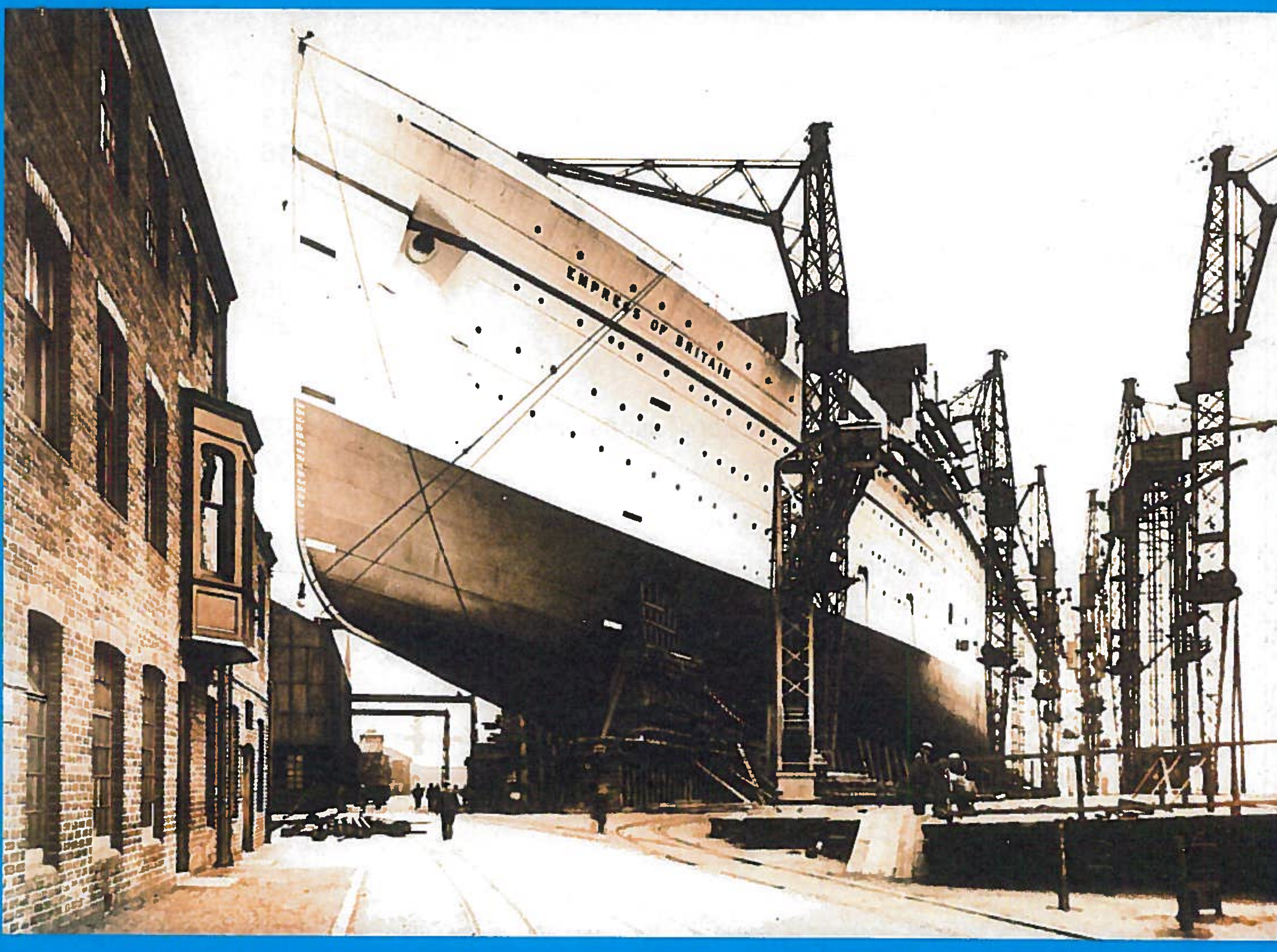
SCOTTISH SCHOOLS EQUIPMENT RESEARCH CENTRE



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FOREWORD

Sponsorship

This issue has been sponsored through the Technology Enhancement Programme which is managed by the Engineering Council. We are most grateful to the Council and to Dr John Williams, Senior Executive, General Education, for this interest in and support for the work of the Centre.

Dr Williams has kindly provided us with an account of the aims of the Technology Enhancement Programme and of the products and services it aims to provide to schools and colleges. Two other Council managed projects are also described - the Neighbourhood Engineers Scheme and the Women into Science and Engineering campaign[1].

The TEP

One of the most exciting projects with which the Engineering Council has been involved over the last three years or so has been the Technology Enhancement Programme (TEP). Funded by the Gatsby Charitable Foundation and managed by the Engineering Council, the programme offers practical support for the teaching of technology in schools.

This it aims to do by producing work-related teaching materials and publications aimed at developing skills needed by industry, by encouraging schools and colleges to form links with industry and by bringing schools and colleges together in collaborative networks so that they can exchange ideas. A number of schools have been involved with the pilot phase of the programme, which is now complete.

To date, TEP has produced a number of texts for the use of 14 to 16 year olds in studying the major areas of engineering and technology. These publications were evaluated and tested in the pilot phase schools and are now available from the Engineering Council. Further texts are planned both at this level and also for 16 to 19 year olds.

Following completion of the pilot phase the next three years will see a major expansion of the programme's activities. The number of UK schools and colleges working with the programme will rise to 1,000 or so. Collaboration, both between schools and of them with industry, will be strengthened considerably. Additional teaching resources will be produced for the project under the leadership of Professor John Cave of the Technology Centre at Middlesex University. In-service training is to be offered through regional meetings, expert classes and opportunities to attend a summer school offered to schools and colleges.

TEP already has a Regional Adviser for Scotland who also covers Northern England (see Address List inside rear cover of this issue). Even in these early post-pilot stages Fife Regional Council has already stated its intention to work with the Technology Enhancement Programme as part of its own *Fife Engineering and Education Partnership*. Additional Scottish support is also being given to TEP through Scottish Engineering as part of its Engineering Initiatives Programme (again see Address List).

Neighbourhood Engineers

This is another weapon in the Engineering Council's armoury for enhancing technology teaching in schools. This scheme has been running since 1988 and links three or four professional engineers and technicians with their local secondary schools. The idea is that they should give students a better understanding of what it is that professional engineers, engineering and technology can do for them and for society in general.

The scheme is very flexible and depends largely on how individual schools actually see it contributing to their own teaching programmes. For example, Neighbourhood Engineers might be asked to provide practical assistance with project work in the classroom or they might supply examples of the products of modern technology for the purpose of illustrating lessons.

Under the scheme, a number of teachers have already benefited also from industrial experience linked to in-service training. In one such case engineers in the scheme were able to provide direct access to the CAD/CAM facilities of a leading industrial company. In other instances neighbourhood engineers have helped students in their studies of a major energy project and on another occasion have assisted in students visiting and participating in a public inquiry into a proposed bypass.

At present, in Scotland the scheme involves more than 200 schools and about 1,200 engineers and engineering technicians. Eventually it is anticipated that every Scottish secondary school will take part and that the number of neighbourhood engineers will increase to about 3,000. The scheme's Project Manager in Scotland is Hamish Stears and his address is listed also on the inside rear cover.

The WISE campaign

The Council is justifiably proud of another aspect of its work which already has had tangible results. In 1984, The Engineering Council and The Equal Opportunities Commission set up the WISE (Women into Science and Engineering) campaign to overcome prejudices in school and at home against women becoming engineers.

There is little doubt as to the success of that campaign. Since it began there has been a steady increase in the proportion of women studying engineering in higher education (up from 7 to 15%). The winners of the last two Young Engineers for Britain (also a Council initiative) were girls. It would appear that at long last that the message is getting through.

[1] For further information on any of these schemes, please contact The Engineering Council, 10 Maltravers Street, London WC2 3ER Tel. 071 240 7891.

