

SCOTTISH SCHOOLS EQUIPMENT RESEARCH CENTRE



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INTRODUCTION

Leading article

Jim Jamieson's piece in Bulletin 182 - *Clyde built : An appreciation of Scottish engineering* was well received. Some readers even took the trouble to write in specially to express their approval of both its content and sentiments.

Because of that reception we have decided, possibly unwisely, to try our hand again at an historical approach to technological subject matter. To that end, Ian Buchanan has researched a piece on historical aspects of Scottish civil engineering works. It uses bridge building as its major theme. One aim is to put some of the more theoretical aspects of Technological Studies, topics such as "structures and materials" into practical, real life, contexts.

Acknowledgements

We are very grateful to all of the individuals and agencies who assisted us in researching the information and in locating suitable illustrations for the article *Lads o'pairs*. These include :

Peter Stephen of Peter Stephen & Partners, Consulting Engineers, for access to a limited edition copy of Westhofen's work, for personal communications on the building of the Forth Road Bridge together with permission to use photographs and for other assistance with texts;

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Staff at the Archives and Museums Section of Gwynedd County Council, North Wales, for copies of lithographs of the Menai Bridge;

Staff of the library of the Royal Commission on the Ancient and Historical Monuments of Scotland (RCAHMS) and

David & Charles, publishers of Bracegirdle and Miles book on Telford in their series *Great Engineers and Their Works*. We have to record here also our failure, despite much effort, to contact either Brian Bracegirdle or Patricia Miles as the primary copyright holders of the photographs of John Telford's headstone at Westerkirk and of Langholm Bridge. We trust that they will forgive us for that. Given that both were teachers and teacher educators, as well as extremely skilled photographers, we have had to assume that they would not object to their work being put to such bona fide educational use.

Materials testing

A related article is included in the Equipment Notes section of this issue. This is a review of Unilab's Materials Testing kit which offers possibilities of practical experience of testing metals and other materials in schools rather than covering such work solely by means of visits or visual aids.

Comment

Recently our local Scottish based supermarket was taken over by a UK chain. At first there was little difference to note on the shelves. There followed a short lived attack of hiccups as some lines ran out and "computer problems" disrupted supplies.

Then the new regime began to take effect. In the ensuing weeks more and more of the distinctive Scottish produce began to disappear from the displays. Then there were no *Simmers* biscuits, no Galloway or Orkney cheeses, Stromness oatcakes or *Scottish Pride* butter.

On another front, war had simultaneously to be waged. At the same time as the supermarket sign went duosyllabic it became clear that my insurers had unilaterally converted the terms of my household policy. Unless I actively opted for it to operate under Scots law then English law would be deemed to apply.

What has any of this to do with education? Well, it set me thinking on how easily national, social and cultural distinctions may be lost. Rarely is this accomplished by any sudden, revolutionary upheaval but rather it happens by a process of gradual erosion. In terms of my supermarket analogy we may go out in economic terms not with a bang but with a *Wispa*. If you think this a ludicrous parallel then remember the global cultural desertification some of our American cousins have managed to achieve with little more than a 'burger and a can of fizzy drink.

Given this apparent nibbling away at our economic and legal fabric, how sanguine can we be about distinctive features of the Scottish educational system. I keep hearing that "Of course, this National Curriculum nonsense doesn't apply here at all". A close scrutiny of parts of some recent consultation or discussion papers and 5-14 documents might lead some to a different conclusion.

There is no intention here to strike negative or narrow chauvinistic poses and certainly not to promote anti-anybody sentiments. Rather the aim is to encourage the continuance of a positive, confident and above all useful Scottish contribution to educational debate and writing. On this more positive side I have been heartened of late by the revival of confidence and interest in the use of the Gaelic and more recently of Scots.

Scotland relies heavily for its cultural health on the one hand on a degree of local economic control and on the other a complex social tapestry of legal, educational and religious institutions. These elements have all, to varied extent, been eroded. What is perhaps lacking still is a sufficient emphasis on that central icon in the triptych of any nation, its language.

Scots, like Catalans, are fortunate in having the possibility of the use of three - more on which some other time.

Lads o'pairs

A celebration of Scottish civil engineering

In Bulletin 182 we discussed some of the reasons why *Clyde built* was synonymous with excellence in engineering. The possibility of an historical approach as one way into cross curricular studies was raised. Unfortunately few now have access to steel and ironworks and little remains of the ships and yards of the Clyde except in one or two remaining pockets. Of the skills and craftsmanship some are possibly lost forever. However in nearly every locale in Scotland some of the achievements of her engineers can still be appreciated. The results of civil and structural engineering are ubiquitous. Not only is the work of some of the engineering giants of the past still there for our appreciation but it is readily accessible to most. Nearly everyone has a bridge, or a viaduct, canal, reservoir, aqueduct or lighthouse which stands witness to the genius - often aesthetic as well as technological - of our leading civil engineers. And, as the illustration on the front cover shows, despite all that talk of monstrous concrete carbuncles, some civil engineers are capable still of the highest aesthetic standards. In the whole of Europe few modern, man made structures sit so at ease in such a sensitive landscape as does the Kylesku bridge in Sutherland.

In the main, bridges are used to illustrate this article. Some merely provide historical benchmarks or links with particular characters in our story. But, three are concentrated upon - the Menai Bridge, the Forth Rail Bridge and the Forth Road Bridge. These were chosen because when each was built engineers were stretching their knowledge of design and materials to new limits. They also provide long threads of continuity.

As if you didn't know, the bridge over the Menai Straits was the work of Thomas Telford, who had been inspired by the earlier work of Smeaton. The designer of the Forth Rail Bridge, Benjamin Baker, offers continuity on from Telford into and through the 19th century. Baker was also responsible for the upgrading of Telford's Menai Bridge, among others. These commissions he carried out with sympathy for the original designs leaving their outward appearance largely unchanged. And finally, the designers and contractors for the Road Bridge in turn had direct links with those responsible for the earlier crossing. As with steelmaking and shipbuilding, so with the development of civil and structural engineering, we can trace their stimuli back to, and before, the Age of Enlightenment.

"A Colossus of Roads"¹

It is no wonder that these engineers from the old school can turn from one subject to another with so much versatility when we consider what an education they had. Instead of having professors to fill them with ready digested knowledge like young men of the present day, they moved from one position to another, and their intellects were hardened and invigorated by constant work. Every step they took was an experiment on a working scale and every fact they learned was imprinted on their memories by the toil and trouble it had cost. Wilhelm Westofen 1890 [1].

Thomas Telford (1757-1834) was born at Glendinning near Langholm. He was a stone mason to trade. The photographs opposite show two of many local monuments to his early work. The headstone provides the most poignant of these. His father, John, died within a year of Telford's birth. Figure 1 shows John Telford's headstone which Thomas cut with his own hands as soon as he had learned how. Figure 2 is of the bridge at Langholm built around 1778 and upon the stonework of which Telford's mason's mark may still be seen.

¹ Not our pun but the poet Robert Southey's, a contemporary and erstwhile companion of Telford.

He was the person who carried the tradition of public works into a new era. He is credited by many scholars with establishing civil engineering as a profession. He put a structure to the work of Smeaton and that of his contemporaries - all those many bridge builders and canal designers who thrived in the 18th and 19th centuries. Although Telford spent most of his life living and working in England, he never forgot his Scottish roots. When in 1801 the government asked him to report on public works in Scotland he did so and, as with all his projects, wholeheartedly. Under his stewardship, and to his own designs, 1200 bridges were built, 1000 miles of roadway completed and countless churches, manses and harbours built or upgraded. On many of these projects he waived his fees - no Director's share options or huge salary hikes for him!



Figure 1 John Telford's headstone, Westerkirk, cut by Thomas Telford's own hand.

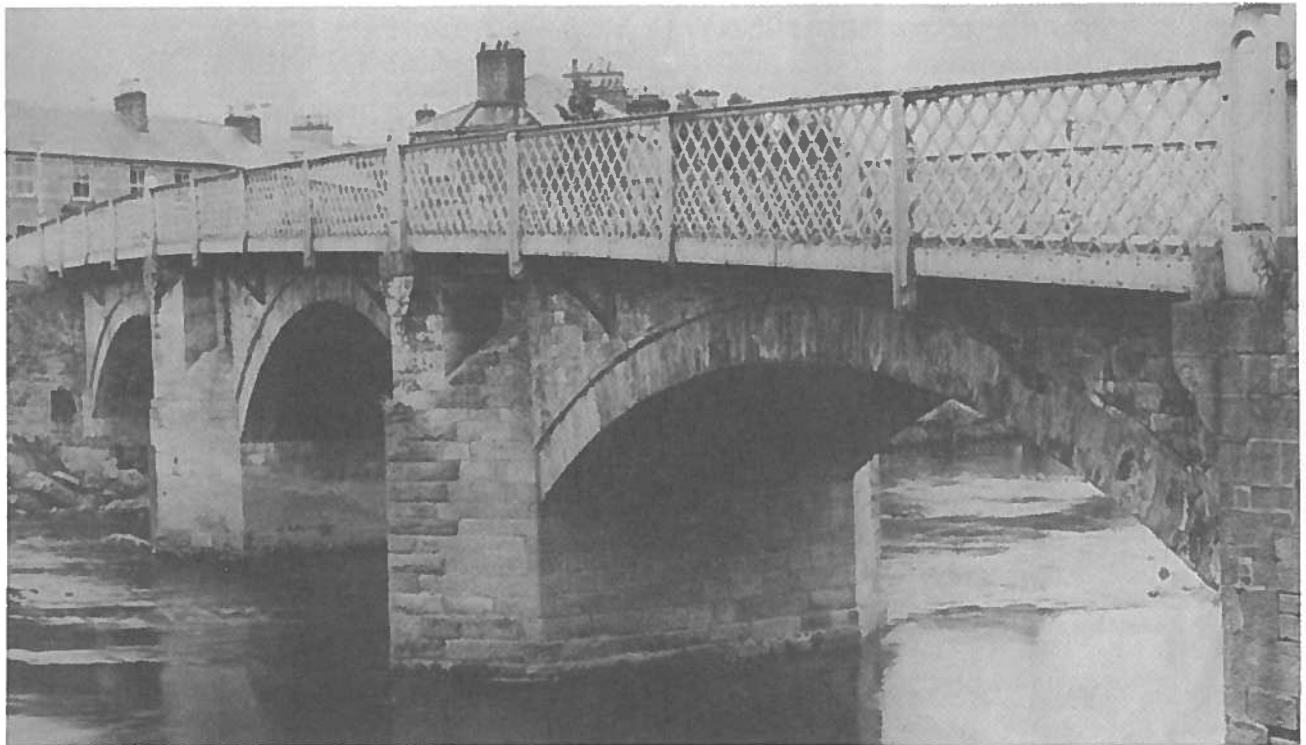


Figure 2 Langholm Bridge, ca. 1778. Note the stone buttresses and corbels as well as the cast iron supports to the extension carrying the cantilevered footway - features to be seen on other Telford designs.

It was during this period back in Scotland that plans were drawn up for the building of the Caledonian Canal (1804), linking the North Sea with the Atlantic¹. This massive undertaking was designed and overseen by Telford. It took twenty years to complete and, although the average wage for those working on the canal was only one shilling and sixpence a day (equivalent to seven and a half pence now), the final cost of the work was over one million pounds. This was only fifty years after the 1745 uprising. The clearances had begun, starvation and privation were commonplace. Telford was acutely aware of this and believed he ameliorated the situation by turning many of his workforce from semi-skilled farm labourers into highly skilled craftsmen. He estimated the numbers of those so trained at around 800 a year.

¹ Some of the drawings being executed by no other than James Watt of steam engine fame.

Even though he was busy overseeing the building of the Caledonian canal, Telford still made the time to visit Sweden. There he designed and supervised the building of the Gotha canal! For this he was knighted by the Swedish king, the only honour he accepted during his lifetime.

Figure 3 is an early lithograph showing one of his most famous works - the bridge over the Menai Straits. This was completed in 1826 and linked the principality's mainland to the ancient kingdom of Anglesey and thus was an umbilical to *Môn mam Cymru* - the mother of Wales. Less poetically and more realistically it had more to do with providing a strategic road link to Holyhead and onward by sea to Ireland. It was built as a suspension bridge incorporating massive iron chain links and tie rods. Originally it had a wooden roadway or deck. There is a huge difference in scale with Telford's early work at Langholm but anyone comparing Figures 2 and 3 will detect aesthetic and technical parallels in some of the uses of iron railings and cantilevered supports for the walkways.

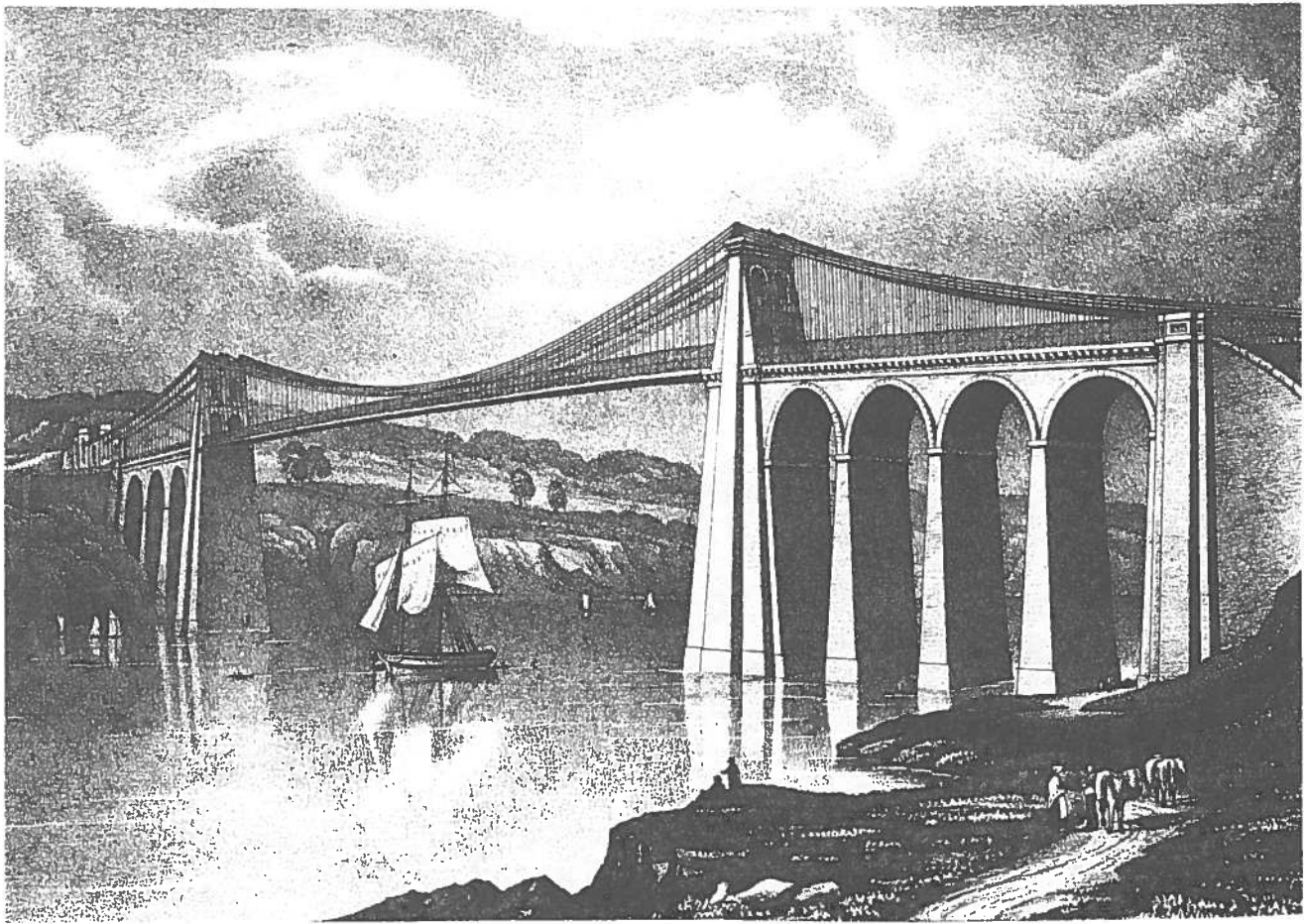


Figure 3 The Menai Bridge taken from a near contemporary lithograph in the collection of the Archives and Museums section of Gwynedd County Council (Archifau ac Amgueddfeydd, Cyngor Sir Gwynedd).

Telford had worked with iron for past projects and in this was closely associated with Hazeldean, the ironmaster, who had cast the trough to carry the Pontcysyllte Aqueduct. This vast iron bath carried the Ellesmere Canal 310 metres (1,007ft) across the river Dee at a height of some 39 metres (127ft). Telford had experimented with cast iron for arched bridges and understood that, while it could take the compressive forces in such a bridge, it was not the material to withstand the tensions inherent in a suspension bridge. The quality of steel available at this time was questionable and the quantities available severely limited. Thus the Menai bridge was built from wrought iron. This is a material which withstands tensile stresses and which could be produced to high standards.

