CRB-166-020V) at £33.

Supplier	Model, cat. no., maker	Price (£)	Design	Range (°C)	Resoln. (°C)	Accuracy
Instruments with digital displays:						
Bibby Harris	TemPen TP150, Bibby =TempPen C78948/6	39.50 47.70	H D	-30 to +150	0.1	fair
British Gas	ESMI Mk2, Portec, (A)	40.00	L D	-50 to +200	1	middling
Griffin	THV-120-010B (E)	16.00	F D	-10 to +110	0.1	fair
Griffin	THV-200K, Brannan	29.50	L D	-40 to +120	0.1	fair
Harris	C78945/0	17.55	F D	+20 to +110	0.1	poor
Mackay & Lynn	TA 138L, Zeal	17.12	F D	-40 to +50	0.1	good
Maplin	FD26D (C)	11.50	L D	-20 to +70	0.1	middling
Maplin	FD25C (C)	8.95	L D	-20 to +70	0.1	good
RS Components	650-419 (G)	14.50	L D	-10 to +110	0.1	good
Solex	PD20C	14.00	S D	-20 to +70	0.1	fair
Solex	PD30C	14.00	S D	+20 to +110	0.1	poorish
Solex	ST100	23.00	L D	-45 to +120	0.1	very poor
Testoterm	0900.0125, Testoterm	11.75	S D	-10 to +110	0.1	fair
UK Instruments Whatman	ELTH, Hanna Temp-u-Sensor, 6251 0000	26.30 35.00	dF D	-50 to +170	1	poorish
Instruments with electrical outputs, but lacking digital displays:						
Griffin	MEP Pt sensor, CRB-166-060J	49.00	dL X	0 to +100	0.2	fair
Griffin	MEP Si sensor, CRB-166-020V	33.00	dL X	-50 to +150	0.2	middling
Harris	T12180/1 (steel probe) (B)	58.43	dL X	-10 to +40 0 to +100	0.1	poor
Harris	T12190/4 (glass probe) (B) with T12180/1 (sig.cond.box)	14.25 58.43	dL X	-10 to +40 0 to +100	0.1	very poor

Accuracy meets spec.	Response time	Sampling period (s)	Depth of immersion test	Thermal inertia	Chemical resistance	Physical robustness	On/off switch	Battery life
yes	slow	0.33	fair	middling	good	satisf.	yes	poor
	good	0.33	fair	good	poor	satisf.	auto	fair
no	very slow	10	poor	fair	satisf.	satisf.	no	good
no	good	0.5	fair	good	satisf.	doubtful	yes	good
no	very slow	15/1 *	very poor	fair	satisf.	satisf.	no	good
yes	slow	15/1 *	poor	good	satisf.	satisf.	no	good
yes	fair	1	good	good	satisf.	satiaf.	no	very good
yes	fair	10	good	good	satisf.	satisf.	no	good
yes	fair	10/1	good	fair	satisf.	satisf.	no	very good
yes	fair	10/1	good	fair	satisf.	satisf.	no	fair
yes	very slow	15/1	poor	fair	satisf.	satisf.	no	fair
no	very slow	1	poor	fair	very poor	poor	no	very poor
yes	slow	10/1	fair	fair	satisf.	satisf.	no	fair
doubtful	fair	1	poor	middling	satisf.	satisf.	yes	good
	extremely slow	analogue	middling	fair	poor	satisf.	n.a.	n.a.
	slow	analogue	good	good	satisf.	satisf.	n.a.	n.a.
	slow	analogue	middling	very poor	satisf.	doubtful	yes	poor
	fair	analogue	middling	poor	good	satisf.	yes	poor

SURPLUS EQUIPMENT OFFER

This offer is subject to our general conditions of sale as revised (published in Bulletin 158).

Please note that items are not necessarily arranged according to the item number. They may be grouped because of similarity of application, or for other reasons. Often the item number serves only for stock identification by us in making up orders.

Customers intending to place orders in the early part of this Summer (May and June) are given notice of probable disruption and delay because of our move to new premises.