Clyde built

An appreciation of Scottish engineering

The ship illustrating our front cover is a work of beauty. It is easy to see why engineering was held in such high esteem a century ago when the products were as magnificent as the *Empress of Britain*. Working conditions then were often harsh. Not only were they dangerously risky and unpleasant, wages were low, housing poor, many were employed casually and layoffs were frequent. The diminutive figures in the shipyard hint at this. Stunted growth! Rickets! Glasgow was rife with rickets! And yet what man, woman or child could not but marvel at the ships? They dominated the local culture. The front cover shows that. The whole Clydeside community took a pride in their ships.

To appreciate why *Clyde built* was synonymous with the finest engineering of its age, why engineers from Glasgow, and indeed Scotland in general, had a worldwide reputation for excellence, we need to look at the historical record.

It might seem strange to some readers that shipbuilding came rather late to the Clyde. At the time of the Great Exhibition of 1851, at which the Victorians recognised and celebrated their burgeoning Industrial Revolution, most of Britain's shipyards were sited in the south of England. Shipbuilding on the Clyde was still relatively modest in scale. The main industry in and around Glasgow then was textiles. However Glasgow and Greenock had been busy seaports since the eighteenth century with the tobacco, cotton and sugar trade to the Americas. Glasgow merchants had prospered, and their wealth was to be a source of capital for nineteenth century industry. This sea trade and capital nurtured the growth of local shipbuilding.

The second main strand in the development was the Age of Enlightenment. It had a radical effect on eighteenth century Scotland. Indeed the Scots were at the heart of this movement. The Enlightenment had science at its core. If the purpose behind this was in defence of religious orthodoxy, its practical applications were not overlooked. One outcome was the belief that living conditions and social order could be improved by the intelligent application of the discoveries of science to agriculture, industry, medicine, architecture and civic works. The agricultural improvements from about the 1750s onwards resulted in vastly better crop yields. Our country changed from a land of recurring, occasional famine to a land of plentiful food supply.

From late medieval times, physics had been one of the subjects taught in the universities. From the 1700s the Newtonian influence was profound. Complex natural phenomena could be explained by simple physical laws. The universities responded by appointing lecturers, firstly in experimental physics and then, by mid century, in chemistry. The assertion of William Cullen, the first chemistry lecturer to be so appointed by Glasgow University, that his course would be "Chemical lectures and experiments directed chiefly to the Arts and Manufactures" shows the appreciation by these early academics that the practical application of science was the route to industrial advancement. It was an age of inventiveness. Watt had a working steam engine constructed by 1765. Here was orderly rotation out of the elements of nature - coal, water, vapour and fire. Science and order. Newtonian mechanics and Watt's steam engine. These were the wonders of the time.

Watt seems to have been an inspiration to local artisans. The rise of the Clyde shipbuilding industry was led by the marine engineers. In 1788, an inventive Dumfriesshire laird, Patrick Millar, with technical assistance from William Symington, experimented in steam powered craft on the loch at Dalswinton. After further efforts by Symington with his *Charlotte Dundas* on the Forth and Clyde

Canal, success in steam propulsion was achieved by Henry Bell's *Comet* launched at Port Glasgow in 1812. Many other vessels quickly followed. By 1820, 42 steam vessels had been built on the Clyde, more than half the British total at that time.

Technically, these early engines were primitive. The success of the steamship depended on solving two main problems : how to build boilers to withstand high pressure and how to improve the efficiency of the engine. Improvements in boilers came gradually, decade by decade. Pressures in the early steamship boilers did not exceed 5 p.s.i. relative. By the 1860s pressures of around 60 p.s.i. were typical. In that decade the newly established firm of James Howden devised the now familiar cylindrical boiler. By the end of the century, boilers were being built to withstand 200 p.s.i.

Engines developed in complementary fashion as steam pressures rose. One problem with pressurised steam is that when it is compressed in the cylinder it is liable to condense. Then when the cylinder expands, it re-evaporates. In consequence there is a loss in efficiency. This was overcome by allowing the steam to expand by stages in the compound engine. By the end of the century, triple- and quadruple-expansion engines were being built.

Of the three principal types of marine engine, reciprocating steam, steam turbine and diesel, Clyde engineers played the dominant role in the development of the first kind, a leading role in the second, but a minor role in the third. And thus to eventual decline! Nevertheless it is probably a fair assertion that their technological reputation rests ultimately on this record of marine engineering.

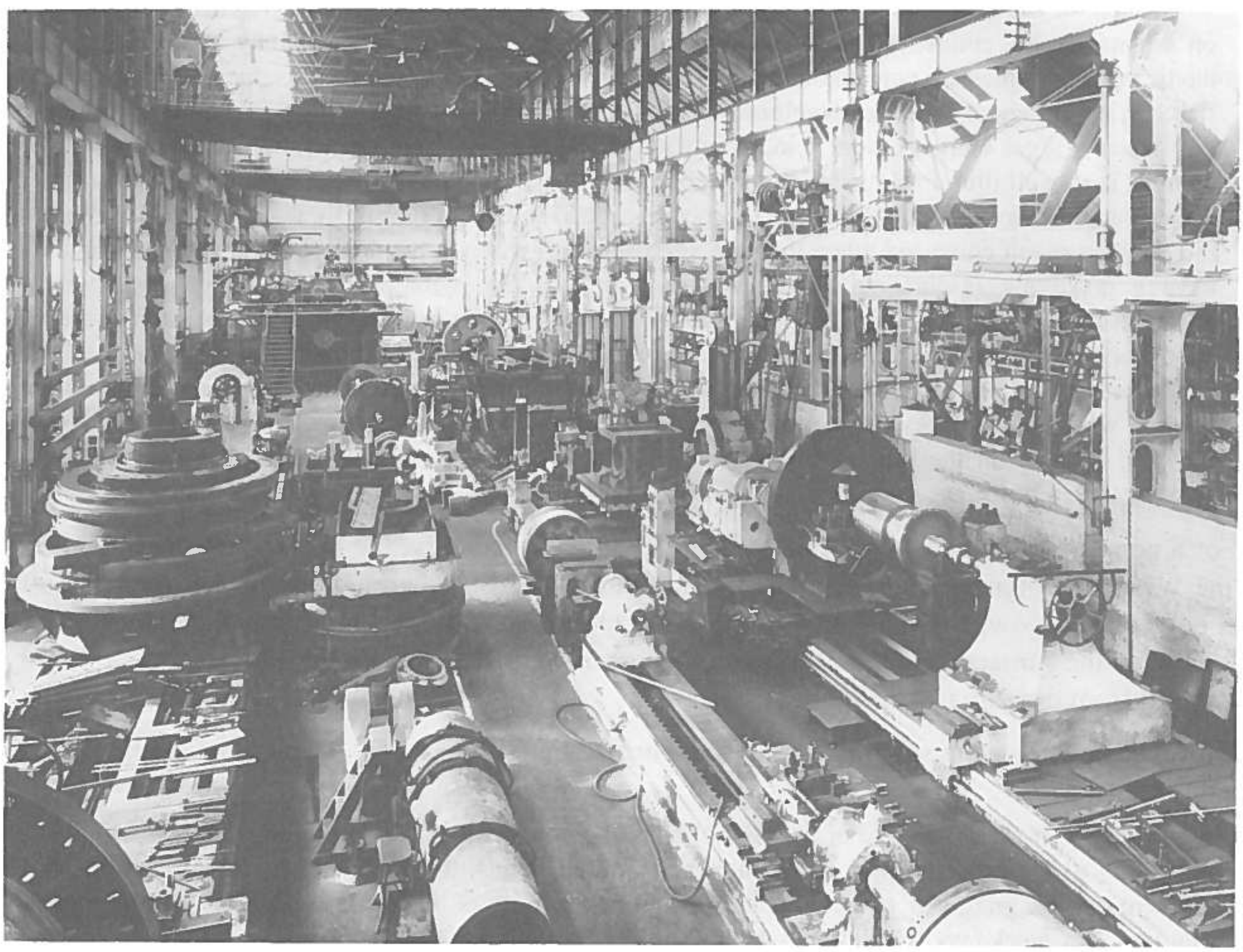


Figure 1. An engine shop at Alexander Stephen's Yard at Linthouse, Govan, 1946.