New ideas and innovative technologies - ever the hallmarks of Telford - were employed at the design stage and throughout the building of the bridge. Water tanks were used to gauge the effects of water flow on the piers. A *Bramah* hydraulic press was modified and put to work testing the tensile strength of the wrought iron chains which suspended the bridge deck from the massive stone piers. This latter testing activity was typical of Telford. No-one had attempted to put wrought iron to such a use. Ever the empiricist, Telford decided to modify the recently invented hydrostatic press as the only way to apply the necessary tensile forces to his iron chains to prove that they would carry the required loads.

Joseph Bramah (1748-1840) is worthy of mention in his own right as a further example of the technological intellects that flourished during the 18th and 19th centuries. Bramah was a cabinet-maker from Stainborough. His inventions, or innovations and improvements, amongst many others, included : the hydrostatic press; a security lock; a water closet; fire-engines; a method for printing bank notes with sequential numbers and, to the delight of his fellow Yorkshiremen and now of all CAMRA members, the ubiquitous beer pump.

A further example of Telford's work is shown in Figure 4. This is the elegant yet functional Dean Bridge in Edinburgh. This structure epitomises Telford's sympathetic use of structures within a landscape. It is a quality apparent in all of his work be it a bridge, church or humble cottage of the lock-keeper. Could he have ever envisaged the volume and form of the traffic that now crosses this viaduct? Some words of encouragement to all you wrinklies of the technology education world - the design and building of this bridge was undertaken when he was 75 years of age.

The majority of Telford's Scottish works still stand, with the exception of the bridges at Bonar and Conon and a little known wooden structure at Laggan. It is difficult to think of any locality in Scotland, or for that matter south of the Border, that does not have an example of his work. In many areas there is at least one within easy travelling distance for schools to visit. Of particular interest is his beautiful bridge over the Tay at Dunkeld which currently is being dismantled stone by numbered stone in a major restoration project.

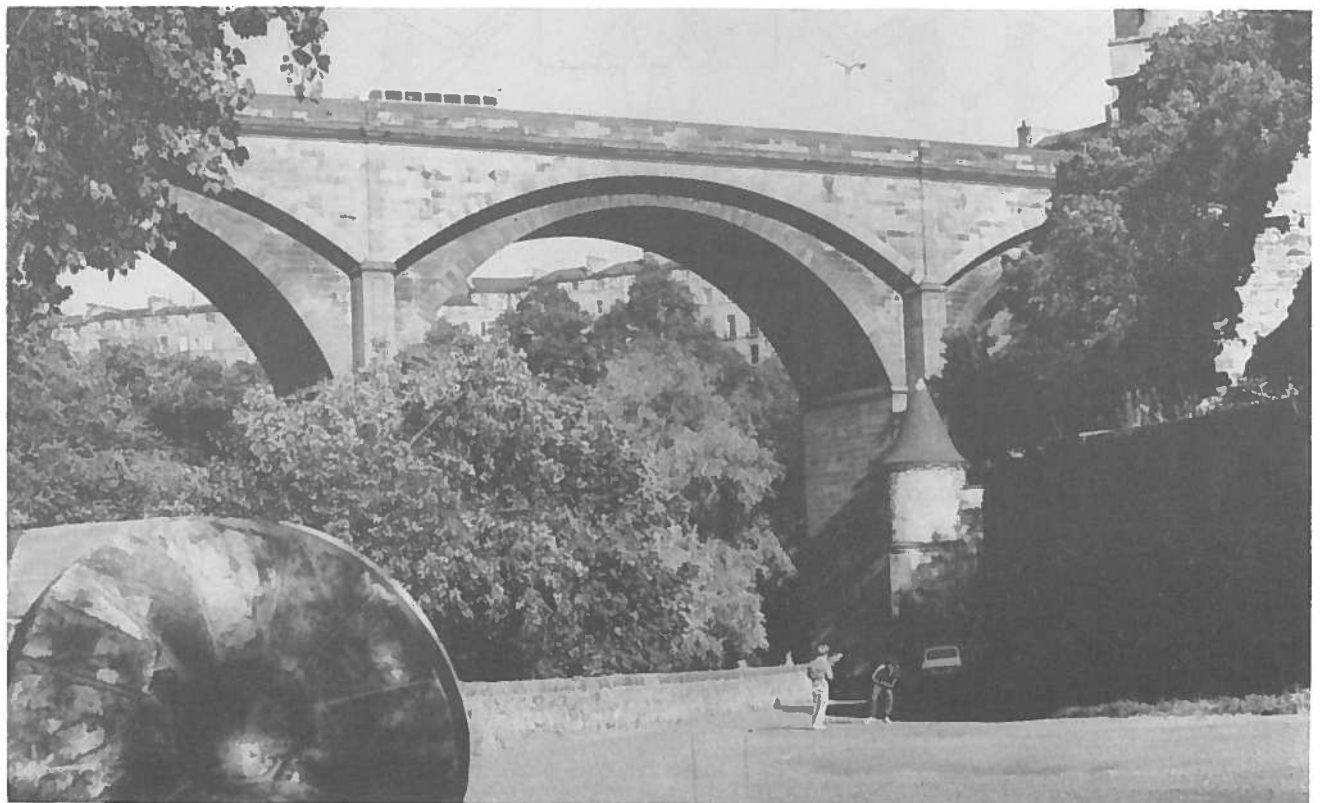


Figure 4 The Dean Bridge which crosses the Water of Leith at the west end of Edinburgh. This was designed and its construction overseen by Telford ca. 1830. (RCAHMS).

Bridging the gap - the Forth Rail Bridge

If I were to pretend that the designing and building of the Forth Bridge was not a source of present and future anxiety to all concerned, no engineer of experience would believe me. Where no precedence exists, the successful engineer is the one who makes the fewest mistakes. The ever modest Benjamin Baker [1].

Benjamin Baker (1840-1907) was the engineer responsible for the design of the Forth Rail Bridge. He started his working life as an apprentice in the ironworks of South Wales. Like many of the engineers of the 19th century, his output was prodigious. It ranged from the London Underground to the Aswan Dam. His lifetime fascination however lay with long span bridges. He even investigated the possibility of a Channel Bridge. He was also responsible for the upgrading of three of Telford's bridges, among them the Menai, battling with the local authorities to keep to the original designs.

There were a number of possible plans and schemes put forward for a bridge over the Forth, ranging from suspension to cantilever. Taking due regard of the overall topography of the site, and in particular a handy little island called Inchgarvie, Baker decided he could put aside earlier ideas for a suspension bridge and instead concentrate on a cantilever structure. A surviving photograph of the period shows how this was demonstrated to the press and public. A line drawing (Figure 5) based on that photograph provides a hint as to how this could be demonstrated in the classroom.

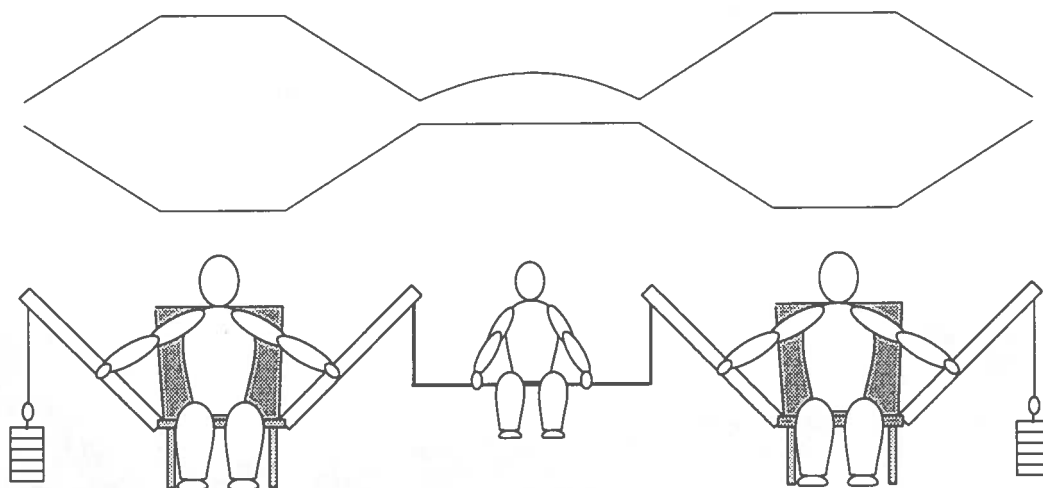


Figure 5 Demonstration of the effectiveness of the cantilever in the design of the Forth Rail Bridge. In the original demonstration the men sat in chairs and the levers held in either hand were pickaxe handles.

The main contractor for the work on the bridge was the Scottish company of William Arrol. An international element during the construction was the help given by a M. Coiseau. He was French and an expert on the use of the pneumatic caissons applied in the construction of the piers on which the base of each cantilever would stand. This involved the building of a stone enclosure sealed at the top into which air was pumped so expelling the sea water. Workmen could then work at the bottom of the caisson excavating the earth to allow the caisson to slowly sink into the foundation. When it was at the correct level, the top was opened and the resulting hollow stone tower filled with concrete. This is a greatly simplified account. Interested readers will find a more detailed description in Westofen's work.

Unlike in the oil boom of the nineteen-seventies and eighties the labour and material used for the bridge were, whenever possible, obtained from within Scotland. All of the whinstone was quarried locally. The sand came from Pettycur and Kinghorn, the rubble from Arbroath and the timber from Grangemouth or other local sawmills. Steel came from Dalziels Iron and Steel Works with some also from Wales, in all 54,000 tons¹.

¹ One titbit for trivial pursuits enthusiasts is the statistic that the Clyde Rivet Company supplied nearly 7 million rivets during the building of this bridge.

As the following sequence of archive pictures demonstrates, the Rail Bridge was a wonder of its age. Its huge superstructure epitomised the brashness, technological arrogance and skills behind so many engineering achievements of the late Victorian period.



Figure 6 Forth Rail Bridge, the part built Queensferry cantilever in December 1886. Note the rivetting cages. (RCAHMS)

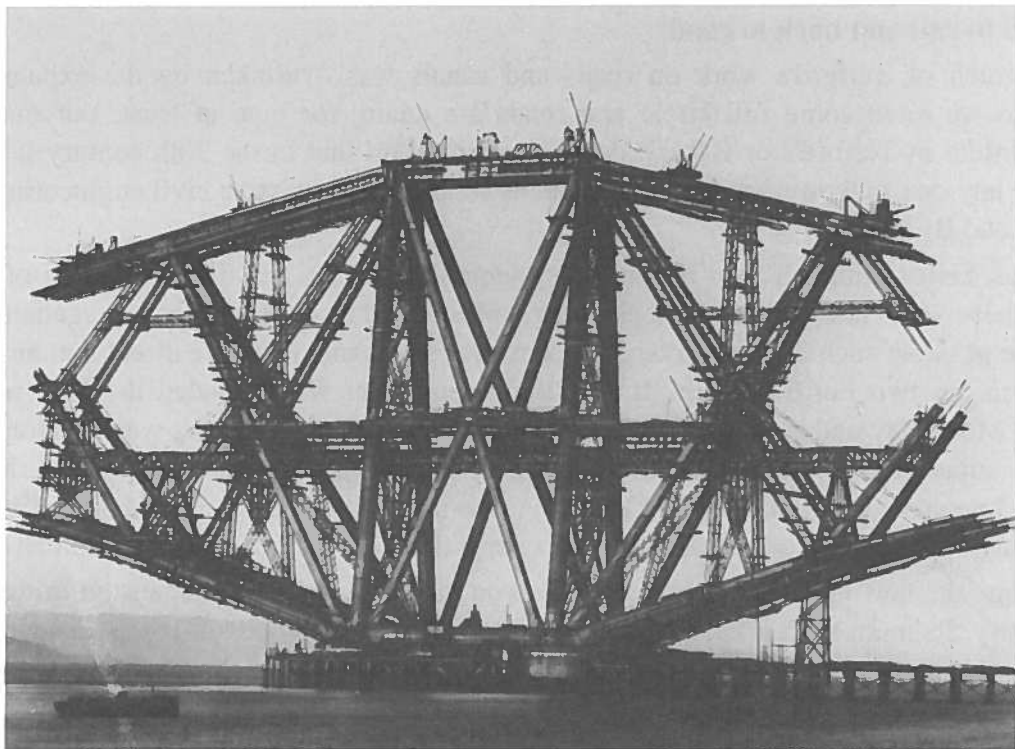


Figure 7 South cantilever of the Forth Rail Bridge - June 1888. (RCAHMS)

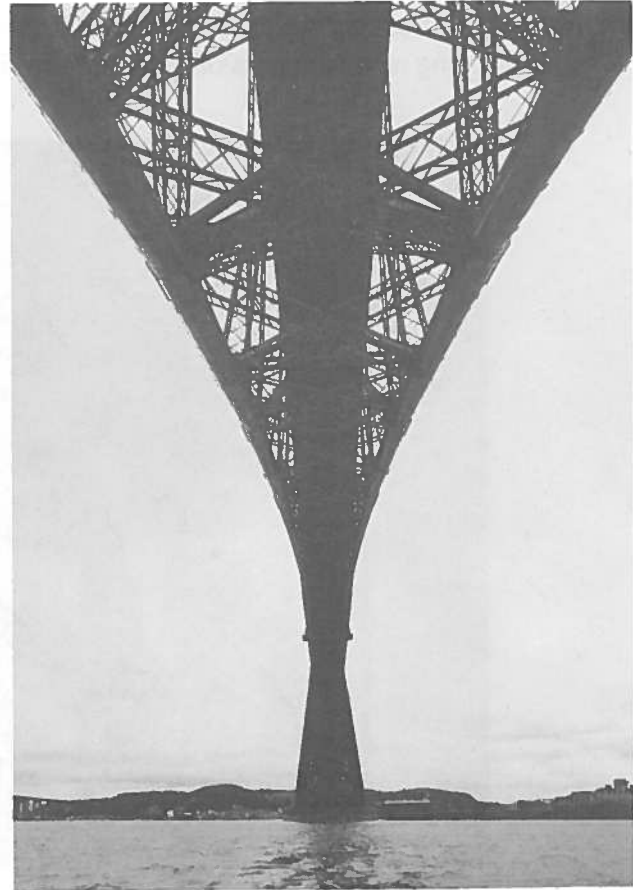
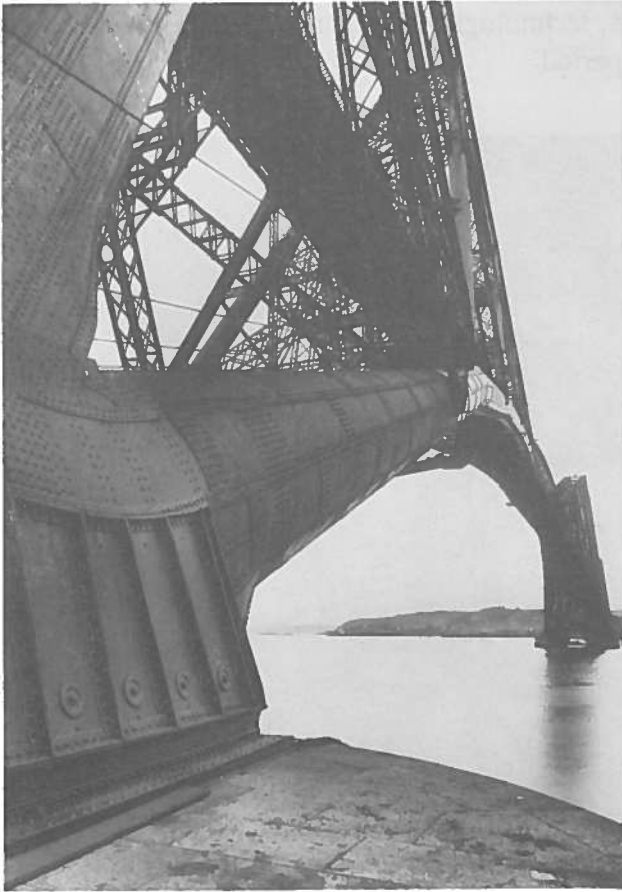


Figure 8 The completed Rail Bridge looking upward from one of the cantilever supports. (RCAHMS)

Figure 9 From directly beneath a cantilever see rear cover for a colour version. (RCAHMS)

From road to rail and back to road

Just as much of Telford's work on roads and canals was overtaken by the expansion of the railways, so we have come full circle and roads are again, for now at least, our main transport arteries. Unlike in Telford's or Baker's days, it would seem that in the 20th century it is no longer feasible for any one individual to have the capacity to undertake massive civil engineering works like the Forth Road Bridge.

Yet it was Telford himself who began the systematic planning and documentation of civil works which, all these years later, have developed into sophisticated tools of project management. It is these which make possible such huge and complex constructions. And, there are direct human connections also between the two Forth Bridges. It was Benjamin Baker who founded the firm of consulting engineers - Mott, Hay and Anderson - who with Freeman, Fox and Partners were responsible for the design and supervised its construction. Erection of the steel superstructure was carried out by a consortium known as the ACD Bridge Company. One member of that consortium was William Arrol and Company - successors to that same William Arrol the main contractor on the Rail Bridge.

At that time the new Forth crossing was carried on the first long-span suspension bridge to be built in this country. Its main span is approximately 1 km or 3,300 ft. Just one of the associated innovative techniques was the use of high tensile steel in building the suspension towers, each of which is some 492ft high. Much of the data on safety and on the stresses in this type of bridge construction was taken from the research carried out after the collapse of the Tacoma Narrows Bridge in the United States. Another example of international co-operation which provides a modern parallel to the French connection and the Rail Bridge.