Motors

Item 590	Stepper motor, single phase, 5 V manufactured for clock or other timing device. Delicate gearing with 40 tooth plastic wheel as output. Suitable for demonstration, or as a method of digital input for control or timing. Unidirectional. Dimens. 30 x 25 x 10 mm. Circuit diagram supplied.	£1.20
Item 591	Stepper motor, 4 phase, 12-14 V d.c., 400 mA, 27.5 R coil. Step angle 7.5 degrees. Powerful motor with 15 mm, 6 mm dia. output shaft. Dimens. 40 mm long, 70 mm diameter on 70 mm square mounting plate with fixing holes at 56 mm centres. Circuit diagram supplied.	£4.50
Item 626	Precision motor, 0.5-15 V d.c., power output 2.2 W, no load speed & current 7700 rpm, 16 mA, stall torque 11 mN m, 34 mm long, 23 mm dia., output shaft, 14t.steel pinion.	£3.50
Item 627	Precision motor tacho unit, consists of motor unit with integral generator. 0.5-15 V d.c.. 55 mm long, 24 mm dia., output-shaft 10 mm long, 3 mm dia..	£5.00
Item 628	Precision motor, 0.1-12 V d.c., no load current & speed, 18 mA 5200 rpm, stall torque 46 mN m, 40 mm long, 28 mm dia., output shaft 8 mm steel spline.	£3.20
Item 594	Precision motor, 0.5 - 12 V d.c. no load current and speed, 12 mA 4900 rpm, stall torque 29 mN m, 48 mm long, 23 mm dia., output shaft 10 mm long, 3 mm dia.	£3.20
Item 592	Miniature motor, 2.5 to 9 V d.c., smooth running, speed governor. No load current 30 mA. Dimensions 35 x 40 mm dia. 8 mm shaft 2 mm dia.	60p
Item 593	Miniature d.c. motor, 1.5 - 3 V No load current 60 mA, speed 4,500 - 3,700 r.p.m. Stall torque 7 mN m. 30.5 mm long by 23 mm dia. 5 mm x 2 mm dia. shaft.	35p
Item 621	Miniature d.c. motor, 1.5 - 3 V Open construction, ideal for demonstration. Dims. 19 x 9 x 18 mm, double-ended output shaft, 5 mm x 1.5 mm dia.	20p
Item 395	Model maker's motor, 3 V d.c. no load speed & current: 6250 rpm, 350 mA. Stall torque 1 mN m. Dimens. 35 mm long and 30 mm dia. with 15 mm shaft 2 mm dia. Small magnet in base for easy mounting.	40p
Item 625	Worm and gear for use with miniature motors. Brass worm with plastic gear wheel.	35p
Item 378	Encoder disk stainless steel with 15 slots, 30 mm dia. with 4 mm fixing hole.	75p
Item 642	Encoder disk stainless steel with 30 slots, 30 mm dia. with 4 mm fixing hole.	£1.30

Miscellaneous items

Item 629 Dual-tone buzzer with flashing light, mounted on small P.C.B. The unit has a PP3 battery clip and two flying leads for switch applications. 40p

Item 643 Solar cell with motor. Cell area 45 x 75 mm, output 0.45 V max., 400 mA. The motor operates with a no load current of 250 mA. £2.50

Item 313 Thermostat, open construction, adjustable, range of operation covers normal room temperatures. Rated at 10 A, 250 V but low voltage operation also possible. 60p

Item 380 Thermostat, with capillary 500 mm long. Operates at low voltage but rated 10 A, 250 V. Can be activated by heat from human hand. £1.25

Item 385 Pressure switch, operable by water or air pressure. Rated 15 A, 250 V (low voltage operation also). Dimensions 3" dia. x 2". 65p

Item 419 Humidity switch operates by contraction or expansion of membrane. Ideal for greenhouse or similar control project with items 348 and 344.Rated 3.75 A up to 240 V. 75p

Item 507 Optical fibre, plastic, per metre single strand 1 mm dia. Used for the optical transmission of sound. See Bulletin 140 for one such application. 35p

Item 429 Metallised polyester film, one square metre, 12 microns thick (see Bulletin 139 for applications) £1

Item 612 Beaker tongs, metal, not crucible type, but kind which grasps the beaker edge with formed jaws. £1.20

Item 615 Wire, for thermocouples, 1 m of each of 0.5 mm dia. Chromel (nickel chromium) and Alumel (nickel aluminium). Makes d-i-y thermocouple - see Bulletin 158. £2

item 348 Submersible pump, 6 - 12 V d.c. Corrosion free nylon construction. £5.60

Item 645 Ceramic magnets, assorted sizes and shapes 7p

Kynar film items

See Bulletin 155 for details of applications such as force/time plots and detection of long wave infra red radiation.