And what of the ships? The advances in building materials from wood to iron to steel accompanied the advances in marine engines. By the 1840s iron was replacing wood as the building material for ships' hulls. The transition from wood to iron was swifter on the Clyde than elsewhere. This resulted in a disproportionately high tonnage of Britain's output of iron-built vessels coming from the Clyde. Throughout the period, methods of working with iron improved. The skills acquired by some Scots ironworkers became second to none. This contemporary account written in the 1860s bears this out :

> . . . and it is gratifying to find Scotch firms occupying the foremost place among the makers of gigantic smithwork. The heaviest forgings required for the largest war and mercantile vessels afloat have been made at Glasgow. When the *Great Eastern* was building, it was feared that no firm would be found willing to undertake the forging of her shafts; but the Lancefield Forge Company, of Glasgow, accepted the task, and executed it in a most satisfactory style [1].

The other impetus to engineering development was the discovery in Lanarkshire of an abundant supply of easily worked coal and iron ore. Previously the Scottish iron industry had been based on small-scale charcoal burning operations in the woods of the West Highlands and at some notable Lowland outposts such as the Carron Ironworks near Falkirk. It now became concentrated in the North Lanarkshire area. Once the ironmasters had adopted the hot-blast method, devised locally by J B Neilson in 1828, it flourished.

> To appreciate Coatbridge, it must be visited at night, when it presents a most extraordinary and - when seen for the first time - startling spectacle. From the steeple of the parish church, which stands on a considerable eminence, the flames of no fewer than fifty blast furnaces may be seen. In the daytime these flames are pale and unimpressive; but when night comes on, they appear to burn more fiercely, and gradually there is developed in the sky a lurid glow similar to that which hangs over a city when a great conflagration is in progress. For half-a-mile round each group of furnaces, the country is as well illumined as during full moon, and the good folks of Coatbridge have their streets lighted without tax or trouble. There is something grand in even a distant view of the furnaces; but the effect is much enhanced when they are approached to within a hundred yards or so. The flames have a positively fascinating effect. No production of the pyrotechnist can match their wild gyrations. Their form is ever changing, and the variety of their movements is endless. Now they shoot far upward, and breaking short off, expire among the smoke; again spreading outward, they curl over the lips of the furnace, and dart through the doorways, as if determined to annihilate the bounds within which they are confined; then they sink low into the crater, and come forth with renewed strength in the shape of great tongues of fire, which sway backward and forward, as if seeking with a fierce eagerness something to devour. [2]

For a period of about 150 years, up to the middle of this century, the majority of the inhabitants of the West of Scotland experienced the thrill of this effect. Being brought up myself on the south-east edge of Glasgow, I remember seeing at six o'clock each winter's night the whole western sky aglow when the furnaces at Dixon's Blazes were opened up. Then at ten there was a repeat display in the east from the furnaces of Clydebridge.

However not everyone saw the scene through rose-tinted spectacles! There was another side to Coatbridge.

> Everything that meets the eye or ear tells of slavish labour united to brutal intemperance. At night, ascending to the hill on which the Established Church stands, the groups of blast-furnaces on all sides might be imagined to be blazing volcanoes, at most of which the smelting is continued Sundays and weekdays, by day and night, without intermission. By day a perpetual steam arises from the whole length of the canal where it receives the waste water from blast-engines on both sides of it; and railroads, traversed by long trains of waggons drawn by locomotive engines, intersect the country in all directions, and are the cause of frequent accidents, into which, by the law of Scotland, no inquiry is made. [3]

The invention of steel was the trigger for the boom in shipbuilding on the Clyde. It was an alliance of the inventiveness of the marine engineers, shipbuilders and iron workers. Steel was to be the ideal material for ships. Its discovery revolutionized ship construction. By 1879, 10% of ships from the Clyde were built of steel. Ten years later, this proportion had risen to 97%.

From producing as little as 5% of Britain's total tonnage of ships in 1835, by 1914 the Clyde was producing 35%. Shipbuilding came to the Clyde because of the native inventiveness of Scottish engineers, but did not really dominate the local economy until wit met steel.

The following sequence of photographs recording the construction of the *City of New York* was taken in John Brown's Yard in 1887. The age of steel had just begun.

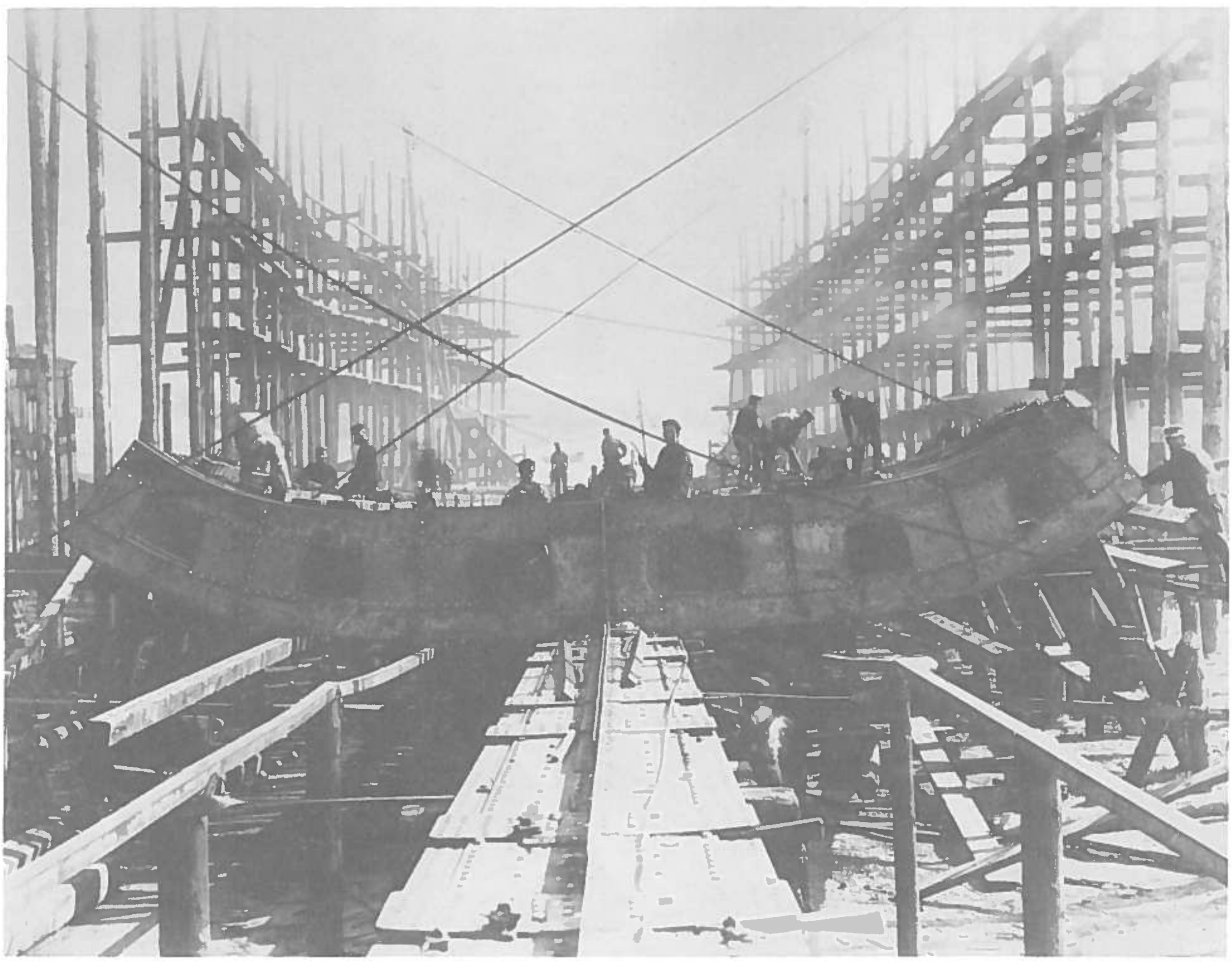


Figure 2. The fitting of hull plates during the construction of SS *City of New York*.