Endpiece

This article is meant to be more than mere nostalgia, a backward-looking "Here's tae us . . ." piece. It is also, we trust, a useful allegory for the engineering professions and for technology education in our own time.

Telford's actual birthplace was a cottage on the Megget Water, remote even for those days. In the early 1970's Bracegirdle and Miles [2] went to photograph and document this cottage. It was no more. All that marked the site from a distance was an old Ash tree standing in one corner of what little was left of the walls. These in turn were rapidly being encroached upon by a Sitka spruce plantation - the archetypal Scottish lowland rural scene. The cottage at "The Crooks", to which Thomas and his mother were moved after John Telford's death, still stands. Once a typical 18th century Scottish vernacular building, in the nineteen seventies it was *improved* out of all recognition. There are no plaques, no National Trust for Scotland car parks. Would his origins have been better marked had he, like his near contemporary Hogg, stuck to ballads rather than bills of quantity or, like Raeburn, daubed oils and not drafted designs?

As with many scientific and technological disciplines in this post-industrial, post-modern, society of ours, civil engineering is yet again at a crossroads. Everywhere there is controversy over its aims and works. For example, we began working on the ideas for this article well before the stories broke but as we finalise it we have already seen rowing over a proposed second road crossing for the Forth, the alleged neglect by Railtrack of Baker's older bridge - parts of which are supposed not to have had a lick of Craig & Rose's finest red paint for many a long day. And to cap it off we have had M77 happenings in the woods of Pollock¹ and one episode over which even we are far too delicate to pick. Yet, despite any such flippancy, it is obvious even to us that the answers to so many pressing problems - environmental as well as economic - lie within the domain of civil engineering. It's not on the need for further progress that one should argue but rather in what directions real progress might lie. Perhaps an even greater transfusion of both the young and the female into the profession might assist (and we could then have a follow up article with a more politically correct "Persons" title or better still redress the balance with a piece, perhaps, on the "Quines o'pairs").

Telford and Baker believed themselves to be enlightened and progressive people. They served the practical apprenticeships currently not being enjoyed (or endured?) by many of our young. They knew, literally at first hand, the materials with which they worked. Neither attended a University engineering department. Telford had acute moral and ethical sensibilities. He believed in educating and training others to the highest levels of which they might be capable. He believed also in affording workers the dignity which comes with a proper appreciation of their worth. Along with many of his contemporaries he exhibited a paradoxical mixture of marked confidence in his own technical abilities and an equally prominent humility in the face of his achievements.

Telford said, of himself, that he preferred :

. . . to be known for my useful works rather than by the enjoyment of splendid orders.

and of the world of business :

I admire commercial enterprise, it is the vigorous outgrowth of our industrial life: I admire everything that gives it free scope, as, wherever it goes, activity, energy, intelligence - all that we call civilisation - accompany it; but I hold that the aim and end of all ought not to be a mere bag of money, but something far higher and better.

Amen to all of that!

References

1. Westofen, W., 1890, *The Forth Bridge*, the Engineering Magazine, in facsimile as a limited Centenary Edition of 2,500 copies, 1989, Moubray House Publishing Ltd.
2. Bracegirdle, B. & Miles, P.H., 1973, *Great Engineers and their Works : Thomas Telford*, David & Charles,

¹ Another one for trivial pursuits - the name of the engineer in charge of tree cutting on the M77 route was a Mr Pollard.

Portable appliance inspecting

This article provides a checklist of fault conditions to look for when visually inspecting portable electrical apparatus. The need for a maintenance programme to include informal as well as formal inspections is explained.

School apparatus is particularly vulnerable to damage because of two factors - the unusually large amount of handling and carrying to which it is subjected, and abuse by children. Almost all of the faults that occur are noticeable by simple visual inspections. Obscure faults that can only be found by complex test instruments such as the portable appliance tester (PAT tester) are not so common. The main line of protection in any maintenance programme lies with the user checking his or her own apparatus, backed up with regular, routine, visual inspections by competent technician staff.

Whilst most of the article relates to fault conditions that can be picked up by visual inspections, it also describes a few of the simpler tests. However it does not consider complex tests such as earth continuity and insulation testing, which were dealt with in an earlier article [1]. Readers wanting up to date advice on these should enquire direct to the Centre.

The numbered sections of the *Inspection Checklist* have been cross-referenced where possible with the checklist in the HSE Guidance Note GS23 [2] (Table 1). Some new material not found in that useful HSE document has been added to our own list.

User Guide

The prime responsibility to provide and maintain electrical apparatus in a safe condition lies with the employer. It is his duty to set up a routine maintenance programme, this being the recognised means of ensuring that apparatus remains in a safe condition. There are several different schemes in operation. Some authorities ask school technicians to carry out annual tests and inspections. Others use local authority technicians or engineers who visit schools annually. Yet others use outside contractors. Some Regions have had schemes in operation for several years. Others are still working out what to do.

Responsibility for the safe condition of apparatus also lies with teachers and technicians. By virtue of being users of equipment, they have a duty of care towards themselves and others. The user is the most important person in any maintenance programme. He or she plays a vital part in assuring that apparatus remains in a safe condition. It follows that teachers and technicians should informally inspect apparatus before, during and after use.

SSERC Inspection Checklist	HSE GS23 Checklist
1a Mains lead	1 Mains lead
1b Mains plug	
2a Cord inlet at enclosure: detachable cords	2 Either: detachable lead connector or non-detachable lead clamp
2b non-detachable cords	
3 Mains on/off switch	3 Mains on/off switch
	4 Conducting case (tests on Class 1 apparatus)
	5 Insulating case (tests and inspections on Class 2 apparatus)
6 Accessible fuseholders	6 Accessible fuse holders
7 Socket outlets	7 Exposed output connections
8 Enclosure inspection	
9 Lampholders	

Table 1. Cross reference between items in SSERC Inspection Checklist and Checklist in Appendix to HSE Guidance Note GS23.

We regard this informal checking as nothing more than the present good practice of checking apparatus before, during and after use. Nearly always it would amount to a cursory examination that need take no more than a fleeting moment. It certainly need not be onerous.

This article is then basically a users' guide on what to look out for. Its function is to inform. It describes the fault conditions commonly found and provides guidance on discriminating between safe and unsafe conditions.

Some authorities expect technicians to make formal, routine inspections every term. This guide provides them with the information needed to undertake that task.

The frequency of tests and inspections is a matter for the employer to decide upon. Our own suggestions are shown opposite (Table 2). The frequency of testing should be reviewed in the light of experience gained.

The *Inspection Checklist* starts overleaf (page 12). Please also note that there is a concluding shortform checklist for users (Table 3, page 19).

Equipment type and environment	Informal inspection by user	Formal inspection	Combined inspection and testing
Extra low voltage: (less than 50 volts a.c.) e.g. telephone equipment, computer keyboards, mice	Not required	Not required	Not required
Class 1 portable apparatus used in classrooms	Before and after usage	Yes, required every term	Yes, annually
Class 1 information technology and business equipment used in classrooms (rarely moved)	Weekly or monthly	Yes, required every term	Yes, annually
Class 1 portable apparatus used in office or staff areas: (hand held or often moved) e.g. electric kettles, floor cleaners, some heaters	Before and after usage	Yes, required 6 - 12 months	Yes, 1 - 2 years
Class 1 portable apparatus used in office or staff areas: (rarely moved) e.g. photocopiers, desktop computers, VDU screens	Not required	Yes, 2 - 4 years	Yes, required at least every 5 years
Class 2 portable apparatus used in classrooms	Before and after usage	Yes, required every term	Only test insulation if its integrity suspect
Class 2 information technology and business equipment used in classrooms (rarely moved)	Weekly or monthly	Yes, required every term	Only test insulation if its integrity suspect
Class 2 portable apparatus used in office or staff areas: (hand held or often moved) e.g. some floor cleaners	Before and after usage	Yes, required 6 - 12 months	Not required
Class 2 portable apparatus used in office or staff areas: (rarely moved) e.g. desk lamps, desktop computers, VDU screens	Not required	Yes, 2 - 4 years	Not required
Detachable flexible cords and plugs, extension leads (used in classrooms)	Before and after usage	Yes, required every term	Yes, annually
Detachable flexible cords and plugs, extension leads (used in office or staff areas)	Before and after usage	Yes, required 6 months to 4 years	Yes, 1 - 5 years depending on type of equipment it is connected to

Table 2. Suggested initial inspection and test frequency of portable electrical apparatus in schools.

CHECKLIST FOR INSPECTING PORTABLE APPLIANCES

Item 1a : Mains lead

Cable type : Check that the flexible cord to Class 1 apparatus is 3-core and to Class 2 apparatus is 2-core.

PVC insulated cord is not suitable for heating appliances where there is risk of contact with hot parts or a risk of significant radiation.

Cord only with silicone rubber insulation should be used on soldering irons [3, 4, 5].

Current rating : In general, the current rating of flexible cord should comply with this scheme below :

Nominal cross-sectional area (mm ²)	Maximum current (A)	Maximum power of appliance (230 V supply) (W)
0.5	3	690
0.75	6	1380
1.0	10	2300
1.25	13	3000

These maximum continuous current ratings apply to the majority of appliances with flexible cords. However if a long length is used, then use cord with a larger cross-sectional area than indicated in the table. In particular, never fit 0.5 mm² cord of length exceeding 2 metres. Use 0.75 mm², or even 1.0 mm², depending on the likelihood of trailing leads that might be walked upon, the likelihood that some of the cord remains coiled in use and for very long lengths greatly exceeding 2 metres.

Colours of internal insulation : When fitting cord to portable mains appliances, the conductors must be colour coded :

	Class 1	Class 2
Live	Brown	Brown
Neutral	Blue	Blue
Earth	Green/yellow	-

Some very old apparatus may be fitted with cord having the old colour code (red for Live; black for Neutral; green for Earth). You do not have to replace old-coloured cord to conform to the present colour coding. However should you have to replace cord for other reasons then you must use cord with brown, blue and green/yellow colourings.

Some low voltage appliances such as ray boxes and model houses are wired with 2-core cord coloured brown and blue. This is dangerous because people have mistakenly fitted 13 A plugs to cords so coloured and applied 240 V across, say, a 12 V lamp [6]. Any such apparatus should

be rewired with, for instance, 2 lengths of 16/0.2 mm wire twisted by hand and fitted with 4 mm plugs.

Two layers of insulation : Flexible cord to mains appliances at 230 V or 240 V, or at 110 V, must have two intact layers of insulation. Fail any cord that does not meet this condition.

(Technically, the insulation of single phase supplies to portable appliances must have a voltage rating of at least 300/300 V. These values mean that the cable's insulation will withstand a voltage of 300 V a.c. r.m.s. between phase live and earth and 300 V a.c. r.m.s. between phase live and neutral.)

An exception to this rule is flex to Xmas tree lights. One layer of insulation on Xmas tree light flex is permissible provided that the lighting set is known to comply with BS 4647, is used indoors for decoration as a temporary installation, and is not used for laboratory benchwork.

No damage : Inspect flexible cord for damage. If cord is damaged near an end, it may be possible to cut off the damaged portion and continue to use the remainder. Otherwise damaged cord should be disposed of and replaced with cord of a specification suitable for the purpose.

The following list indicates types of damage to look for :

- **Cuts in the insulation :** A cut in either the outer or inner insulation, or in both layers, must be classed as a failure. Cuts should never be taped over except in exceptional cases as a very short term expediency. In such cases the apparatus must be withdrawn from use forthwith thereafter and the cord replaced.
- **Heat damage in the insulation :** Heat damage can be from an external source, such as from the hot tip of a soldering iron, or from internal self-heating due to underrated cabling or shorting. Flexible cord known or thought to be so damaged must be replaced.
- **Damage due to excess tension :** If cord has been tensioned severely, the electrical conductors can be grossly drawn out to such an extent that they sever and go open-circuit. Even if some strands remain intact, at this point of weakness there can be significant resistive heating which causes further damage. Similarly the insulation may be drawn out and become electrically weakened. Flexible cord known or thought to be so damaged should be replaced. Appliances particularly at risk include cleaning equipment, portable tools, stage lighting and extension leads.
- **Damage due to compression :** If a severe load is placed on flexible cord, it can be damaged by compression. This can sever or short circuit electrical conductors and weaken or render ineffective insulation. Flexible cord known or thought to be so

damaged should be replaced. Appliances particularly at risk include heavy stationary equipment and extension leads. The latter are vulnerable to damage by heavy stage sets.

- **Damage due to bending :** If flexible cord is forced into a tight bend, tension gashes can occur in the insulation. Remove the damaged section of the cable.
- **Damage due to excess manipulation :** Repeated flexing can work harden the metal conductors and insulated sleeving. This can either cause the flexible cord to become brittle, which may result in it snapping in two, or it can cause the internal conductors to twist relative to each other giving the appearance of knots or gnarls in the cord. This first fault type usually occurs beside the cord grip bush on the appliance enclosure. The second type can affect extension leads, or extra-long leads on outdoor equipment or workshop tools.
- **Damage due to daylight :** Ultraviolet radiation in sunlight embrittles PVC. This cause alone can account for cable failures. Also it can exacerbate either of the above two problems.
- **Chemical damage :** Chemical reactions take place between rubber and PVC, rubber and polystyrene, and PVC and polystyrene, causing solid materials to become goeey. These reactions can occur where the cord goes through a grommet, or at a strain relief bush. If the damage is severe the cord and other part should both be replaced.

Item 1b : Mains plug, 13 A type

External inspection of plug : Check the exterior of the plug for the following :

- **Damaged enclosure :** If the plug enclosure is cracked, chipped or broken, then the plug should be disposed of and replaced.
- **Fitment of plugtop :** This must fit snugly and securely to the base part of the enclosure. It should be impossible to rock the plugtop relative to the base. There should not be a gap between the two parts. The screw fitting the two parts together must be secure. Defective plugs should be disposed of and replaced.

Internal inspection of plug : Open the plug and check the following :

- **Correct polarity :** Check that the brown conductor is connected to the Live terminal, the blue conductor is connected to the Neutral terminal and the green/yellow conductor is connected to the Earth terminal.
- **Connections secure :** Screw connections often naturally work loose. With a screwdriver, check that the connections are tight.

(We are sometimes asked whether a conductor should be folded over before insertion into the hole of a pillar terminal, where it is clamped under the pressure of a screw. Conductors in 3 A and 6 A cable

should be folded. With 10 A cable the decision is optional whereas in 13 A cable conductors should not be folded back because there would be too great a bulk.)

(Tinning conductors does not seem to be advisable. Often the wire at the edge of the tinned section weakens, possibly by work hardening.)

- **Clockwise rotation :** Check that wire is wrapped in a clockwise sense round screw terminal posts.
- **No frayed or stray copper strands :** Carefully look for loose or stray strands of copper wire. To put right this fault condition, either undo the terminal, tidy the strands and remake the connection, or undo all the connections, cut back all the conductors and rewire the plug neatly.
- **Damaged strands :** Check that all the copper strands are intact. If some have been broken, unwire the plug, cut off the damaged wire and rewire the plug.
- **Damaged insulation :** Check that the insulation around the wires is sound. Possible causes of damage include compression between internal plug compartments, heat damage, carbonisation, ageing and cutting. If faulty, remove the damaged part and rewire the plug.
- **Insufficient insulation :** Check that the internal conductors are all protected by insulation to within 3 mm of the terminal pins. If faulty, rewire the plug.
- **Cord grip :** Check that the outer insulation is adequately held by the cord grip. There should be no significant movement or twisting of the flexible cord with respect to the plug. There must be at least 5 mm of outer insulation protruding on the plug side of the cord grip. (It is difficult to give an exact minimum value because it depends on the type of cord and on the type of plug.)

The conductors between the cord grip and the terminal pins must not be stretched tight under tension, but should be loose. The protective earth conductor should have a greater amount of slack than either the Live or Neutral conductors so that in the event of the cord grip failing the last connection to be under stress is the protective earth.

If the cord grip is broken or defective, replace it, or dispose of and replace the whole plug.

- **Fuse rating :** Check that the fuse has the appropriate rating. We recommend that if the power rating is less than 690 W, the plug should be fitted with a 3 A fuse unless the appliance has a large inductive load that causes nuisance fusing on switching, in which case you should use a 5 A fuse. For power ratings of 690 W and over, fit a 13 A fuse.

On a point of law, manufacturers and suppliers are not obliged to fit 3 A fuses to plugs on low power apparatus. However it is always worth making a fuss and objecting when you buy low power equipment fitted with a 13 A fuse in the plug.

- **Damaged fuse holder :** Check that the fuse sits securely in the fuseholder. If insecure, resistive heating can damage the plug. The only remedy may be the disposal of the plug and its complete replacement.
- **Heat damage :** Check for signs of heat damage. Resistive heating occurs when connections are loose or corroded. It can occur on the terminal pins, at wire connections and at the fuse holder. It can cause carbonisation. This covers surfaces with an electrically conducting film of carbon. It is highly dangerous. When a carbonised film forms the only remedy is disposal and replacement of the plug.
- **Chemical corrosion :** This sometimes occurs on the fuse and fuseholder. It may be caused by a mismatch of metals, or by a metal-air reaction. The effect sometimes causes metal parts to get a coating of a black powder. If this happens, the affected parts should be carefully wiped clean with a tissue. It is not generally necessary to dispose of a plug so affected, but in some instances is.