Item 502 Kynar film, screened, 28 um thick, surface area 18 x 100 mm. With co-axial lead and either BNC or 4 mm connectors (please specify type). £20

Item 503 Kynar film, unscreened, 28 um thick, 12 x 30 mm, no connecting leads. 55p

Item 504 Copper foil with conductive, adhesive backing, 1" strip. Makes pads for Kynar film, to which connecting leads may be soldered. 10p

Item 505 Sensifoam, 0.25" thick, 6" X 6" £1.00

Item 506 Resistor, 1 gigohm, ¼ W £1.00

Resistors fixed & variable, components

Item 328 Potentiometer,wire wound, 15R linear, 36 mm dia. 20p

Item 329 As above but 33R. 20p

Item 330 As above but 50R and 40mm dia. 20p

Item 331 As above but 100R and 36 mm dia. 20p

Item 421 d.i.l. resistor networks per 10 following values available: 62R; 100R; 1K0; 1K2; 6K8; 10K; 20K; 150K; 125/139R and 1M0/6K0 30p

Item 420 5% carbon film, ¼ watt resistors values as follows: 6p/10
10R; 15R; 22R; 33R; 47R; 68R;
100R; 120R; 150R; 180R; 220R;
270R; 330R; 390R; 470R; 560R;
680R; 820R; 1K0; 1K2; 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;
470K; 680K; 1M0; 2M2; 4M7 & 10M.

N.B. If anyone is interested in purchasing other values in the E12 range between 1R0 and 10M, which are not listed above, please let us know so that we can consider extending our stock list.

Item 322 Germanium diodes 8p

Item 371 Ferrite rod aerial, two coils MW & LW, dimens. 10 X 140 mm. 40p

Item 511 Loudspeaker, 8R, 2 W, 75 mm, resonant frequency 250 Hz. 50p

Item 333 Microphone inserts, high impedance, 23 mm dia. 12 mm depth 40p

Item 631 Microswitch, miniature, SPST, normally closed, push to break. 40 mm long actuating arm, 4 mm spade connections. Dims. 20 x 10 x 16mm. 25p

Item 632 Microswitch, standard, SPST, normally closed, push to break. 28 mm long angled actuator arm. Dims. 27 x10 x 16mm. 25p

Item 633 Infra-red sensors, emitter and detector, spectrally matched pair. Data sheet supplied. Priced for pair. 45p

Item 640 Disk thermistor with flying leads, resistance at 25° C 15KR. 25p

Item 641 Bead thermistor with flying leads, resistance and temperature matched. £2.60

Item 354 Reed switch, s.p.s.t., 46 mm long 10p

Item 508 l.e.d.s, red, green, yellow: each 6p
or 10 for 50p

Item BP100 Precision Helipots, Beckman mainly 10 turn, many values available. Please send for a complete stock list. 10p to 30p

We also hold in stock a quantity of other electronic components including capacitors, diodes, transistors, etc. To list all of these items would be uneconomical since most articles are priced at 5p or under. If you do have requirements for such items please let us know and we will do our best to meet your needs.

* * * * *

Portec Instrumentation Ltd., 3-5 George Street West, Luton, Beds. LU1 2BJ Tel.(0582) 32613.

RS Components Limited, PO Box 99, Corby, Northants., NN17 9RS; Tel. (0563) 201201.

Soar (Solex Agent), 95 Main Street, Broughton Astley, Leics. LE9 6RE Tel.(0455) 283486.

Testoterm Ltd., Old Flour Mill, Queeen Street, Emsworth, Hampshire PO10 7BT Tel.(0243) 377222.

UK Instruments Ltd., Happy Valley Industrial Park, Primrose Hill, Kings Langley WD4 8HZ Tel.(09277) 60655.

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

Whatman Labsales Ltd., Unit 1, Coldred Road, Maidstone, Kent ME15 9XN Tel.(0622) 674823 [Direct Tel. orders 0622-674821].

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

BULLETIN 162

CONTENTS

April 1989