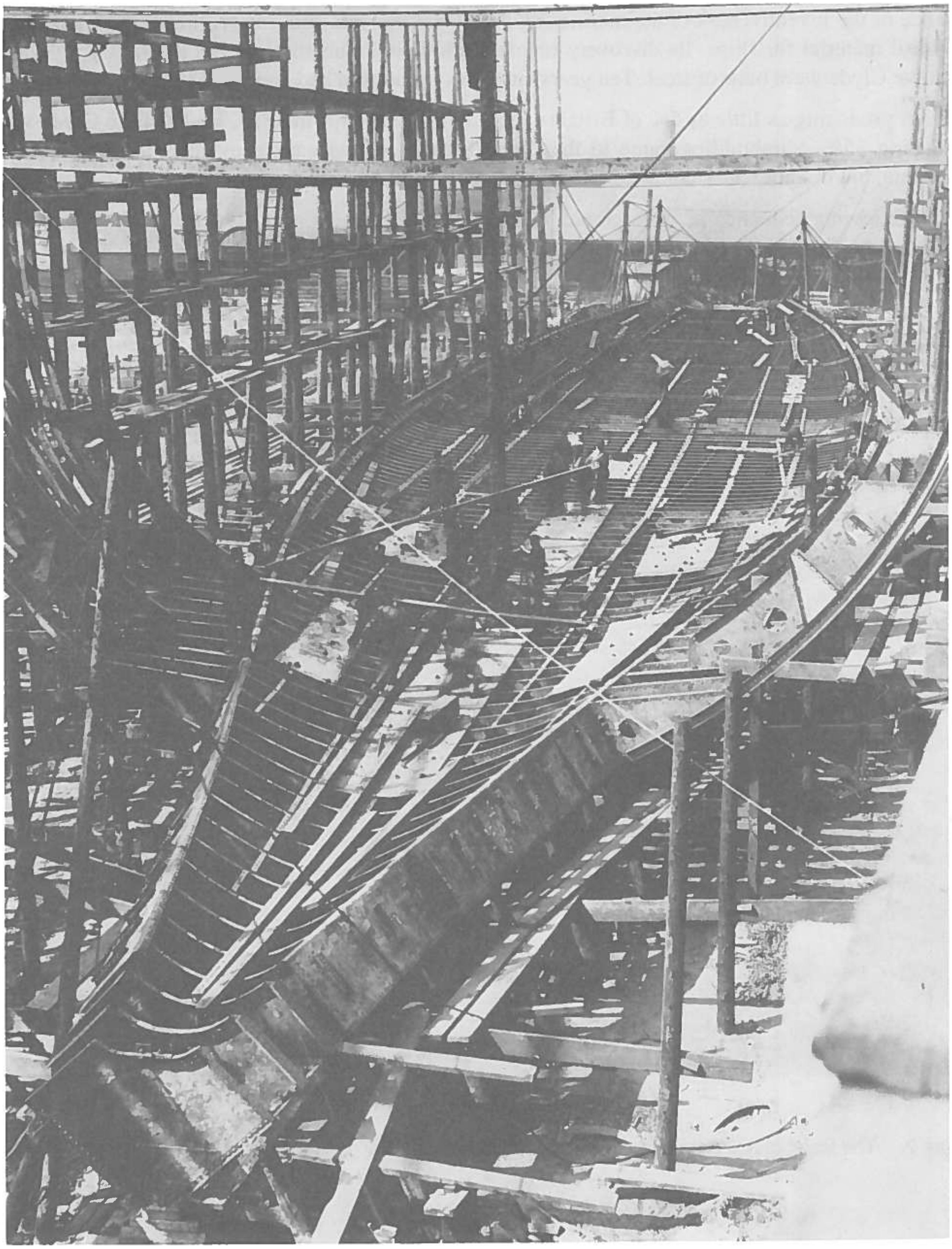


Figure 3. The construction of SS *City of New York*. Keel and hull laid. Work on ribs begun.

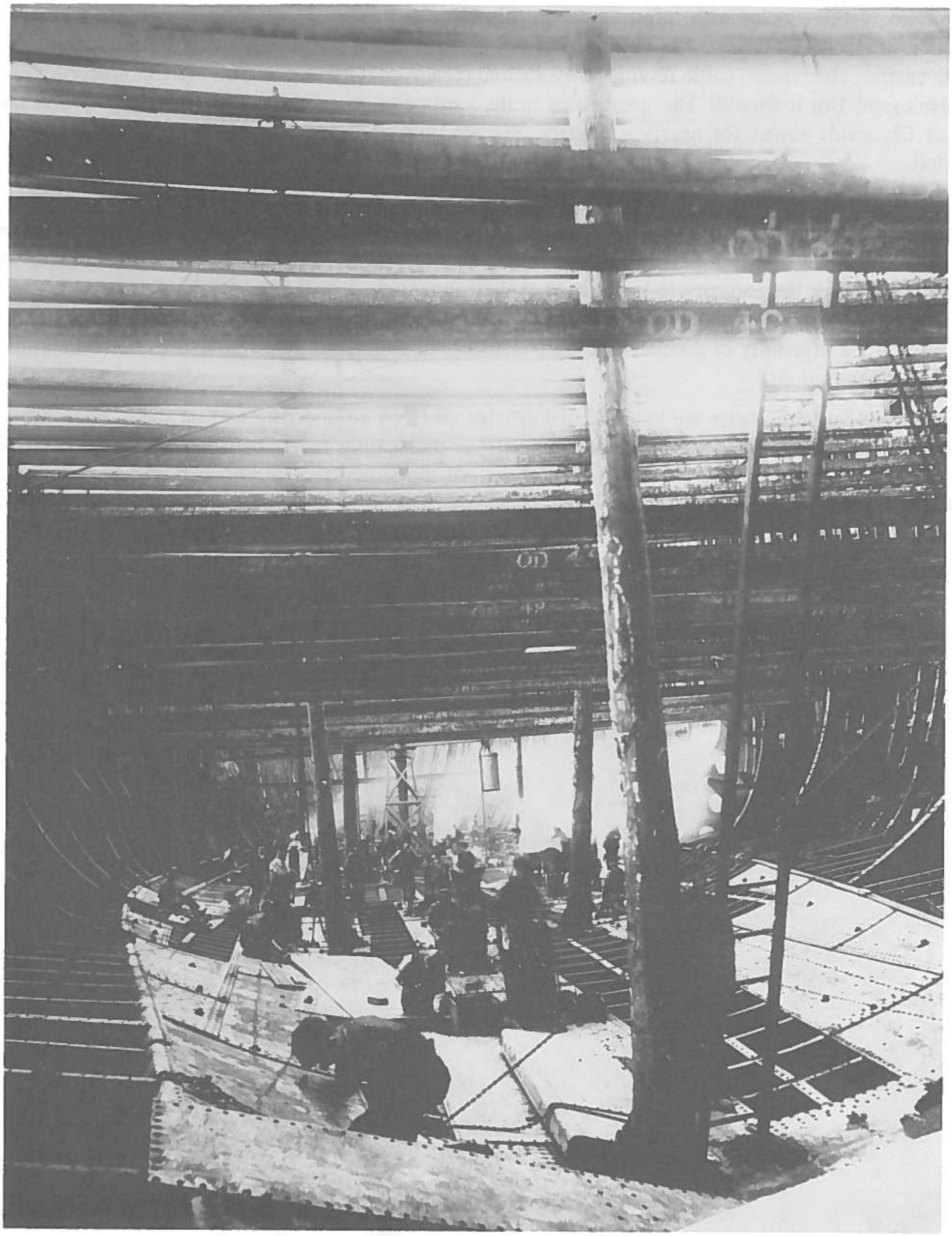


Figure 4. Later stage in the fitting of internal hull plates during the construction of SS *City of New York*.