Fitted plugs on new appliances : Finally it should be noted that under new Government regulations all portable electrical equipment at 230 V intended for domestic use must be fitted with 13 A plugs by the manufacturer as from 1st February 1995. Suppliers other than manufacturers of electrical equipment have until 1st February 1996 to comply with this requirement.

Item 2a : Cord inlet at enclosure : detachable cords

Many portable appliances have detachable cords. The coupling between the detachable cord and appliance should conform to the standard IEC 320 (related derivative standards include EN 60 320, CEE 22 and BS 4491). On Class 1 apparatus the live connector at the end of the flexible cord must be a shrouded 3-way socket outlet. This mates with a 3-pin chassis plug.

The IEC socket is moulded to the flexible cord. The connection is permanent and seems to be very reliable.

The IEC chassis plug should be fitted to the chassis through a precisely made cut-out. There are two types of IEC chassis plug fitment. The screw type seems to be very reliable, but there is always the possibility that screws may come undone - perhaps from vandalism. The snap-in type relies on quality control. It has been our experience that some snap-in fittings are removable with finger pressure. In the event of finding one which can be removed like this, you may have to substitute a plug that is secured by machine screws and nuts.

Detachables with non-IEC connectors are a menace. The old Bulgin connectors have two defects. For one, the Bulgin socket outlet is openable by hand without the aid of tools. For another, the cord grip is deficient and unreliable. The electrical connections in Bulgin socket outlets usually provide the sole protection against tension

in the cord. This type of connector is dangerous and must be disposed of. You should either replace with an IEC connector, or connect a non-detachable cord to the apparatus.

Another specific problem [7] relates to a modern Bulgin connector which, in some apparatus, is a socket outlet for supplying mains voltage to the apparatus, and in other applications is a socket inlet for supplying low voltage to appliances. Some versions of Radford Labpacks and equipment made by Eduequip use the 240 V application. Many solder stations use the other application to supply 24 V from the isolating transformer to the iron. Because it would be highly dangerous to mix the two applications, we recommend that all apparatus using this connector to supply mains voltage be modified. The Bulgin connector should be replaced with either an IEC connector or with a non-detachable cord.

The following inspection and tests should be carried out on the connectors for detachable leads :

- Check that the connectors are of the IEC 320 type. If they are not either replace with this type, or fix a non-detachable cord, or ensure that all the following tests are met.
- Attempt to open the socket outlet by hand. It should not be openable.
- Attempt to pull the cord from the socket outlet with moderate force. There should be no significant movement.
- Attempt to rotate the cord with respect to the socket outlet with moderate force. There should be no significant rotation.
- Attempt to remove the chassis plug from the apparatus enclosure without the aid of tools. It should not be removable.

Item 2b : Cord inlet at enclosure : non-detachable cords

The inspection must check that there is adequate strain relief at the point where the non-detachable cord enters the enclosure. It must also look for signs of damage to either the cord or bush.

At the initial inspection, check that the cable clamping and protection does not rely solely on a grommet and knot in the cable. Much old apparatus was so protected - and designed as such. If you find this arrangement, then it should be upgraded with something more satisfactory.

The following devices can be satisfactory depending on the nature of the apparatus, cord and application :

- IEC connectors and detachable cord;
- Strain Relief Bush (RS 543-866, etc.);
- Cord Grip Bush (RS 607-897, etc.);
- Conclamp (RS 390-022, etc.);
- Glass-Filled Nylon Cable Gland (RS 614-025, etc.);
- Nylon Cable Gland (RS 544-011, etc.);
- Nylon A2P IP66 Cable Gland (RS 381-517, etc.).

The following inspection and tests should be carried out on the cord entry system :

- Check that the cord insulation is intact and not showing signs of perishing or becoming brittle.
- Exert a sharp pull on the cord. There should be no significant movement.
- Attempt to rotate the cord at the cord grip bush. There should be no significant turning.

Item 3 : Mains on/off switch

The points to look for are the following :

- The switch is undamaged and operates.
- The switch cannot readily be dismantled by hand or by a simple implement.
- The switch cannot be removed without the aid of tools.
- The switch cannot be rotated.
- If the switch has external metal parts, then these should be bonded to the protective earth conductor. This should be checked in an earth continuity test.

With respect to the fourth point, it should be noted that any electrical fitment which has a circular cross-section should have an anti-rotation mechanism. These mechanisms may either be a key and spigot, or a flat in the cross-section. The inspection is a test that the anti-rotation mechanism is in place and continues to be effective. If fitting a switch or fuseholder, do not ignore or override the anti-rotation mechanism [8].

It is common to find double-pole switching with the switch operating both the Live and Neutral conductors.

Item 4 : Tests on Class 1 apparatus

Notes on testing for earth continuity and insulation resistance can be found in Bulletin 170 : *Portable Appliance Testers*. Further advice can be obtained from the Centre.

Item 5 : Tests on Class 2 apparatus

Notes on testing for insulation strength can be found in Bulletin 170 : *Portable Appliance Testers*. Further advice can be obtained from the Centre.

Item 6 : Accessible fuseholders

This relates to accessible, panel-mounting fuseholders which protect hazardous live conductors. Fuseholders protecting extra low voltage conductors on the secondary side of the isolating transformer do not need to be tested.

The points to look for are the following :

- Check that the fuseholder is undamaged.
- Check that the fuseholder is firmly attached to the enclosure and cannot be pulled out.
- Check that the fuseholder cannot be rotated with respect to the enclosure [8]. (Refer back to the point made about anti-rotation mechanisms in switches.)
- Check that the fuse-carrier cannot be released and removed by hand and that removal requires the use of a tool. The release of the fuse-carrier by a very simple tool such as a screwdriver, knife or coin is acceptable.
- Remove the fuse and confirm that the current rating and fuse type complies with the manufacturer's specification.
High breaking capacity (HBC) fuses are preferable to low breaking capacity (LBC) fuses on mains equipment. HBC types include Ultra-Rapid (FF), Quick-Acting (F) and Anti-Surge (T).
- The Live conductor should be connected to the rear terminal on the fuseholder; the load side of the apparatus should be connected to the side terminal so as to connect with the front of the fuse. Fuseholders wired with the incorrect polarity are dangerous [8]. The person removing the fuse from such a fuseholder can get an electric shock if the appliance is not unplugged.

The fuseholder wiring polarity should be tested at the first annual inspection. Before doing this test, the apparatus must be dead - i.e. disconnected from the mains supply. By using a multimeter, check for continuity between the rear terminal (Fig. 1) on the fuseholder and the Live pin on the 13 A plug.

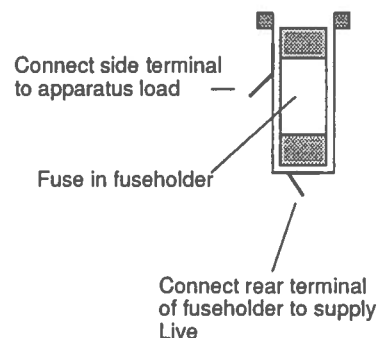


Figure 1. Fuseholder polarity.

It should also be noted that the fuse must be on the Live conductor. If a fuse is being added to equipment it is preferable to site it as the first component after the supply inlet. If there is also a switch, then the fuse should be sited between the supply and the switch so as to protect the switch.

Item 7 : Output connections

This inspection and test sequence relates to socket outlets on laboratory supplies and to the nature of the electrical supplies that they deliver.

Visual inspection : As well as checking that socket outlets are undamaged and secure, also check that they are captive, i.e. the socket is blanked off at its rear so that a wire probe inserted into the socket cannot enter the interior of the enclosure.

Certain manufacturers of laboratory apparatus used non-captive 4 mm sockets in the past. If you come across any, the enclosure has to be opened and the risk assessed. (Before doing this, ensure that the apparatus is dead by unplugging it from the mains.) In general, if a wire probe of length 10 cm can touch any uninsulated conductor at hazardous live, then the test is a fail and the socket should be replaced.

Where replacement is difficult, it may be easier to fit a metal plate inside the enclosure that blocks off the backs of non-captive 4 mm sockets. Any such metal screen must be bonded to the protective earth conductor.

Hazardous live : A small proportion of laboratory equipment has socket outlets at hazardous live. That is to say a person touching the outlet, or a wire connected to it, could get a harmful electric shock.

The definition of *hazardous live* depends on three factors - voltage, current and capacitance [9]. In general, values above the voltage, current and capacitance levels quoted below are deemed to be hazardous live :

- **Voltage levels :**

AC	30 V r.m.s. and 42.4 V peak
DC	60 V d.c. ripple free
	For unsmoothed DC, apply AC level
- **Current levels :** If the voltage exceeds one of the above values, the current levels are :

AC	0.5 mA r.m.s.
DC	2 mA ripple free
	For unsmoothed DC, apply AC level
- **Capacitance levels :** If the voltage exceeds one of the above values, the capacitance levels are :

	45 μ C charge for voltages up to 15 kV peak or DC
	350 mJ stored energy for voltages above 15 kV peak or DC

The above values relate to indoor dry conditions. Lower values [10] for hazardous live should be used for adverse environmental conditions. For instance in wet conditions the resistance of the skin and the conducting path between skin and earth are reduced. The voltage limits for steady-state voltage should be modified to :

AC	16 V r.m.s.
DC	35 V d.c. ripple free

Lower still values would pertain for immersed conditions. The use of shrouded plugs is advisable when working with hazardous live. Typically educational apparatus has not

been fitted with 4 mm sockets with shrouded contacts that are compatible with shrouded plugs and leads. In some instances it may be advisable to adapt such apparatus with suitable sockets.

Shrouded 4 mm sockets in a range of colours are stocked by RS (404-137, etc.). Compatible shrouded plugs are also stocked (446-838, etc.), as are test leads (404-345, etc.). This system of connectors has a working voltage of 1000 V r.m.s.

HT supplies : HT laboratory supplies have DC outlets exceeding the voltage limit of 60 V d.c. The maximum voltage from these units may lie between 150 V and 300 V depending on type. They are not current limited. An output current of 100 mA may typically be drawn. Therefore the output is hazardous.

HT supplies must be marked "*Not for use by pupils*", or in words to that effect.

HT supplies may be used by senior pupils in S5 or S6 provided that the teacher is technically competent, and provided that the pupil has had appropriate oral and written instruction on safe working procedures and is closely supervised. The working area beside the HT supply must bear a prominent sign marked "*DANGER - Hazardous live*", or in words to that effect.

HT supplies should have outlet terminals that accept shrouded 4 mm plugs. Such supplies may have to be adapted [11].

Hybrid power supplies with HT and LT outlets are particularly dangerous because if the user is working on a low voltage circuit then he or she is lulled into a false sense of security. Several accidents have occurred [12] when such users have mistakenly connected to the HT outlets. With any such hybrid supply that might be used by pupils, the HT outlet must be permanently rendered dead by removing internal leads between the transformer and socket terminals.

EHT supplies : These have a variable voltage output with a maximum value of 5000 V (or 5 kV). The outputs are current limited by internal resistors to the Nuffield specification of 5 mA d.c. This value is higher than the 2 mA d.c. hazardous live limit specified above. However even an EHT shock current of 5 mA d.c. is unlikely to have harmful physiological effects. EHT supplies are therefore effectively safe if they comply with this design standard.

At the annual maintenance inspection, the current limitation on EHT supplies should be tested. This is done by measuring the maximum short circuit current. The test meter should preferably be an analogue d.c. milliammeter with a range of 0-5 mA or 0-10 mA. However you may use a digital multimeter, but take care to set it to measure the appropriate current value. On most multimeters, the appropriate current scale would be 20 mA d.c. This should be set before the multimeter is connected into the circuit. Also take care that you connect to the appropriate terminals on the meter. On a multimeter, the terminals would be "*I*" and "*COMMON*".

The procedure for testing the short circuit current of an EHT supply is as follows :

- Ensure that the EHT supply is dead by checking that it is unplugged from the 13 A mains socket outlet.
- Choose the ammeter as described above. If using a multimeter, set the switch selectors to measure on the DC current range of 20 mA.
- Using two 4 mm leads, connect the ammeter across the EHT outlets so as to short circuit the supply.
- Ensure that the variable voltage selector on the EHT supply is set to its minimum voltage setting.
- Plug in the EHT supply to the 13 A mains socket outlet and switch on the supply.
- Turn the variable voltage selector to its maximum setting of 5 kV.
- Read the ammeter. A pass is a value not exceeding 5 mA.
- Turn the voltage selector to its minimum setting.
- Switch off the EHT supply and disconnect the 13 A plug from the mains socket outlet.
- Disconnect the leads from the EHT supply to the ammeter.

In the event of a fail, the unit must be withdrawn from use and the fault investigated by a competent person. Please contact SSERC in the event of registering a fail.

Note that shrouded connectors are not generally required with EHT supplies because the electrical system is not hazardous live. However the addition of capacitance to such a system would increase the risk of shock. This would require a special risk assessment.

Variac transformers : This is a variable voltage transformer with a rotary switch. The output from the secondary winding may have a range of 0-250 V a.c., or 0-300 V a.c., depending on type. The outlet terminals are often 4 mm sockets.

This apparatus is unquestionably hazardous. There are two measures which the employer might take, listed in order of preference :

- Dispose of.
- House in an appropriate enclosure to Class 1 classification and designed to EN 61010-1 standard. The electrical outlet should be through a 13 A socket outlet to BS 1363 specification.

Demountable transformer : Because these can generate an electric output at hazardous live, the kit should be clearly marked "*Not for use by pupils*".

Note here that some early versions have hazardous connectors to the 240 V primary winding. Some versions have detachable cords fitted with a 13 A plug at one end and a pair of 4 mm plugs at the other end. Any such apparatus must be withdrawn from use and disposed of or modified to a safe construction [13].

HT transmission line : Designs which generate a voltage at hazardous live must be enclosed so that persons cannot

come into accidental contact with dangerous conductors. A safe design at voltages not exceeding 25 V a.c. r.m.s. was published in Bulletin 158 [14]. This is the preferred method.

Item 8 : Enclosure inspection

Loss of integrity : The enclosure should be inspected for loss of integrity. The following list indicates points to look for :

- Cracks and breakages.
- Weakness of panels or structural defects.
- Loose fitment.
- Loose or missing screws.
- Missing parts.
- Openable parts.
- Heat damage.

If repairs cannot be carried out, the apparatus may have to be disposed of. Damage caused by internal heating should be investigated by a competent person.

Apertures : The principle to apply is that there shall be no uninsulated conductors at hazardous live within the enclosure which are readily accessible through the apertures.

This should be qualified by the use to which the apparatus is put. For instance apparatus that is used by the complete range of pupils in S1 to S4 courses needs to be better protected than apparatus that is used exclusively in S5 and S6 courses. It also depends on historical precedent. If there is a record of vandalism and wanton abuse of apparatus, then more stringent standards should be imposed than in other places where these occurrences don't happen.

The general test of apparatus to be used by any pupil in S1 to S4, or in Primary, makes use of a 1 mm diameter straight wire rod 10 cm long. The test is applied to apparatus that is dead, i.e. disconnected from the mains. If the test probe can be inserted through an aperture and touch a conductor at hazardous live, then the test is a fail.

The following qualifying remarks about the test should be heeded :

- Internal conductors and connections that are covered by insulation such as sleeving, boots, etc., are unlikely to be hazardous.
- Where apparatus is used for electronic construction exercises with pupils who have an incidence of misbehaviour, then a higher test standard should be imposed. We suggest replacing the straight wire probe with a flexible wire probe of 1/0.6 mm wire of 10 cm length. If such a probe can be inserted in any direction and touch a conductor at hazardous live, then the test result is a fail.
- Where apparatus is used with senior or academic pupils who have no incidence of apparatus abuse, then a less stringent test may be appropriate. For instance it would be reasonably safe for such pupils

to work with oscilloscopes that have circular ventilation apertures of diameter not exceeding 4 mm.

- In general the maximum width of a slotted aperture is 4 mm.
- In general the maximum diameter of a circular aperture is 4 mm.
- Larger sized apertures are permissible provided that uninsulated conductors are inaccessible. Apply the general principle if in doubt.

Wet conditions : If apparatus is to be used in wet conditions such as habitually beside a sink, in a pond, greenhouse or aquarium, then the enclosure should have the appropriate IP rating. The second numeral after the letters "IP" denotes the category :

IPX0	non-protected
IPX1	vertically dripping
IPX2	dripping (15° tilted)
IPX3	spraying
IPX4	splashing
IPX5	jetting
IPX6	powerful jetting
IPX7	temporary immersion
IPX8	continuous immersion

Radiant heaters : Because of the inherent vulnerability of their design, radiant heaters operating at 230 V are no longer permitted in schools [15]. They must be disposed of.

A suitable low voltage substitute is available from Harris (Q44200/9). It draws 8 A at 12 V.

Cleanliness : The enclosures and flexible cords of apparatus should be kept in a clean state. Deposits of dirt, dust, swarf, grease or oil should be wiped off.

In particular, take care to keep machine tools clean. The ingress of foreign matter inside the enclosure is a possibility. The enclosures on some models of machine tool do not completely prevent dust or swarf from entering. Once this fault condition has been recognised, the enclosure should be opened routinely and cleaned out.

Another eventuality to watch for is the abuse by children wherein foreign objects are inserted through apertures.

Homebuilt apparatus : Homebuilt electrical apparatus must comply with the same tests that you would apply to commercially built apparatus.