Finding information on the development of Scottish engineering is hard going. There are surprisingly few books with information on this subject. Indeed if you visit the Scottish History section of any large Glasgow bookshop, you are unlikely to find anything much on this. Compared with castles, clearances, cattle reiving, crowdie and cream, coal mining or Culloden, engineering just doesn't rate! But it should! The great ships in the yards dominated the culture of Glasgow and the other Clydeside towns for nearly a century. We are now only one generation removed from that period.

Whilst it was easy for earlier generations to marvel at the effects and products of engineering, whether the pyrotechnics of the blast furnaces, or the ships on the stocks, it has become much harder to do so nowadays. It is a paradox of our times. Having surrounded ourselves with machines, we have largely lost the capacity to be amazed at their ingenuity. Whether as teachers of science or of technology, we have a challenge on our hands. How can we impart in youngsters the sense of wonder at the ingenuity of artefacts, of craftsmanship, of engineering design, that came so naturally to earlier generations?

In recent Bulletin issues we have carried articles on DNA engineering and on the Schools Chip. Here is state of the art modern engineering. 10^{11} is the scaling factor between the dimensions of molecules and ships. On a modern 6 inch wafer, all the structures on silicon might be sited to a tolerance of half a micron. From an overall size of 0.15 m, these structures are in place to within 1 part in 3×10^5. This compares well with a ship of overall length 100 m and in many of its components a tolerance of, perhaps, 1 mm.

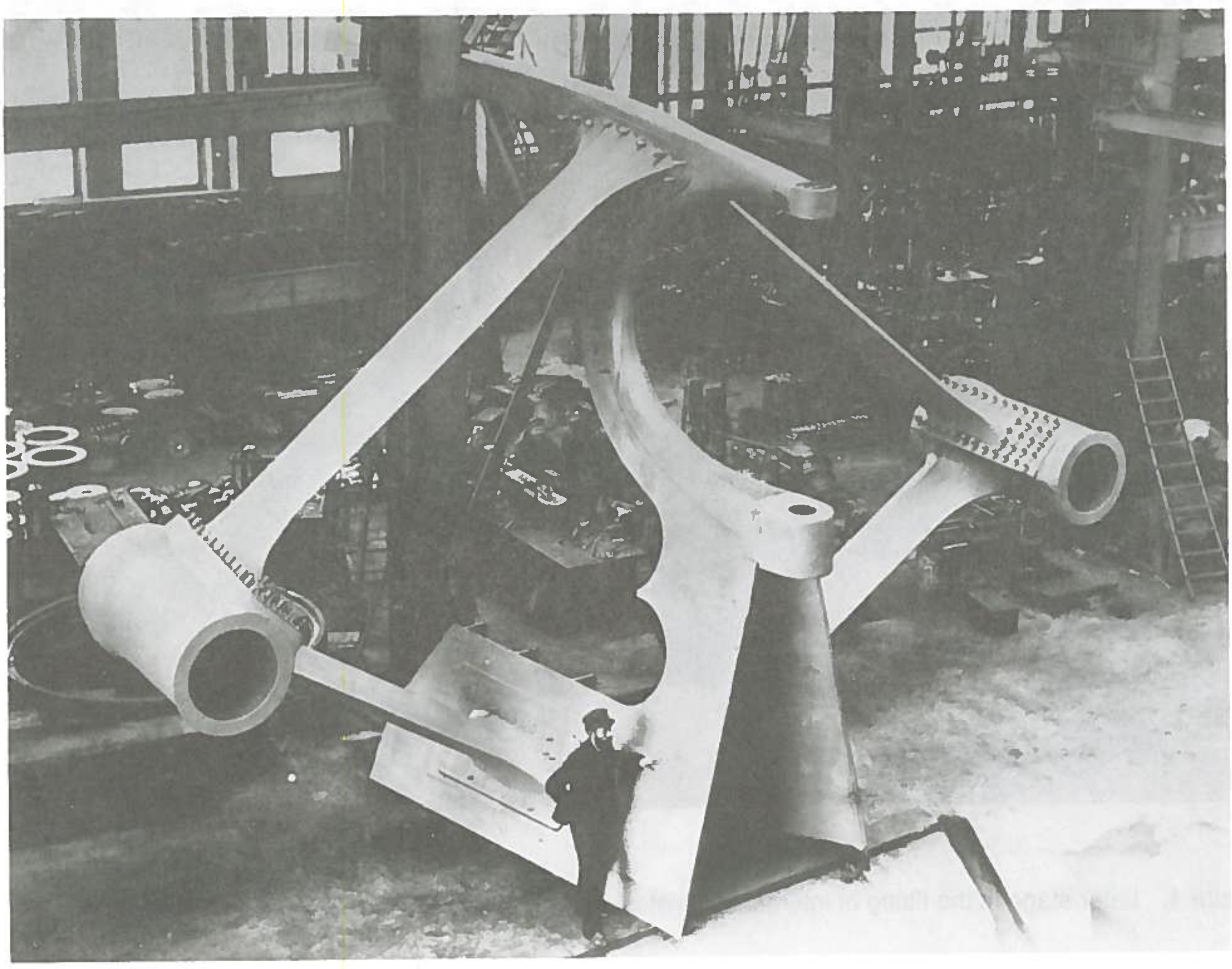


Figure 5. Stern post and brackets awaiting fitment to the hull of SS *City of New York*.

Imagine scaling down the stern post and brackets of the *City of New York* by a factor of 10^6. This would put the structure into the world of nanotechnology. I recently came across an electric motor built on silicon by an undergraduate engineer. Its rotor was about 100 µm in diameter. This revolved on a 10 µm diameter spindle. Modern artefacts can have the capacity to amaze. The challenge facing us is to find ways of effectively presenting technology to youngsters. In yesteryears technology spoke effectively, and sometimes elegantly, for itself. The whole community was in thrall. Today, whilst we would not choose to live without it, we pay it scant appreciation. One route to a better appreciation might be the historical one : by addressing questions such as why was *Clyde built* an expression of excellence?

This Bulletin issue

This issue of the Bulletin uses traditional engineering as its theme. It contains two articles on model steam engines. We suggest that the steam engine might be a basis in years S1 or S2 for looking at the historical development of engineering in Scotland. Such a study could be arranged cross-curricularly with joint approaches by the History, Technology and Science Departments. It provides a stimulus from the past which can enliven discussion both on contemporary issues and those for the future. It encompasses social as well as scientific and technological developments. Despite the great dreams of the Age of Enlightenment, major engineering achievements were made in the poorest of general social and environmental conditions. And where were the women, so conspicuous by their absence from our shipyard illustrations?

The *Equipment Notes* section has a technical review of model steam engines. As well as testing steam engines designed for use by children as toys - the sort mainly used in schools - we also report on an engine designed for adult hobbyists. Teachers may find that by upgrading to this standard of engine, they can devise more interesting tasks for the engine to tackle.

Some quite horrific accidents to children, fortunately very infrequent, have occurred during classroom demonstrations of steam engines. From studying the causes of these accidents, we can learn how to conduct these demonstrations in reasonable safety. We have therefore an article in *Safety Notes* advising on safe operational procedures. By following reasonable preventive and protective measures, there should be no risk of harm.

Acknowledgement

The photographs in this article and on the front and rear covers were obtained from, and have been reproduced with kind permission of, Glasgow University Archives.

References

1. D. Bremner, *The Industries of Scotland*, Edinburgh, 1869; reprinted 1969.
2. *Ibid.*
3. *Report of Commissioners to Children's Employment Commission on Employment of Children in Mines and Colleries,* vol. ii, 1842.

Work Equipment Regulations

A summary of the *Management of Health and Safety at Work Regulations 1992* was provided in this section of Bulletin 181. The Management Regulations are but one of a group of six made under the enabling powers of the Health and Safety at Work Act. Here we essay a description of another set of specific Regulations in the so-called "six-pack".

We know that educational employers and others in the sector are exercised about the practicalities of these Regulations. It seems also that the general requirements of the Work Equipment Regulations, as to the purchase of suitable equipment and its proper use, cannot be separated from the specifics of some earlier legislation. Nor can any of the detailed requirements for particular pieces of equipment be understood unless one refers out to technical standards such as those of BSI, IEC or ISO (see Glossary). HSE inspectors increasingly may use such technical standards as measures of enforcement.

And this was all meant to simplify the system?

The Regulations implement European Community (EC) Directive 89/655/EEC. This is one of many provisions for the Single Market. It requires similar basic laws throughout the EC on the use of work equipment. The Work Equipment Regulations are thus only part of a wider set of such safety legislation. Essentially the Provision and Use of Work Equipment Regulations (PUWER for short) use general principles previously laid down in the Health and Safety at Work Act 1974, principally those in Sections 2 and 6 of the Act. Section 2 dealt with employers' responsibilities to provide safe plant and systems. Section 6 covers the duties of manufacturers, suppliers and importers of equipment, articles and substances for use at work.

Under PUWER the definition of *work equipment* is very wide. It extends to a range of items from a simple tool such as a handsaw or scalpel through laboratory apparatus like a centrifuge, to larger items such as workshop machinery. It even covers a complex manufacturing facility if it is designed and intended to operate as an integrated whole. *Use* is also widely defined and covers all activities involving work equipment. These include stopping, starting, repair, modifications, maintenance and servicing. In addition to these operations normally included under *use* are cleaning and transport (carrying materials by use of equipment also being covered but not the use of a motor vehicle on the public highway). Excepted however are many items whose use is already covered by other legislation, such as hazardous substances subject to the COSHH Regulations.

The PUWE Regulations did not all come into force at once for all equipment. As from 1st January 1993 some of the Regulations applied to all equipment, whether existing or provided for the first time as new or second hand after that date. Other parts do not apply now to existing equipment, employers having until 1st January 1997 to comply fully.

Because of these transitional arrangements it is convenient to consider the Regulations split roughly into three sub-sets. Issues likely to be peripheral to most readers are to be found at both beginning and end. Regulations 1 to 3 deal with matters such as definitions and interpretations, commencement etc. whilst 25 and 26 deal with exemptions and extensions. Regulation 26 is of interest however since it lists those parts of older legislation effectively repealed or revoked once various provisions of PUWER come into force.

The important practical effects of PUWER stem from Regulations 4 to 10 and 11 to 24. Regulations 4 to 10 deal with :

- the applications of the regulations and the selection and suitability of equipment;
- maintenance arrangements;
- specific types of risk;
- information and instructions;
- training (some earlier provisions will still apply however, eg The Woodworking Machines Regulations 1974);
- conformity with EC Directives (one of the most significant being the Machinery Directive).

All employers who provide work equipment in their premises or undertakings have had to comply with the above provisions as from 1st January 1993. This is so even where the equipment was already in use before that date. These ten regulations also apply to second hand as well as new equipment supplied after that date. In addition Regulations 11 to 24 also apply to any new or second hand equipment first provided after 1st January 1993. They only come into force for existing equipment as from 1st January 1997.

Regulations 11 to 24, taken together, deal with :

- dangerous parts of machinery;
- protection against specified hazards;
- high or very low temperature (of equipment or articles produced by or stored within it, but not of the workplace itself which is covered under another set of new Regulations);
- controls for starting or significantly changing operational conditions;
- stop controls and emergency stop controls;
- controls and control systems;
- means of isolating equipment from sources of energy (eg electrical supplies, compressed air or hydraulic fluids);
- stability;
- lighting (possible need for local lighting of the work equipment in addition to ambient illumination);
- maintenance operations;
- markings and warnings.

It would take all of this Bulletin to describe each of these requirements in detail. Those with specific responsibilities for such matters are recommended to obtain a copy of the relevant HSE Guidance document [1]. All we can do here is to point to parts of PUWER of more general interest.

For example, Regulation 9 of PUWER deals with training. The HSE guidance on this requirement reinforces earlier advice in the *Management Regulations* that such training is best based upon *statements of competence* and that these may be embodied in Vocational Qualifications (NVQs and SVQs). Also of interest to the education and training sectors is the HSE advice on Regulation 9 and *Additional requirements for young people*. This indicates that specific training requirements will continue to apply to young people using certain machines (eg Section 21 Factories Act 1961, Section 19 Shops, Offices and Railway Premises Act 1963 and Regulation 13 of the Woodworking Machines Regulations 1974).

A feature shared with some other recent EC inspired legislation is Regulation 10 on conformity with Community requirements. This aims to ensure that work equipment meets essential health and safety requirements. The *Provision and Use of Work Equipment Regulations* place duties on employers which complement those laid on manufacturers and suppliers by other legislation as to the initial integrity of equipment (eg Section 6 of the Health and Safety at Work Act). Existing national legislation in these areas is increasingly supplemented by new and more specific Regulations implementing EC Directives made under Article 100A of the Treaty of Rome.

These *Product Directives* are intended to remove technical barriers to trade and secure free movement of goods throughout the Community. They lay duties on the manufacturers and suppliers of new equipment.

In the short to medium term the situation will remain complex. This is because many categories of work equipment are not yet covered by a Product Directive and because such directives are not retrospective. Also they are designed to eliminate differing national controls and to harmonise essential technical and safety requirements. They are sometimes called *New Approach* Directives and share a common feature in that compliance is claimed by the manufacturer affixing a mark - the *CE* mark - to the equipment. One way of demonstrating such compliance with essential safety requirements will be by designing and manufacturing to the new harmonised standards. These are made by the European Standardisation Bodies - CEN and CENELEC - and are known as EN Standards or European Normes. In the UK they are transposed by the British Standards Institution so that the EN and the British Standard bear a common number. Thus EN 1234 will become BS EN 1234 here. It is expected that most manufacturers will design and construct to such Standards - although their use is voluntary. Once these Product Directives are fully in force only those conforming products with a CE mark may be placed on the market in the UK or anywhere else within the Community.

The approach taken by Regulation 11 on *Dangerous parts of machinery* is also of interest. It is important to remember that the term *work equipment* goes far beyond the traditional categories such as those in the Factories Acts. Those who had to interpret that older legislation will be familiar with the fairly rigid approaches to the guarding of machinery adopted therein. They will know too the arguments over concepts such as the absolute duty to guard and safe by position etc. HSE's interpretation in its guidance on PUWER takes a somewhat different tack. HSE guidance suggests a risk assessment based approach. It quotes Regulation 3 of the Management Regulations in support of this. As with the Management Regulations and the earlier COSHH Regulations, a risk management hierarchy of preventive and protective measures[1] is then used. This hierarchy of prevention and protection has several levels :

- fixed, enclosed guards;
- other guards or devices which may include :
  - movable guards (probably interlocked);
  - adjustable guards;
  - guards which whilst fixed are not fully enclosing;

cont./over

[1] This terminology was possibly adopted to avoid confusion. The COSHH Regulations lay down a hierarchy also. There the risk limiting steps are termed "Control Measures". The wish to avoid confusion between "Controls" on equipment and "Control Measures" in COSHH is understandable.

- protection devices which do not prevent access but stop movement of the dangerous part before contact can be made;
- protection appliances which include jigs, pushsticks etc which allow the feeding of a loose workpiece into a machine (e.g. a wood-working type machine) whilst allowing the operator to keep his or her body clear of the danger zone;
- adequate information, instruction and training (which are needed also even where guards are fitted but are crucial where the hazards cannot be eliminated by the hardware measures listed above.

These other measures may have to be written down (thus describing a *safe system of work*). The use of certain equipment may have to be restricted to those who have had instruction and training and who thereby might be deemed competent to operate it safely.

Appendix 3 of the HSE Guidance is particularly helpful in explaining these *Dangerous Machinery* requirements. The risk assessment and hierarchy of controls approach is also likely to be useful when assessing situations other than the more familiar technology workshop problems.