Item 9 : Lampholders

Edison screw (ES) lampholders : There are two points to note about ES lampholders [16, 17] at hazardous live voltages :

- The polarity of wiring matters! It is vital that the Live conductor is bonded to the terminal at the base of the lampholder. The Neutral conductor is bonded to the side terminal on the screw thread.

- The standard BS EN 60238 to which ES lampholders are nowadays manufactured is far safer than that used originally. Under the present design, lamp caps are not accessible when they become live during insertion. This ensures that the thread on the lamp only makes contact with the Neutral conductor when very nearly screwed fully in.

The first point must be tested for - a once and for all test usually being all that is necessary. The lamp must be dead when tested, i.e. disconnected from the mains. Test for continuity using a multimeter between the Live pin on the 13 A plug and the central lampholder terminal in the base of the lampholder.

Testing ES lampholders that supply Philips spectral lamps through autotransformers poses special problems [18]. There should be direct continuity between the Neutral pin on the 13 A plug and the Neutral terminal on the ES lampholder. The resistance of this path should be less than 1.0 Ω. However the conducting path between the Live pins on the 13 A plug and the ES lampholder is routed through part of the autotransformer winding and has a resistance of about 10 Ω. The method of testing is described in Bulletin 164. As with the other tests, it is carried out with the apparatus dead and disconnected from the mains supply.

With respect to sub-standard ES lampholders (i.e. the original type with a continuous thread on the neutral terminal) it would be prudent to replace either the lampholder or the entire lamp with a modern substitute.

Bayonet cap (BC) lampholders : Any batten BC lampholder, or any other BC lampholder permitting easy access, at hazardous live, should be replaced with a Safety Lampholder made by Crabtree [19]. These are now widely available in DIY stores and are stocked by many suppliers including RS Components :

Safety Pendant Lampholder	5850	RS 566-465
Safety Batten Lampholder	5851	RS 566-471

Strain relief : The attachment of the flexible cord to the lampholder must have adequate strain relief. On many modern lampholders this consists of a plastic bush that attaches by a screw thread to the lampholder and is secured to the cord by pressure exerted by a screw. This plastic bush tends to work loose over a period of several months. It should be routinely inspected and, as necessary, retightened.

Lampholder tests : The following inspection and tests should be carried out on lampholders :

- Check that the parts of the lampholder are securely screwed together.
- Attempt to pull the cord from the lampholder with slight to moderate force. There should be no significant movement.
- Attempt to rotate the cord with respect to the lampholder with slight to moderate force. There should be no significant rotation.

References

1. *Portable appliance testers*, Bulletin 170, SSERC, June 1991, pp 14-22.
2. Guidance Note GS23 *Electrical safety in schools (Electricity at Work Regulations 1989)*, Health and Safety Executive, 1990.
3. *Soldering - what precautions to take*, Bulletin 163, SSERC, September 1989, pp 5-7.
4. *Flexible cords - special types*, Bulletin 164, SSERC, December 1989, pp 4-5.
5. *Rewiring soldering irons*, Bulletin 166, SSERC, June 1990, p 9.
6. Safety Note warning against fitting mains type flexible cord to extra low voltage apparatus, Bulletin 151, SSERC, May 1986, p 4.
7. *Ambiguous connectors: 3-pin Bulgins*, Bulletin 176, SSERC, March 1993, pp 7-8.
8. *Electrical safety problems, Radford Labpack accident report*, Bulletin 176, SSERC, March 1993, pp 6-7.
9. *Preventing electric shock*, Bulletin 173, SSERC, April 1992, pp 5-13.
10. IEC 1201 : 1992 *Extra-low voltage (ELV) - Limit values*.
11. *Microwave apparatus - HT hazard*, Bulletin 164, SSERC, December 1989, p 7.
12. *Electrical accident report*, Bulletin 172, SSERC, January 1992, pp 5-7.
13. *Demountable transformer*, Bulletin 173, SSERC, April 1992, pp 3-4.
14. *HT transmission lines*, Bulletin 158, SSERC, October 1987, pp 17-18.
15. *Radiant heaters*, Bulletin 173, SSERC, April 1992, p 4.
16. *ES fittings - spectrum lamps*, Bulletin 162, SSERC, April 1989, p 7.
17. *Edison screw (ES) lampholder*, Bulletin 164, SSERC, December 1989, p 6.
18. *Philips spectral lamps - polarity checks*, Bulletin 164, SSERC, December 1989, pp 5-6.
19. *Bayonet cap (BC) lampholders*, Bulletin 173, SSERC, April 1992, p 3.

PORTABLE APPLIANCE INSPECTING : SHORTFORM CHECKLIST

Inspection	Pass condition
Mains plug	Mechanically sound and secure No significant internal heating Cord grip soundly gripping sheath of flexible cord
Flexible cord	Two intact layers of insulation No damage to sheath Effective strain relief at enclosure
Apparatus enclosure	Enclosure undamaged Separate parts securely fastened together Clean condition No sign of foreign objects inserted through apertures
Fitments on enclosure	Fitments mechanically secure In proper working order
Outlets	Restricted use of apparatus with outlets at hazardous live
Operation	In proper working order

Table 3. Suggested shortform checklist for users of portable appliances. For interpretation of *Pass conditions* refer to the full *Inspection Checklist*.

This article may be copied for use within Scottish schools and colleges in current membership of SSERC.

Materials testing

The need in technology courses for some first-hand, practical experience of the testing of materials and for the theoretical aspects of such work to be put into real engineering contexts is discussed. A testing kit from Unilab is reviewed.



Figure 1 Forth Road Bridge. From atop the south main tower looking north to Fife. Taken during the fabrication of the main suspension cables. Unusually for the time, the tower construction used high tensile steel.

Consider the two photographs above - taken during the construction of the Forth Road Bridge. Think of the multiplicity of problems related to the properties of all of the various materials used in its construction. For example how did the designers arrive at the dimensions of the cables? Why were the main suspension cables spun on site from separate strands of wire? How did they decide where and how to arrange the cable anchorage points at either end of the bridge?

Now consider the theoretical structural problem set in Figure 3 opposite. Or, consider the following examination type question :

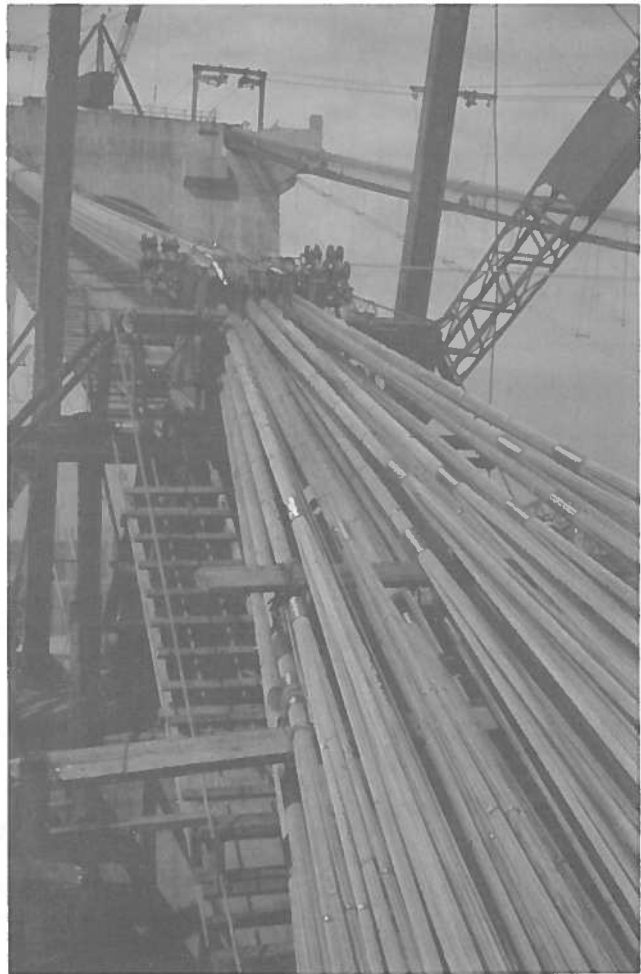


Figure 2 Main cable showing the splay developing back toward the anchorage points (each wire rope being separately anchored in fixing sockets embedded in concrete many metres back from the ends of the bridge deck).

A specimen of aluminium alloy, 15mm dia., gave a straight-line load extension curve under test up to a load of 40kN. The measured extension on a length of 20cm was 0.7mm. Calculate the stress at the proportional limit and the modulus of elasticity for the alloy.

These are 'problems', surely, to set racing the pulse of any pubescent pupil of technology. In the absence of either any practical experience of the physical properties of constructional materials, or of real life contexts in which set their findings, it isn't hard to understand why some pupils and students of Technological Studies find this part of the course a tad dry for their taste.

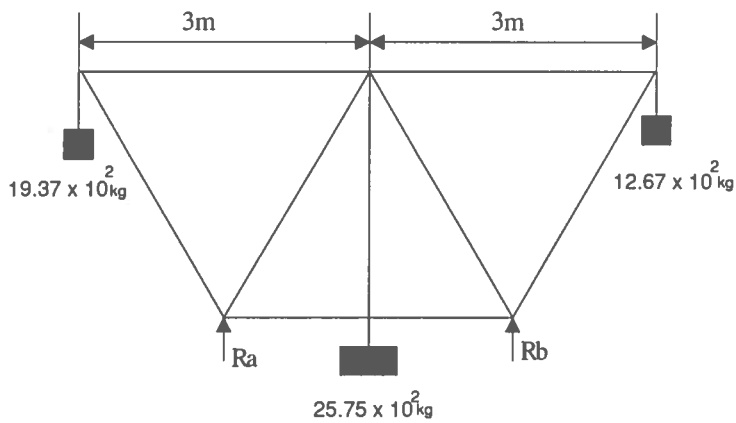


Figure 3 - Calculate the resultant loads at points R_a and R_b

Contrast such experience with that of Telford or Baker as described in our feature article. They directly handled and tested the materials with which they worked on a day to day to basis. They knew their strengths and weaknesses as well as contemporary techniques allowed.

In fairness to teachers, this is an area of Technological Studies which is difficult to investigate directly in schools. Because of the scale and expense of the equipment needed it is often dealt with as a theoretical exercise, a simulation or through a visit to a materials testing laboratory at a local university¹.

Whilst visits to well equipped testing labs are useful, in many such cases all that is provided is demonstration of a range of testing techniques. In the absence of any hands-on work how can students get a feel for, and appreciate the dimensions of, properties such as ductility, malleability or hardness?

We do know of one school where staff have designed their own test rig, but this does need lots of time or an experienced technician with an engineering background. We were therefore very interested when Unilab, introduced a Materials Testing Kit (Cat. No. 871.620) that seemed to meet many of these requirements of the technology curriculum.

The Unilab kit offers a fairly full range of tests covering tensile, compressive and shear failures as well as tests on bending and hardness.

Investigations can be carried out through direct reading of the meters on the mains operated amplifier, by computer interfacing or by data logging. A review of this kit and some opinionative comment on the usefulness or otherwise of these investigations follows.

¹ Nowadays, excepting - for now - our colleagues in the Highlands and Islands, we all seem to have a *local university*.

Unilab materials testing kit - a review

The kit comprises: a modified engineer's vice; load cell; a rack and gear mechanism driving a potentiometer to measure displacement; an amplifier unit with two analogue meters calibrated in a number of ranges to show force and displacement; connections both to computer interfaces and to data loggers; an instruction manual and a quick action clamp.

A box of sample materials is supplied. Specimen materials for use in tensile testing are machined to identical shapes with dimensions calculated to give an approximate cross-section of 5mm^2 . Software is available for the Archimedes computer or for PC Windows to enable the user to easily rearrange graphs and to aid calculations.



Figure 4 Test rig : modified vice with rack and load cell.

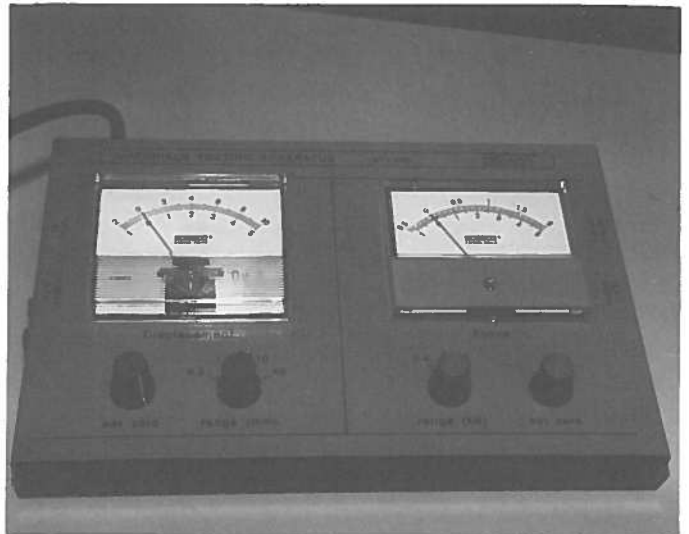


Figure 5 Amplifier unit with twin meter display.

The instruction book is fairly comprehensive, the methods described for setting up the various tests are easy to follow. Those of us who remember enough of the old Engineering Science should have no difficulty in interpreting the sample graphs provided in the appendices.

Applications

Manual plots : We decided to use the test kit to produce force-displacement graphs (questions on the results of tensile tests always being popular with examiners).

Our first attempt was to follow the instructions for tensile testing by plotting meter readings directly to graph paper. This proved to be a simple exercise. The resulting graph is shown in Figure 6. With a little imagination it is possible to detect when necking begins and to identify the point of fracture.

Computer generated plots : Computers are there to help with the gathering and manipulation of data, so our next attempt was to try interfacing the test rig to one of our own resident computers.

Unilab supply software for the kit in either an Archimedes (or A series) *RISCOS* version (Cat. No. 871.623) or a PC version which runs under *Windows*® (Cat. No. (871.622)). Both of these cost £60 and this includes the supply of a serial lead. We trialled the Archimedes version. This tailored software supplied with the kit gave graphs which were close to the theoretical or expected results see Figures 7 and 8.

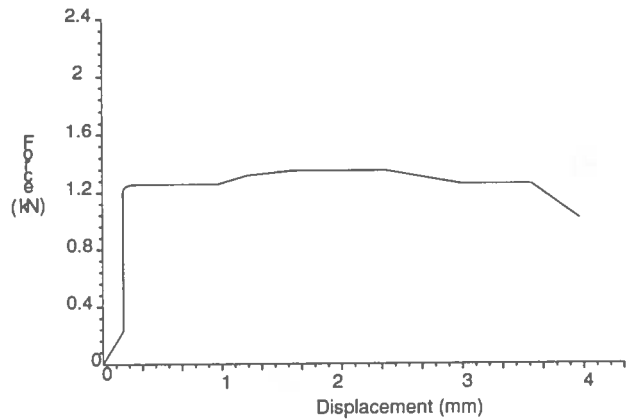


Figure 6 Tensile test on copper, results recorded and plotted manually. Applied force (kN) versus displacement (mm).

The program has a number of other useful features. For example it will allow you to :

- find the distance between two points or the co-ordinates of a single point;
- call up the gradient of any line on a graph simply by using the mouse. This is useful when determining both the yield point and Young's modulus;
- highlight the area under the graph to show the total work done on a force v displacement graph or work done to the point of failure;
- save data and export it to a spreadsheet program;
- superpose text onto the graph to serve as a title or as explanatory notes.

Materials Testing
Steel Force/Extension

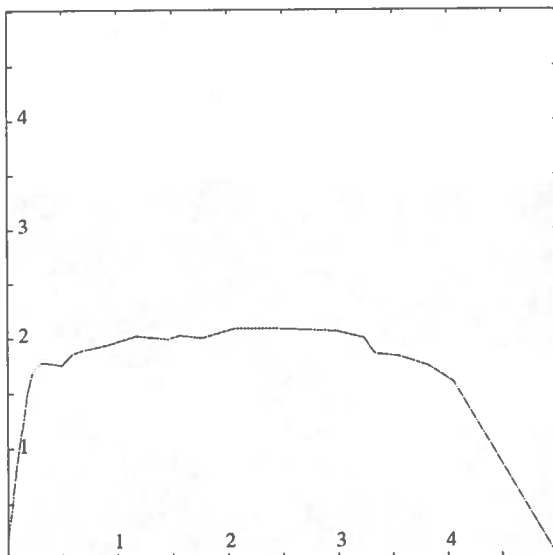


Figure 7 Steel test piece. Force in kN versus displacement (extension) in mm. Unilab software running on an Archimedes A3000. Note use of facility to add textual material before obtaining a screen dump.

Materials Testing
Copper Force/Extension

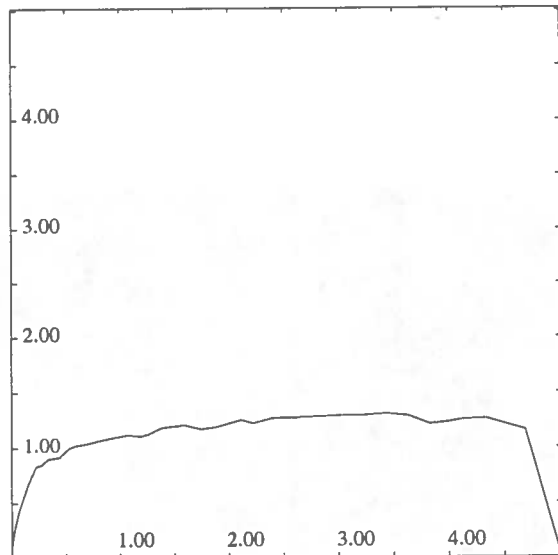


Figure 8 Copper test piece. Screen dump of results. Force (kN) versus displacement (extension) in mm. Unilab software running on an Archimedes A3000.

Third party software : Unilab sell the Materials Tester Kit on its own without the associated software. Potential buyers with existing datalogging devices and software may be interested in our attempts to gather and process the tester's data with other programs and devices.

Acorn's BBC models all allow signals to be sent straight to the Analogue Port on the machine. With an Archimedes or Acorn A-series model a podule or add-on board is needed. All that this interfacing involved was to take the 0-1V displacement and force outputs from the materials testing amplifier to Channels 1 and 2 of the Analogue Port.

For example we used a Harris or DIY four channel connector with *Datadisc+* software. This allowed the results from each channel to be shown on a single graph (see Figure 9).

Some useful interpretation of these results is possible but they aren't quite text book stuff. With this particular combination, for whatever reason, we weren't able to obtain a satisfactory plot for the initial extension in the elastic zone. Nor is the plateau in the plastic or working region as obvious as in the Unilab software plots.

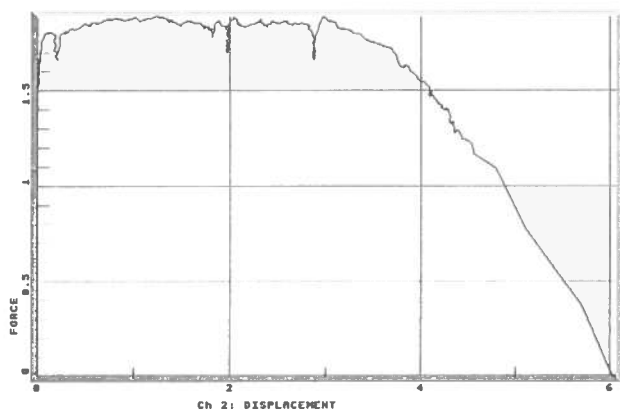


Figure 9 Results for a steel test piece showing applied force versus displacement.

Similar trials were carried out using the software package *Insight*. Sample results for a force/extension graph with a copper test piece are shown in Figure 10. This time the elastic, linear region is evident.

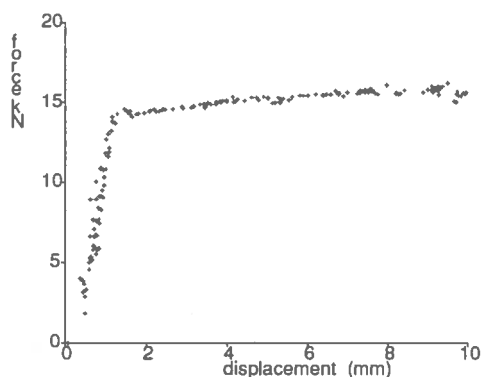


Figure 10 Applied force versus displacement (extension) plot for a copper test piece using *Insight* software.

Datalogging : Application of load cells to materials under test may have to be carried out over long periods of time. Bridge structures in particular are now often fitted with strain gauge patterns linked up to data loggers to give engineers information on stresses and strains induced by weather and traffic.

Because datalogging forms part of the Technological Studies syllabuses we decided to try the Materials Testing Kit with *LogIT* and the associated software *Linkpack+*.

A graph of the result is shown in Figure 11.

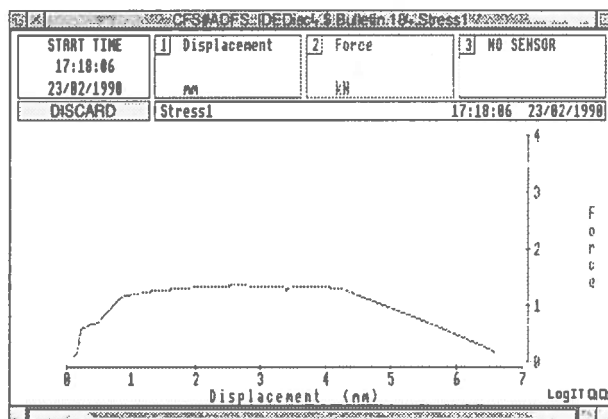


Figure 11 Copper test piece. Applied force versus displacement (extension). Data gathered using *LogIT* and *Linkpack+* software.

Performance

The tester and Unilab's tailored software both worked to the manufacturer's specification. The tester is also easy to use as a stand alone unit, allowing the pupils to draw their own graphs from manually recorded meter readers.

Ease of use

The tester is relatively simple to operate. All of the controls as well as the signal inputs and outputs are clearly labelled as to their functions. The two analogue meters have clear and easily read scales. With steel samples of any greater dimensions than of those supplied, some less muscular students may have a problem turning the handle of the vice. The vice itself needs to be clamped firmly to the bench. It would benefit from fitting a large diameter wheel in place of the conventional lever.

The Archimedes software we tried was supplied without a handbook and as we believe an early version. However this did not cause any great inconvenience. Even without instructions the on-screen prompts are probably enough for those with some experience of RISCOS and of Archimedes or A-series computers. The software has the ability to save graphs as sprites, Draw! files, or data files.

An aspect of the software which suggests that it may have been written by a practising teacher is the ability to have on-screen visual prompts which Unilab describe as *help diagrams*. These show the set-up of the vice and load cell as well as the position of the sample under test.

Because the outputs from the amplifier unit are 0 to 1V this enables the tester to be used with a variety of dataloggers and associated software. Again we found no major difficulties in using the tester with such devices.

Reliability

The vice and load cell are, as one would expect, of robust construction. The amplifier unit is a little more delicate and needs to be treated with care. The first we tried was an early production model. It did give us quite a lot of problems proving intermittently unreliable and being effective only at turning air various shades of blue. Once we had established that the fault lay in the unit and not with us, we informed the manufacturer. The unit was then speedily replaced, the fault already having been identified and corrected by Unilab.

The sensor cable from the load cell to the amplifier unit and the connectors fitted to it were not, in our opinion, of good enough quality. This is because the relatively weak signal from the load cell is sensitive to interference, particularly if the integrity of the shielding has been breached. Again we are given to understand that Unilab, having been informed of this problem, intend upgrading the cable and connectors.

Conclusion

The *Unilab Materials Testing Kit* is, we believe, the first small scale unit to enable pupils to have direct experience of quantitative investigations of the mechanical properties of basic materials. And, to iterate : it may be the only chance many pupils will have to explore, for themselves and at first hand, a range of such properties.

We thus consider the tester fills a gap in the technology curriculum where perhaps suitable instrumentation has very rarely been available for investigating materials and structures. It may be that, following the demise of Engineering Science (RIP), that teachers and suppliers lost interest in this subject and perhaps that electronics was seen as sexier. This kit should dispel that idea. The tester could be of use in science and technology departments from Standard Grade through Sixth Year Studies.

Value for money

At just over £550 (including software) the price tag will probably be seen by some as too high considering the number of times in a school session that this kit would be used. But, we feel that once it was purchased other uses would quickly be found for it. For example, dare we say it, what about sharing it with science or physics courses? There is also a set of textile testing accessories for the kit which opens up possible applications in Standard Grade Science and Home Economics courses.

In any event much bigger sums have been expended on technology resources which have proved far less educationally useful.

It may be that a kit could be purchased jointly and used throughout a school cluster or neighbourhood group. Or it could form part of Resource Centre's loan stock. Given imminent local government re-organisation and past experience of difficulties with resource sharing, even through a Centre, it is somewhat difficult to see such an arrangement working in practice over the longer term.

A summary of order codes and prices is given in Table 1 below.

Item	Code	Price (£)
Materials Tester Kit	871.620	495.00
Samples pack	871.630	58.80
Textile Accessories	871.627	31.85
Acorn software & lead	871.623	60.00
PC (Windows) software and lead	871.622	60.00
Tension, compression test samples ext. pack	871.635	TBA
As above, bending test	871.638	TBA

Verdict : B

A = most satisfactory for use in Scottish courses

B = satisfactory for use in Scottish courses

C = unsatisfactory

Erratum etc. : Bulletin 183

Data Harvest

Firstly we apologise to Data Harvest : Educational Electronics for a transposition error in Table 2 of our article on interfaces, dataloggers and sensors in the Equipment Notes section. This made it appear that Educational Electronics' Distance Sensor (Catalogue reference 9200, £69.00) was made and supplied by Deltronics.

Philip Harris lamps

Secondly it seems that we upset marketing staff at Philip Harris with a small part of our article on tungsten filament lamps. This appeared in the Technical Articles section of the same issue. It may be that we gave the impression that the 10% underperformance of a batch of raybox lamps (each delivering only about 90% of the power which was indicated on them) was a problem peculiar to Harris lamps. This is not the case. Raybox lamps of the same make purchased from other firms may exhibit similar under-performance.

Announcements and notices

Managing health and safety

It is some months since we first mentioned the imminent availability of an important Health and Safety Commission publication on the management of health and safety in schools. This document prepared by the commission's Education Service Advisory Committee (ESAC) is, at long last, on sale. It is priced at £5.95 and is available from HSE Books on mail order or through good booksellers. Its full title is *Managing health and safety in schools* (ISBN No. 0-7176-0770-4 and the price £5.95 net)

Special needs

We have recently obtained a copy of the latest version of Alan Jones' book on *Science Education for Pupils with Special Needs*. This updates his two earlier books with similar titles published in 1984 and 1990.

Much of the emphasis in this latest edition is on putting the material into the context of the English and Welsh National Curriculum. There are also a number of points of detail where one might be tempted to start nit-picking. Nonetheless this is a very useful contribution to the literature in this relatively neglected field.

It is also useful a starting point in that it contains a loose-leaf set of references which will lead the interested on to further information and study. The book is available

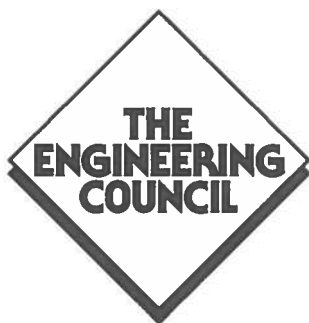
from Nottingham Trent University (see our Address List on the inside rear cover of this Bulletin).

SSERC Graphics for PCs and Macs

We still intend producing a PC compatible version of our Graphics Collections CD ROM. Were it not for the DOS restriction of 8 characters or less for directory names the Acorn format CD could be used. We are keeping our fingers crossed for *Windows '95*® to overcome some of the restrictions. We know, from the many requests already to hand, of immediate demand for our science and technology graphics from PC users.

We have negotiated with Oak Solutions to market *Oak Draw*® for *Windows*® at a special discount price of £65.80 (including VAT) instead of the usual £82.25. This application gives PC users access to any SSERC Draw files originally drawn on Acorn computers. We are currently compiling a graphics collection on high density 1.44 Mb floppy disks. You can even swap the same disc between high density Acorn and PC drives and load the Draw files into either application. Write to us to register an interest in an *Oak Draw*® and graphics discs package.

The conversion of our graphics to Mac format is continuing apace. Check out the SCET stand at the Scottish ASE to see them demo the results thus far.



The Technology Enhancement Programme (TEP) is a collaborative venture in partnership with UK schools and colleges, aimed at improving learning and teaching in technology. It brings together the teaching of technology, science and mathematics through projects set within an industrial context, and offers a vocational framework mainly for students in the 14-19 age group.



TEP has produced the following photocopiable texts to support technology teaching at 14-16 and post-16:

<i>Control</i>	ISBN 1 898126 28 8	<i>Electronics</i>	ISBN 1 898126 05 4
<i>Manufacture</i>	ISBN 1 898126 10 0	<i>Mechanisms</i>	ISBN 1 898126 15 1
<i>Structures</i>	ISBN 1 898126 25 9	<i>Omnibus Edition</i>	ISBN 1 898126 40 2

These texts are available at a cost of £10.00 each plus £2.00 p&p or at £45.00 plus £5.00 p&p for the omnibus version of all 5 texts. Otherwise please add for postage and packing : £2.00 for orders up to £10.00; £3.50 for orders between £10.00 and £40.00; £5.00 for orders between £40.00 and £50.00; £7.50 for orders over £50.00. Cheques enclosed with orders should be made payable to "The Engineering Council". To place an order for books, to receive sample pages, or for full information on the TEP programme, please contact Virginia Harris at:

**The Engineering Council, Essex House, 12/13 Essex Street, London WC2R 3EG
Telephone 0171 240 7891; Fax 0171 379 5586**

Electrocardiograph simulator

An ECG simulator can be constructed from a couple of integrated circuits and some resistors and capacitors. It might either be a useful teaching aid in Biology, or a construction exercise in Electronics.

The circuit (Fig. 1) was taken, with minor adaptations, from the Circuit Ideas column [1] of *Electronics World + Wireless World*.

IC2 is a clock driven decade counter which produces sequential highs on its outputs Q0 to Q9. At any state in the cycle one output is high and the other nine are low. Each output is connected through resistors to a common node which acts like the output tap on a complex potential divider network. The nett result is that a signal comprising ten separate voltage levels is synthesised at this point (Fig. 2).

The clock pulses are generated by IC1a and IC1b, which are wired as an astable oscillator with a nominal frequency of 20 Hz. When the decade counter output Q9 goes high it triggers a monostable comprising IC1c and IC1d for a time set by the 2.2 MΩ variable resistor. This has minimum and maximum periods of about 50 ms and 1300 ms. The monostable inhibits the 20 Hz astable after a burst of nine pulses, so controlling the pulse rate from 35 per minute to 120 per minute.

The signal from the decade counter is taken in sequence through low pass and high pass RC filters. These deliberately cause a small amount of distortion so as to round off the sharp voltage transitions (Fig. 2) that would otherwise be there. The final attenuation reduces the peak to peak output to a value of about 2 mV, which is near to the real thing. The output monitor can be connected across any combination of outputs. The diagram shows a CRO across the right arm and right leg terminals (Fig. 1).

The signal is best viewed with a storage oscilloscope. If the trace is allowed to roll, you can watch a fresh signal being generated whilst at the same time being able to look at the previous couple of signals. If a storage CRO is not available, a non-storage instrument may be used whose time base is set either at its slowest sweep rate, or switched off altogether. If a computer and interface or datalogger are used, then the system should be capable of sampling at 100 per second or faster to resolve the signal in the x-axis, and of measuring voltage to a precision of 10 μV to get sufficient definition in the y-axis. Two signals recorded by

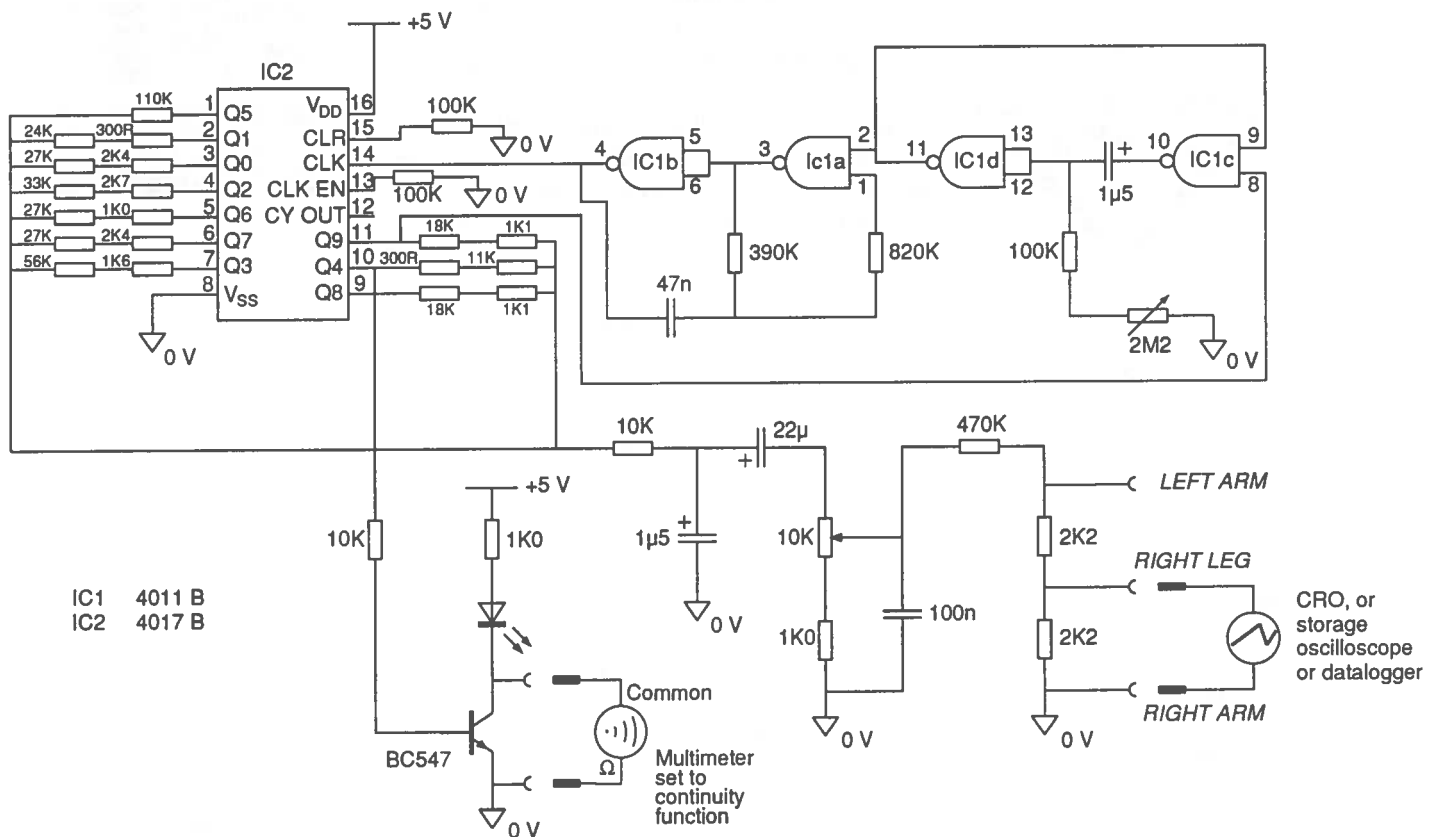


Figure 1. Circuit diagram of electrocardiograph simulator. The 2.2 MΩ variable resistor controls the pulse rate; the 10 kΩ potentiometer controls the output amplitude.