Overall summary

The *Provision and Use of Work Equipment Regulations 1992* have the following major provisions and effects :

- a wide definition of use taking in the old Factories Acts concept of *in motion* and *in use* by including setting up, cleaning and maintenance operations etc;
- an equally broad approach to the meaning of equipment and application to every workplace whatever its nature;
- immediate application to new equipment as from 1st January 1993 and a transitional period up to 1st January 1997 for applying parts of the legislation to existing equipment;
- broad general principles laid down on stopping, starting, controls, information, supervision and training etc. with the detail in Product Directives and relevant technical standards (EN standards) with compliance indicated by the CE mark;
- protective and preventive measures to be decided upon by risk assessments (cf. COSHH and the Management Regulations)

Where adequate control of risk cannot be achieved solely through hardware design then it may be acceptable to further limit risk through improvements to the systems of work (information, instruction, training and supervision - see also the articles on centrifuges and autoclaves in the Equipment Notes section).

Conclusion

A particular difficulty for us is that educational users of equipment often find themselves at the margins of these matters. This is true of both of the key processes - the drafting of Regulations and the writing of the technical standards which are increasingly used to back them up. A number of related issues are illustrated in the rest of this Safety Notes section. This is in the context of specific problems with autoclaves, centrifuges and steam engines. On a happier note - Machine Safety is the subject of a technical article for teachers and pupils of technology. There we attempt to show how safety technologies can provide great interest as well as a stimulating context for problem solving exercises of wider application.

Caveat

Please, don't shoot the messenger, but . . .!

When we were first considering the content of this article the Health and Safety Commission (HSC) had just announced a consultation process on the "six-pack". This is part of a wide ranging review which may well lead to rationalisation of the original six sets of Regulations. This may also extend to other, earlier legislation such as the COSHH Regulations (1988) and the Noise at Work Regulations (1989) both of which share the central feature of the six pack - a requirement for risk assessments.

As we went to press the consultation process still had a month or so to run. Changes to the law, if any, will obviously not be made for a considerable time after that, (months if not years may pass). We will try to keep readers informed on any significant developments if and when they occur.

Reference

1. *Work Equipment : Provision and Use of Equipment Regulations 1992 : Guidance on Regulations L22*, Health and Safety Executive, HMSO, 1992, ISBN : 0 11 886332.

Glossary

Note that a number of these acronyms may have no direct equivalent in any Community language. The English interpretation given is that in general use for technical publications and similar purposes.

BS	British Standard
BSI	British Standards Institution
CE mark	European Community (Communauté Europêene) compliance mark or label
CEN	European Committee for Standardisation
CENELEC	European Committee for Electro-technical Standardisation
EN	European Standard or European Norme
prEN	Provisional Standard (ENV - draft or pre-standard)
IEC	International Electrotechnical Commission
ISO	International Organisation for Standardisation

SAFETY NOTES

Pressure Systems Regulations

The Pressure Systems and Transportable Gas Containers Regulations 1989 came fully into force as from 1st July of this year. The major requirements are summarised. A reminder is given of earlier circulation by SSERC of proforma providing schemes of examination and for recording the results of annual inspections.

Application and scope - The Regulations apply to :

- equipment ("plant" in the jargon) which contains a "relevant" fluid ie gas or liquefied gas including air and
- which is used used at work by employees or the self employed where it is
- operated at a pressure greater than 0.5 bar (about 7 psi) above atmospheric and
- where the product of pressure x volume for any pressure vessel in the system exceeds 250 bar litres (eg a 30 litre vessel at 8 bar relative gives a figure 8 x 30 = 240 bar litres which just escapes the requirements).

If the Regulations had stopped at that, then most pressure equipment used in schools would have been outwith their scope. Unfortunately, there is a catch-all for any pressure vessel containing steam, regardless of the product of its pressure and volume. We are not convinced that the legislators foresaw the full consequences of that requirement[1].

For schools this means that the Regulations apply to pressure cookers, autoclaves and model steam engines. More sensibly they also apply to some larger models of compressors. These are of the type with a receiver for storing the compressed air. Some compressors of this type are used in schools and FE in the teaching of pneumatics. Most operate at about 8 bar and where the receiver capacity exceeds 30 litres or so they will breach the 250 bar litre limit (see above).

The Regulations also apply to the *owners* of transportable pressurised gas containers and accessories. We italicise "owners" to emphasise an important distinction. Usually, cylinders of gas for teaching purposes are not in the ownership of the EA, school or college but are hired or leased from a specialist supplier. In that case the onus is on the supplier to meet the requirements of the Regulations. What complicates matters is that any valves, regulators and gauges used with such cylinders may well be owned by the EA or the school as user.

1. This is just a long winded, if politer, way of saying that we're fairly sure they cocked-up.

So, as far as the "... Transportable Gas Containers" bit of the Regulations is concerned, most schools and colleges may only need to get exercised about the accessories for controlling the flow of gas rather than with the ongoing integrity of the container. Even so, whilst it may be good practice to examine periodically such valves and other accessories, recent interpretations by HSE would indicate that these items are not seen as part of the pressure system and are not subject to the Regulations. It should be noted also that there is little or no accident history to the use of diaphragm or needle control valves on these cylinders. Reputable suppliers have assured us that even if their valves were to fail such failure would not result in significant risk.

Basic requirements - The Regulations require users, or persons in control of the system, or both of these to :

- establish *safe operating limits*;
- have a suitable scheme drawn up, or certified, by a *competent person* for the examination at appropriate intervals of vessels and safety devices;
- arrange for such examinations by a competent person[2] according to the intervals set down in the scheme[3], keep records of the results and of any manufacturer's tests;
- provide adequate operating instructions so that equipment is used within its operating limits, and that an emergency can be properly dealt with;
- ensure that equipment is properly maintained.

2. The "competent" persons referred do not have to be the same individual or corporate body (EA, organisation, firm etc) in each case.
3. Although other provisions came into force as from 1st July 1990, those for regular examination became mandatory only as from 1st July of this year. Nevertheless several Scottish EAs voluntarily began inspections (usually annual) as from 1991. This was as part of their overall systems for routine maintenance. Some also integrated these pressure vessels checks with others such as for performance (on autoclaves as COSHH control measures) and electrical safety testing (GS23). This meant that the same item of equipment wasn't subjected to three separate inspections at different times of the year.

Interpretation of terms and detailed requirements -

Safe operating limits?

The upper limits of pressure or of pressure and temperature for which the equipment was designed to ensure its safe operation. This is sometimes also termed *design pressure*. This is not the same, and is usually several orders of magnitude less than, the maximum pressure which would destroy the integrity of the vessel itself. It is also less than the *proof test* pressure which is routinely used for non-destructive batch or sample testing in the manufacture of pressure vessels.

The upper operating limit for pressure is determined from one or more of the following :

- the maximum working pressure as stated on the most recent examination report;
- the manufacturer's safe working pressure as stated in any manual or instruction sheet;
- a maker's plate affixed to the actual equipment.

A *competent person* may review and reassess safe operating limits when equipment is subjected to a regular inspection according to the scheme of examination. They may also have to be reviewed whenever equipment has been repaired or modified. In practice this is most unlikely to happen for equipment used in a school or college. The equipment will tend either to be safe for use at its original design limit or not. If *not* then setting a lower limit is likely to be impracticable and the equipment would have to be replaced.

It is important to note that there is no requirement to subject equipment, of the kind used for teaching in schools, to any hydraulic or other pressure tests on the vessel itself. The manufacturer's design and test certificate(s) provide sufficient evidence for the purposes of establishing safe operating limits.

Who draws up, or certifies, the written scheme?

A *competent person* does this. *Person* does not necessarily mean an individual. It may be a body corporate such as a company (eg an insurer or his specialist inspectors), an education authority, or a professional association.

What makes this person competent?