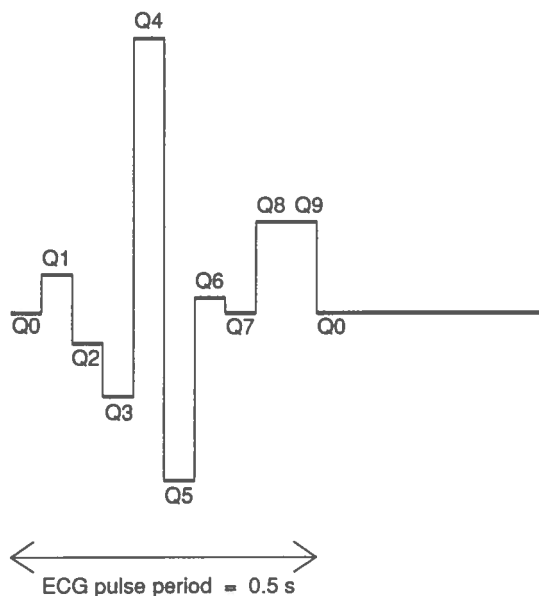


Figure 2. Theoretical shape of signal synthesised at summing junction of decade counter's resistor bank.

computer are given. The first (Fig. 3, overleaf) shows the stepped voltage levels at the summing junction of the decade counter's resistor bank. The second (Fig. 4, overleaf) is across the right arm, right leg terminals, the actual signal being amplified by x25 and offset by 15 mV to appear as shown.

The LED emits a burst of light at each ECG pulse. Some multimeters have a continuity function wherein an audible beep is produced when a short circuit is sensed. If such a meter set to detect continuity is connected across the collector and emitter of the transistor, then it emits a tiny blip each pulse. This is quite pleasing. You feel that the circuit is alive!

The design specifies metal oxide semiconductors 4011B and 4017B. We have tried substituting other CMOS families but failed to get reliable performance.

The original design specified resistors from the E96 range for connection to the ten outputs of the decade counter (Table 1). Since these cost nearly £4 for five, we have substituted values from the less expensive E24 range. It is advisable to measure the values of these resistors before use. Any which are out of tolerance should be discarded. A complete parts list has been given (Table 2).

Acknowledgement

We are grateful for permission from the Editor of *Electronics World + Wireless World* to republish this circuit, with minor adaptations. The original [1] appeared in the Circuit Ideas column of that journal.

Reference

1. A R Marino, *Electrocardiograph simulator*, *Electronics World + Wireless World*, October 1993, 852.

Decade counter output	E96 value	E24 values
Q0	29K4	27K + 2K4
Q1	24K3	24K + 300R
Q2	35K7	33K + 2K7
Q3	57K6	56K + 1K6
Q4	11K3	11K + 300R
Q5	110K	110K
Q6	28K0	27K + 1K0
Q7	29K4	27K + 2K4
Q8	19K1	18K + 1K1
Q9	19K1	18K + 1K1

Table 1. Values of resistor bank versus Decade Counter output. E96 values specified in original article. E24 values substituted to reduce cost of components.

Part	Supplier	Stock number	Qty.	
IC1,	4011B	Rapid	4011B	1
IC2,	4017B	Rapid	4017B	1
Transistor,	BC547	RS	296-087	1
LED,	red	SSERC	508	1
Resistor,	300R	RS	148-376	2
	1K0	RS	148-506	3
	1K1	RS	148-512	2
	1K6	RS	148-556	1
	2K2	SSERC	420 2K2	2
	2K4	RS	148-590	2
	2K7	RS	148-607	1
	10K	SSERC	420 10K	2
	11K	RS	148-742	1
	18K	RS	148-792	2
	24K	RS	148-821	1
	27K	RS	148-837	3
	33K	RS	148-859	1
	56K	RS	148-916	1
	100K	SSERC	420 100K	3
	110K	RS	148-988	1
	390K	SSERC	420 390K	1
	470K	SSERC	420 470K	1
	820K	RS	149-206	1
Pot.,	10K	Rapid	67-0230	1
	2M2	RS	375-764	1
Capacitor,	47n	RS	820-848	1
	100n	RS	115-578	1
	1µ5, tant	RS	117-704	2
	22µ, elec	RS	103-963	1

Table 2. List of parts for ECG simulator.

Figures 3 and 4 overleaf

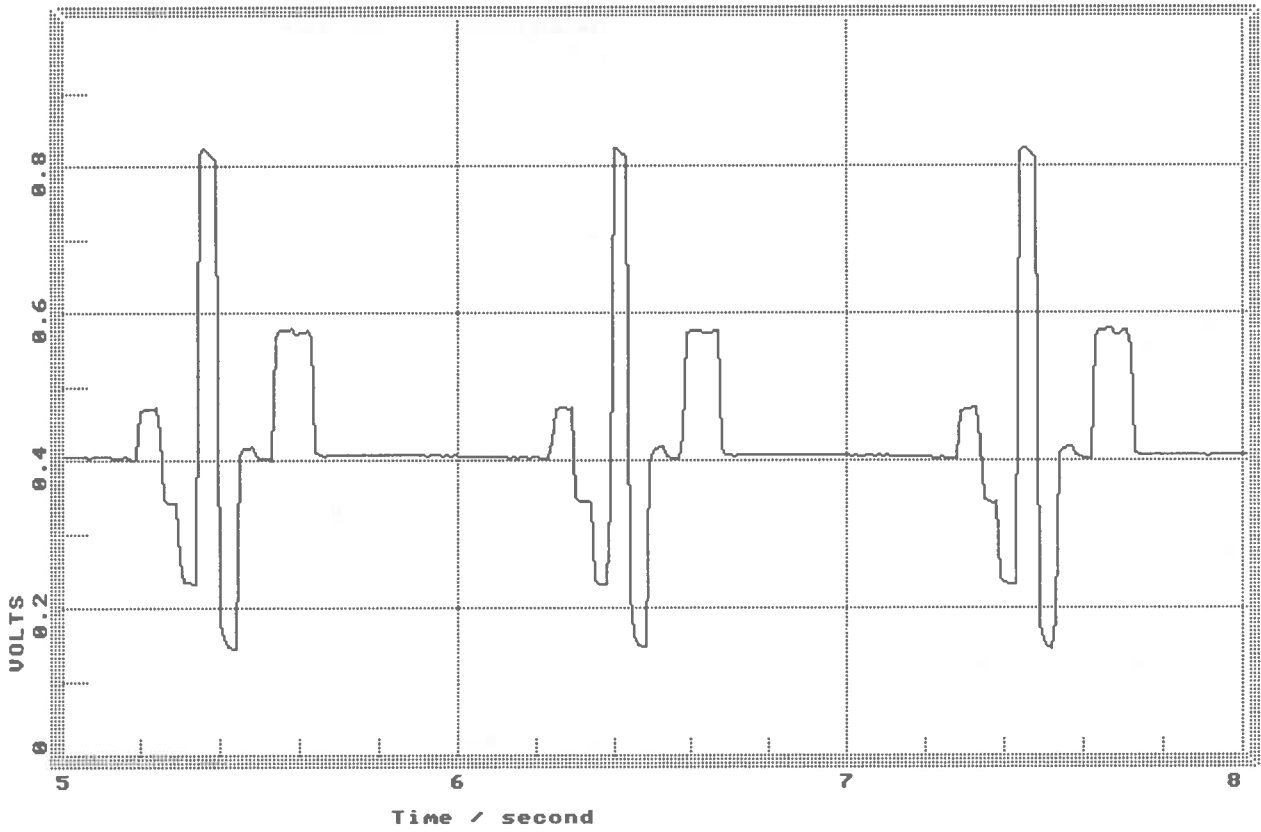


Figure 3. Actual shape of signal synthesised at summing junction of decade counter's resistor bank. Signal captured with Datadisc PP running on an Acorn A3000 Computer. Sample rate 100 samples per second.

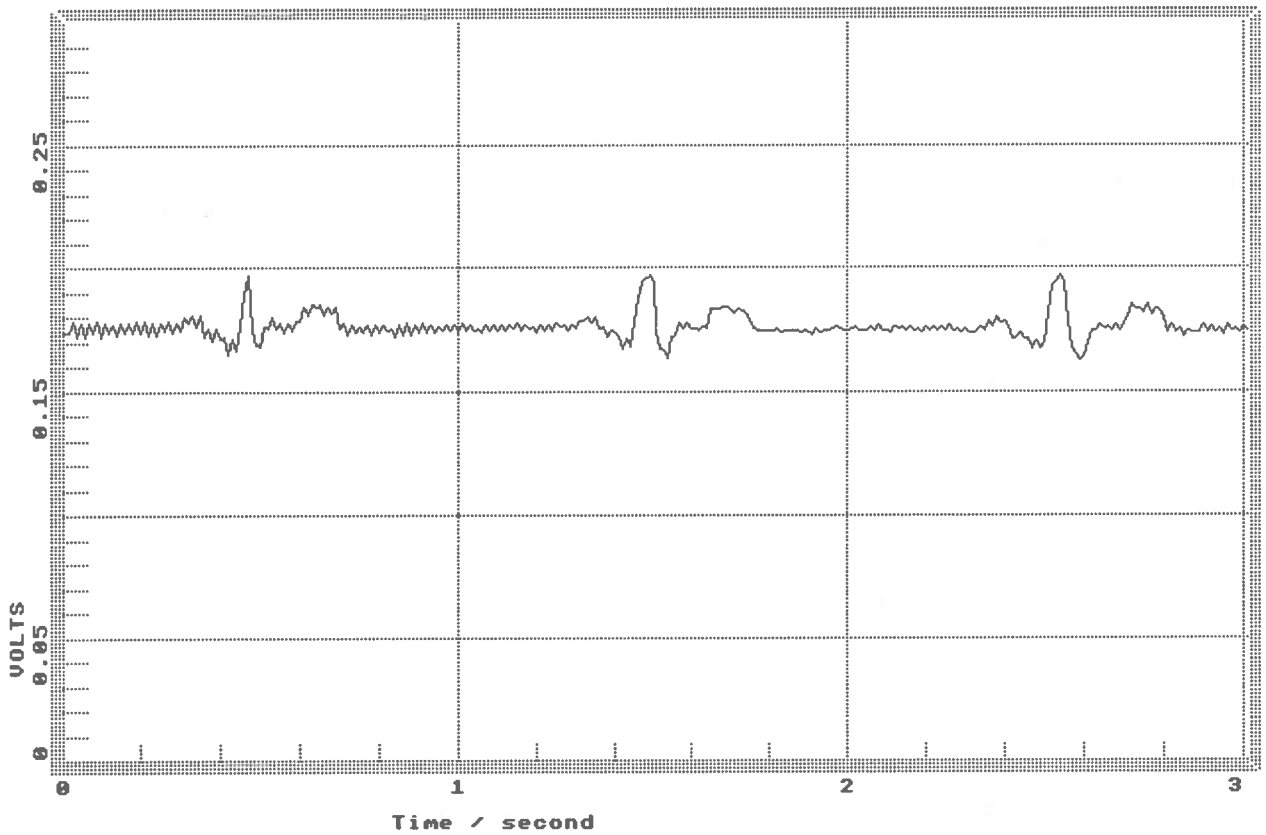


Figure 4. Output across the right arm, right leg terminals, the actual signal being amplified by x25 and offset by 15 mV. Signal captured with Datadisc PP running on an Acorn A3000 Computer. Sample rate 100 samples per second.

LOOSE ENDS

Protein identification in foods

A number of biology teachers were using ELISA type kits for the identification of proteins in foodstuffs. These are based on enzyme immunoassay technologies and thus provide useful classroom illustrations of a modern biochemical technique.

The kits then seem to have disappeared off the mainstream educational market and we were requested to try to find alternative suppliers. We suggest that interested teachers contact Cortecs Diagnostics Ltd. (see inside rear cover) and request details of their FAST Immunostick Test Kits. As for the original ELISA kits, these are not cheap at about £70 for four, five test packs. That price includes VAT and Cortecs will take schools VAT exemption into account when invoicing so specifically mention the fact if the order is coming from a school. That should get you ca. £20 knocked off the price.

Phenol oxidases

The title is convenient shorthand for what is effectively a family of enzymes which includes phenolases, cresolase and catecholase. They form part of those enzyme complexes which catalyse a sequence of reactions which lead to the formation of phenolic polymers responsible for the browning of the cut surfaces of plant tissues.

In Bulletin 178 we gave the impression that the optimum pH for these enzymes was always about pH7 and that this explained the inhibitory effects of citrus fruit juices on browning of apples, bananas and avocados. As a result of enquiry work for CSYS students we now have to hand a collection of references on the extraction and assay of some of these enzymes which make such good subjects for investigations and projects. Some of these were kindly supplied by the Sigma Chemical Co. Other information came from the *DART* publication on this topic.

We now know that we gave far too simple an account. The optimum pH values for this type of enzyme can go as low as pH5.5 with a secondary optimum at just over pH7 and typical maximum reaction rates at about pH6. It may well be that citrus fruit juices exert some other influence besides simply lowering the pH. Ascorbic acid (vitamin C) has a direct effect on these reactions. What effect might that be?

'Express' autoclaves

Various models of these devices are widely used in Scottish schools. These are the type with a lid retained by drop bolts. Some are electric others need an external heat source, such as a gas ring.

Until recently the primary supplier of spare parts and rewiring kits was a company called Hospital Management and Supplies Ltd. This firm is no longer trading. Spares can however be sourced directly from the manufacturers who are Dixons Surgical Instruments Ltd (see Address List, inside rear cover).

Some of the Express models have a thermostat fitted in addition to the thermal cut-out in the base and on which some words of warning : We have recently examined a few samples of different models which were apparently faulty. In one case it appeared that the thermostat had failed. A replacement is incredibly expensive (about £148 including VAT and post and packing). The adjustment controls for this thermostat protrude through the body of the autoclave about a third of the way up the pot. The cover is held on simply by two slotted screws. Now, we are not for a moment suggesting that any student would do anything so unworthy but, we found that the thermostat wasn't broken it merely needed to be readjusted and calibrated. It's well worth considering this possibility before rushing out to spend your precious £148.

Similarly, with some of the older models it is by no means obvious that the thermal cut-out can be reset manually after it has tripped through the pot boiling dry or whatever. This involves making the device safe and dead by unplugging it, removing the base plate to get access and then inserting a screwdriver into a central aperture in the cut-out. It can be heard to click over when it resets. More recent models carry a cut-out with a more obvious reset switch. If the cut-out really has failed then Dixons Surgical Instruments will supply a replacement for £20.47 (inc. VAT).

BC lampholders for bench lamps

Several schools have contacted us for advice on mains bench or microscope lamps. In general there are two problems. Either the lampholder has no proper earth terminal, or lacks adequate strain relief on the cord sheath. Often both of these safety provisions are absent. The usual answer is the replacement of the lampholder - quite a simple task that is no harder than fitting a 13 A plug.

We can recommend two sources of supply of bayonet cap (BC) earthed lampholders with cord grip. One is the lampholder manufacturer S Lilley & Son Limited (item number 3000E). They are sold in boxes of 10 at £1.00 per lampholder. Add £5.20 for delivery of one box and £2.66 for VAT. The wooden collar which is part of the cord grip of this lampholder should be prised apart down the split in the wood into two halves for fitment round the cord sheath.

The other supplier is C & D Scientific Instruments, who can supply a BC earthed lampholder with cord grip at £2.00 each. They also supply the lampholder ready wired to 0.75 mm² flexible cord, 2 m in length, fitted with a 13 A plug. The price of this item is £4.50, which seems very reasonable.

Finally it should be noted that some modern bench lamps are designed to Class 2 construction and thereby do not require protective earthing. Any such lamp would be marked with a double insulation symbol. However in the absence of such a marking, it may be prudent to fit an earthed BC lampholder as specified above.

Surplus 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. Of particular interest is our limited stock of condenser lenses, which would ordinarily cost £80 each.

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 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 Ω 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 | 802 | <u>Motor</u> , 9 V d.c., no load current 20 mA at 9 V. Back EMF constant 1.5 V/1000 r.p.m. Overall length 44 mm, dia. 37 mm. Shaft 8 x 2 mm dia. Suggested application - tachogenerator.
£5.00 |
| 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 | 378 | Encoder disk, 15 slots, stainless steel, 30 mm dia. with 4 mm dia. fixing hole.
80p |
| 779 | Miniature motor, 13.2 V d.c., smooth running, speed governor, no load current 24 mA at 12 V, dims. 36 mm x 39 mm dia., shaft 10 mm x 2 mm dia.
£1.25 | 642 | Encoder disk, 30 slots, stainless steel, 30 mm dia. with 4 mm dia. fixing hole.
80p |
| 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 mNm, dims. 30 mm x 24 mm dia., shaft 10 mm x 2 mm dia.
45p | 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 electronic circuitry see Bulletin 146.
£3.00 |
| 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 mNm, dims. 25 mm x 21 mm dia., shaft 8 mm x 2 mm dia.
30p | Precision motor stock | |
| 621 | <u>Miniature motor</u> , 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 | 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 |
| 739 | Miniature motor, 1.5 V d.c., dimensions 23 mm x 15 mm dia., shaft 8 mm x 1.7 mm dia.
25p | 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 |
| 732 | Motor with gear box, high torque, 1.5 V to 12 V d.c., 125 r.p.m. at 12 V, dimensions 40 x 40 x 28 mm, shaft 10 mm x 3 mm dia. with key. Suitable for driving buggies, conveyor belt, or any other mechanism requiring a slow drive
£6.00 | Miscellaneous items | |
| 773 | Tachometer (ex equipment)
£2.25 | 791 | <u>Propeller</u> , 3 blade, to fit 2 mm shaft, blade 55 mm long.
45p |
| 811 | <u>Worm and gear</u> for use with miniature motors, 34 : 1 reduction ratio plastic worm and gear wheel.
35p | 792 | <u>Propeller kit</u> 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 | <u>Buzzer</u> , 3 V.
55p |

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.	55p	692	Battery holder, C-type cell, holds 4 cells, PP3 outlet.	20p
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).	45p	730	Battery holder, AA-type cell, holds 4 cells, PP3 outlet.	20p
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	729	Battery connector, PP3 type, snap-on press-stud, also suitable for items 692 and 730.	5p
313	Thermostat, open construction, adjustable, temperature range +10° to +65°C. Rated at 6 A, 250 V, but low voltage switching also possible.	60p	724	Dual in line (DIL) sockets, 8 way	5p
165	Bimetallic strip, length 10 cm; high expansivity metal: Ni/Cr/Fe - 22/3/75 low expansivity metal: Ni/Fe - 36/64 (invar)	15p	760	14 way	7p
166	Ditto, but 30 cm length.	40p	776	16 way	8p
385	Pressure switch, operable by water or air pressure. Rated 15 A, 250 V (low voltage operation therefore possible). Dimensions 2" x 3" dia.	65p	808	<u>Electrodes</u> 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
753	Submersible pump, 6 V to 12 V d.c., 8 litres/min., 0.6 bar, dry operation protected.	£5.50	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
758	Loudspeaker, 8 Ω, 0.5 W, 66 mm dia.	50p	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
771	Neodymium magnet, 13.5 mm dia. x 3.5 mm thick.	£1.30	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
745	Sub-miniature microphone insert (ex James Bond?), dia. 9 mm, overall depth 5 mm, solder pad connections.	40p	763	Sign "DANGER, Electric shock risk" to BS spec., rigid plastic, 200 x 150 mm.	£2.70
781	Toggle switch, panel mounting, 2 Amp rating, SPST, mounting bush 0.468 inch, flattened white 10 mm lever.	35p	764	Sign "DANGER, Laser hazard" to BS spec., rigid plastic, 200 x 150 mm.	£2.70
782	Toggle switch, panel mounting, 3 Amp rating, SPST, mounting bush 0.468 inch, flattened black 18 mm toggle.	50p	727	Hose clamp, clamping diameter from 8 mm to 90 mm, 101 uses - securing hose to metal pipe, tree to stake, joining wooden battens for blueing, etc.	30p
723	Microswitch, miniature, SPDT, lever operated.	40p	731	Re-usable cable ties, length 90 mm, width 2 mm, 50 per pack.	12p
354	Reed switch, SPST, 46 mm long overall, fits RS reed operating coil Type 3.	10p	752	Shandon chromatography solvent trough.	£1.00
738	Relay, 6 V coil, DPDT, contacts rated 3 A, 24 V d.c. or 110 V a.c.	75p	803	<u>Test tube rack</u> , used.	10p
774	Solenoid, 12 V, stroke length 30 mm, spring not provided.	£2.25	804	<u>Evaporating basin</u> , porcelain, 80 ml capacity.	£1.00
742	Key switch, 8 pole changeover.	40p	805	<u>Condenser lens</u> , bi-convex, 200 mm focal length, 75 mm dia. Crown glass.	£12.50
382	Wafer switch, rotary, 6 pole, 8 way.	70p	806	<u>Condenser lens</u> , plano-convex, 150 mm focal length, 75 mm dia. Crown glass.	£12.50
688	Croc clip, miniature, insulated, red.	5p	Components - resistors		
759	Ditto, black.	5p	328	Potentiometer, wire wound, 15 Ω, linear, 36 mm dia.	30p
788	Crocodile clip leads, assorted colours, insulated croc. clip at each end, 360 mm long.	£1.35	737	Ditto, 22 Ω, lin., 36 mm dia.	30p
809	<u>Wire ended lamp</u> , 3 V	10p	329	Ditto, 33 Ω, lin., 36 mm dia.	30p
741	LES lamp, 6 V.	15p	330	Ditto, 50 Ω, lin., 40 mm dia.	30p
770	ditto, but 12 V.	15p	420	resistors, 5% tolerance, 1/4 W : 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. Per 10.	6p
789	<u>MES lamp</u> , 3.5 V, 0.3 A	9p	421	DIL resistor networks, following values available: 62R. 1K0, 6K8, 10K, 20K, 150K. Per 10.	30p
690	MES lamp, 6 V, 150 mA.	9p	BP100	Precision Helipot, Beckman, mainly 10 turn.	10p-50p
691	MES battenholder.	20p			

Components - capacitors

695	Capacitors, tantalum, 15 μ F 10 V, 47 μ F 6.3 V.	1p
696	Capacitors, polycarbonate, 10 nF, 220 nF, 680 nF, 1 μ F, 2.2 μ F.	2p
697	Capacitor, polyester, 15 nF 63 V.	1p
698	Capacitors, electrolytic, 1 μ F 25 V, 2.2 μ F 63 V, 10 μ F 35 V.	1p
358	Capacitor, electrolytic, 28 μ F, 400 V.	£1.00

Components - semiconductors

807	<u>Schools' Chip Set</u> , designed by Edinburgh University, comprises the 4 chips and prototype board.	£4.00
	Edinburgh University support material : Volume 1 : Teaching Support Material (+£2 p&p).	£4.50
	Volume 2 : Laboratory Work (+£2 p&p).	£5.00
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, see Bulletins 158 and 165.	£2.20
640	Disk thermistor, resistance of 15 k Ω at 25°C, β = 4200 K. Means of accurate usage described in Bulletin 162.	30p
641	Precision R-T curve matched thermistor, resistance of 3000 Ω at 25°C, tolerance \pm 0.2°C, R-T characteristics supplied. Means of accurate usage described in Bulletin 162.	£2.90
718	Pyroelectric infrared sensor, single element, Philips RPY101, spectral response 6.5 μ m to >14 μ m, 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 μ m. Data sheet supplied. For application see SG Physics Technical Guide, Vol.2, pp 34-5.	50p
751	Hacksaw blade with pair of strain gauges, terminal pads and leads attached. Suitable for impulse measurement as described in Bulletin 171. Delivery time 3 months.	£12.50
501	Kynar film, screened, 28 μ m thick, surface area 18 x 100 mm, coaxial lead and 4 mm connectors. Applications: Impulse (Bulletins 155 and 174), long wave infrared (Bulletin 155, SG Physics Technical Guide, Vol.2, pp 33-4)	£20.00
503	Kynar film, unscreened, 28 μ m thick, surface area 12 x 30 mm, no connecting leads.	55p

504	Copper foil with conductive adhesive backing, makes pads for unscreened Kynar film to which connecting leads may be soldered. Priced per inch.	10p
506	Resistor, 1 gigohm, ¼ W.	£1.40

Opto-electronic devices

507	Optical fibre, plastic, single strand, 1 mm dia. Applications described in Bulletin 140 and SG Physics Technical Guide Vol.1. Priced per metre.	40p
508	LEDs, 3 mm, red. Price per 10.	50p
761	Ditto, yellow. Per 10.	60p
762	Ditto, green. Per 10.	60p

Items not for posting

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

Glassware

663	Flat bottom round flask, 250 ml.	50p
664	Flat bottom round flask, 500 ml.	50p
768	Sodium lamp, low pressure, 35 W. Notes on method of control available on application.	85p
810	<u>Watch glasses</u> , assorted sizes	20p

Chemicals etc.

712	Smoke pellets. For testing local exhaust ventilation (LEV) - fume cupboards and extractor fans, etc. large, 50p, small 35p
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NB : Other chemicals are named here as described on supplier's labels. Please order according to our description. Unless coded "A" substances are not Analar grade. Must be collected.

amino acids, sugars, various for chromatography etc.	p.o.a
(prices range from 25p to £1 depending on quantity)	
ammonia sol'n, 27% w:w 2.5 l :	50p
ammonium ferric sulphate 500 g	25p
barium chloride, 500 g	25p
barium sulphate (soil tests), 500 g	50p
buffer, universal sol'n	25p
caffeine, 100g	75p
casein, 500 g	25p
copper sulphate crystals, 500 g	50p
decanoic-n-acid (lauric), 500 ml	25p
diastase from malt, 100 g	50p
dodecan-1-ol, 500 ml	50p
glycerol monostearate, 500 g	25p
indol-3-ylacetic acid (IAA), 25 g	10p
iron filings, 3 kg	75p
Keiselguhr acid, washed, 500 g	25p
magnesite, native lump, 500 g	75p
manganese, metal flake, 99%, 250 g	50p
ninhydrin powder, 5 g	5p
oxalic acid, 500 g	25p
potassium dihyd. orthophosphate, "A", 200 g	50p
pyrogallol, var.pack sizes, from 25 to 500g	p.o.a.
resazurin tablets, 100 tabs.	25p
sodium n-butyrate, 100 g	25p
sodium malonate, 100g, sodium molybdate 100 g	10p
strontium chloride, "A", 500 g	25p
sulphur, 1 kg	75p
urea, 1 kg	1.00

SSERC, 24 Bernard Terrace, Edinburgh, EH8 9NX;
Tel. 0131 668 4421, Fax. 0131 667 9344.

British Standards Institution, Linford Wood, Milton
Keynes MK14 6LE.

C. & D. Scientific Instruments, 439a London Road, Hemel
Hempstead, Herts. HP3 9BD; Tel. 01442 255194
Fax. 01442 214107.

Cortecs Diagnostics Ltd., Techbase 1, Newtech Square,
Deeside Industrial Park, Deeside, Clwyd CH5 2NT;
Tel. 01224 288781 Fax. 01224 280221.

Data Harvest (Educational Electronics), Woburn Lodge,
Waterloo Road, Linslade, Leighton Buzzard,
Bedfordshire, LU7 7NR; Tel. 01525 373666,
Fax. 01525 851638.

Deltronics, Church Road Industrial Estate, Gorslas,
Llanelli, Dyfed SA14 7NF; Tel. 01269 843728
Fax. 01269 845527.

Dixons (Surgical Instruments) Ltd., 1 Roman Court,
Hurricane Way, Wickford Business Park, Wickford,
Essex SS11 8YB; Tel. 01268 764614
Fax. 01268 764615.

The Engineering Council, (TEP), Essex house, 12/13 Essex
Street, London WC2R 3EG; Tel. 0171 240 7891
Fax 0171 379 5586.

Fisons (Griffin & George) Limited, Bishop Meadow Road,
Loughborough, Leicestershire, LE11 0RG;
Tel. 01509 233344, Fax. 01509 231893.

Philip Harris Education:

2 North Avenue, Clydebank Business Park, Clydebank,
Glasgow, G51 2DR; Tel. 0141 952 9538;

Lynn Lane, Shenstone, Lichfield, Staffordshire,
WS14 0EE; Tel. 01543 480077, Fax. 01543 480068.

HSE Books, Customer Services Department, PO Box
1999, Sudbury, Suffolk CO10 6FS Tel. 01787 881165
Fax. 01787 313995. (Cash with order if you don't have
an account - and quote the ISBN of the publication).

A.V.Jones, Assoc. Head, Dept. of Chemistry and Physics,
The Nottingham Trent University, Clifton Lane,
Nottingham NG11 8NS Tel. 01602 418418
Fax. 01602 486636. (STD after 14.4.95 - 01159).

S.Lilley & Son Ltd., 80 Alcester Street, Birmingham
B12 0QE; Tel. 0121 622 2385.

Oak Solutions Limited, Dial House, Chapel Street, Halton,
Leeds LS15 7RN; Tel. 0532 326992
Fax. 0532 326993. (STD after 16.4.95 - 01132).

Rapid Electronics Limited, Heckworth Close, Severalls
Industrial Estate, Colchester, Essex CO4 4TB; Tel.
0206 751166, Fax. 0206 751188.

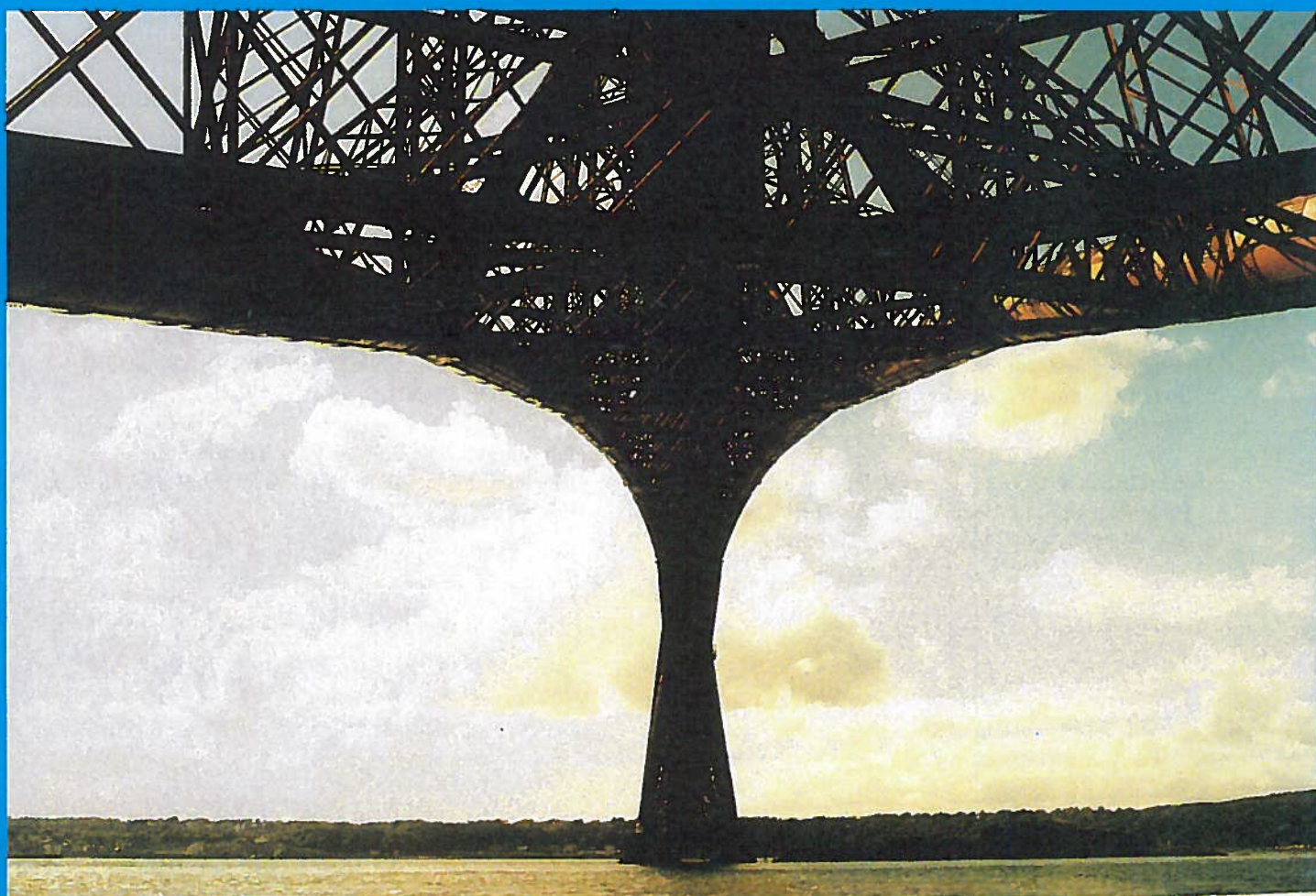
RS Components Limited, PO Box 99, Corby,
Northamptonshire, NN17 9RS; Tel. 01536 201201,
Fax. 01536 201501.

Unilab Limited, The Science Park, Hutton Street,
Blackburn, Lancashire, BB1 3BT; Tel. 01254 681222,
Fax. 01254 681777.



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