In official guidance to the Regulations relevant equipment is categorised as *major*, *intermediate* or *minor*. This is important because the requirements of a competent person become more onerous as the equipment type shifts up the categories. In our opinion, nearly all equipment used in schools for teaching purposes and much in FE colleges falls into the minor category. As indicated earlier we doubt that some items - for example model steam engines, pressure cookers or small autoclaves - would have come under the Regulations at all had the Parliamentary drafting system been wider awake.

Because of that and because the requirements for most relevant educational equipment are simple it is our view that at this level a requirement for incorporated or chartered engineer status, as a test of competence, is inappropriate. In any case that is a suggestion made in the guidance rather than laid down in the Regulations themselves.

Some time ago SSERC, in association with CLEAPSS and HSE, drew up guidance on the Regulations and produced written schemes of examination. One such circular covered autoclaves, pressure cookers and steam engines. The other dealt with pneumatics systems. These were circulated in Autumn 1990 to Scottish science and technology advisers, health and safety officers and chief technicians where appropriate.

Who is competent to carry out the examination?

To quote HSE guidance : "An organisation is competent to examine a pressure system under the Regulations only if it employs staff with adequate practical and theoretical knowledge to assess the actual condition of the plant (*or equipment*), and whether it will not cause danger in the period up to the next examination when properly used."

It follows from the comments in the preceding sub-section that recognised engineer status is not needed for the examination of most items of teaching equipment in schools and FE colleges. Whilst it makes excellent sense for boilers or other large, pressurised plant in an educational building it verges on the ridiculous to suggest that this is required of staff to assess a small, portable autoclave or model steam engine. It may be appropriate for the internal examination of the receivers of compressors whether or not these breach the 250 bar litre limit. Such examinations require the use of specialised optical equipment unlikely to be held in the average school or college.

Given suitable training there is no reason why an experienced science or technology technician might not carry out other routine examinations against written schemes. There are parallels here with inspections and tests carried out on portable electrical apparatus as recommended in HSE Guidance Note GS23. Most of the checks to be formally recorded in the annual inspection are those which any responsible user would informally and routinely carry out before using such equipment. The inspection pro-forma drawn up by SSERC or our colleagues in CLEAPSS merely provide both aide-memoire and a convenient form of record.

Some Regional and Islands education departments have established arrangements with specialist inspectors of their insurers for the examination of pressure vessels. Some may well choose just to continue with, or extend these to, the examination of autoclaves etc. There is however no requirement that an insurance company or associated inspectors be used. For items such as pressure cookers it could then be more cost-effective just to renew the equipment routinely, say, every three years or so.

When might staff not be deemed competent examiners?

It is important also that technicians are trained to recognise the limits of their expertise. This is a key part of any scheme of safety inspection and of the associated training.

When certain defects become apparent to inspection it may need the judgement of a more experienced and formally qualified person to assess their seriousness and decide whether or not those defects are likely to cause danger before the next due date for examination. One example is pitting or other signs of corrosion in the base or walls of a pressure vessel. It may need a more experienced person to assess whether the extent and depth of such pitting signals a need to repair or replace the equipment.

A definite, if arbitrary, limit can be set to trigger such referrals. In the example quoted we set a limit with a comfortable margin of safety. This was that in any case where pitting included holes more than 1 mm deep and, or, extended to more than 20% or so of the area of the base[1], a second opinion be sought as to the need for replacement.

The other limit to competence is that simple pro-forma must not be used for the inspection of more sophisticated equipment. For example, some FE colleges have large floor-standing autoclaves for the preparation of microbiological media and materials. It should be obvious that these are not amenable to simple checking against a list designed for use with small portable, bench-top devices.

How do you provide operating instructions?

This normally means using the original manufacturer's instructions or manual for the equipment. For some pieces of older equipment that may prove problematical or even impossible. In these cases you shall have to write your own. In the case of autoclaves Topics in Safety, Chapter 5a, (ASE, 1988) or SSERC Bulletin 126 should prove helpful. SSERC is also willing to assist further in cases of specific difficulty. For advice on the use of model steam engines see later in this issue and SSERC Bulletin 149.

Another potential problem with autoclaves is that the manufacturer's instructions may have been written primarily with other user groups in mind. They may proscribe some applications which are routine in education. This means that some sections of the manufacturer's manual may have to be amended or replaced with your own user-specific instructions (see Equipment Notes in this issue for some specific examples). It may also bring a need for simple in-service training and supervision.

1. Area estimated by visual inspection and pit depth with a suitable gauge.

How is pressure equipment "properly maintained"?

Any manufacturer's service or maintenance instructions should be carried out at appropriate intervals (e.g. gasket or safety valve replacement).

Operational points which may have long term effects on the integrity of the vessel should be acted on. For example it is important to use distilled or deionised water and not tap water in any steam engines (corrosion and deposits clogging safety valves) and in autoclaves with aluminium alloy vessels (some tap waters lead to excessive and early pitting).

Faults which become apparent during day to day use should be attended to straightway. Any faults recorded in the annual examination should be reported to the person responsible for remedying them. The inspection pro-forma and records should provide space for recording both the reporting of any faults and the actual outcome (dates of repair, re-entry into service or replacement [no action?] etc).

What records do you need to keep?

One of the current problems in health and safety management is excessive paperwork. School based work lies right on the boundaries of this (and much other) legislation, so keep your paperwork to the bare minimum. This would be :

- the written scheme of examination;
- a record of the latest results from the above and
- also helpful, but not required, is a record of any maintenance, repairs or modifications carried out between examinations.

All three elements may be combined on one sheet of paper. With a little imagination it is even possible to fit several years records on one sheet of A4 per device (although you only ever need the preceding years results). The only other paperwork you need to keep on file are manufacturers' test certificates, reports and instructions specifically relating to the equipment and to your written scheme of examination.

Do you have to replace any old equipment?

Equipment which does not meet current standards of design and construction can continue in use so long as an inspection report by a competent person confirms that it *will not give rise to danger* before the next inspection.

Further detail

If you do not have other means of access to the SSERC schemes of examination (or your EA's modified versions thereof) further copies can be obtained by writing to the Director here at SSERC.

Steam engine safety

Following three serious accidents in the mid 80s, which followed on a spate of earlier incidents, advice on the safe use of steam engines and on the risk of alcohol fires was published both in this journal [1] and in Education in Science [2] [3]. That was some eight years ago. The lack of subsequent accident reports may possibly be attributable to this counsel. Either teachers are now more careful, or the damn engine is no longer being used! It would be a shame if the use of this apparatus has indeed declined. Running a steam engine is educationally valuable and it should also be a bit of fun. This article arises out of a need to :

- help schools and employers carry out a risk assessment as required jointly by the new Management of Health and Safety at Work Regulations and Work Equipment Regulations [4] [5];
- allay fears that all such boilers must undergo routine pressurised safety tests; and
- advise on safety procedures for model engines designed originally for the adult hobbyist but that have recently appeared also on the educational market.

Your attention is therefore drawn to the table listing the hazards associated with operating a model steam engine (Table 1). Alongside each hazard type, appropriate preventive and protective measures to limit the risks are recommended. The applicability column refers to the three model engines reviewed in Equipment Notes. These three types are believed to be generically representative of the range of models currently on the market.

When running an engine, it is important that you follow the manufacturer's operating instructions and observe his safe operating limits. We have had a report of a person intentionally soldering up the safety release valve to attain a higher pressure. That person then proceeded to heat the boiler with a Bunsen burner. This sort of action would certainly seem to be in breach of Sections 7 and 8 of the Health and Safety at Work Act and, quite apart from being dangerous, could lead to prosecution.

The Cheddar engine we have tested is a little more complex to run than the Mamod and Wilesco engines sold mainly as toys. It therefore seems advisable that unless you are reasonably competent at operating steam plant, you should have had some simple, informal training before using a Cheddar engine with a class. Also, because many teachers operate a steam engine only once a year, it can be presumed that the full procedure may be forgotten after such a time span. The familiarization routine should therefore be repeated every year. Suitable training might consist of little more than reading the manufacturer's Operating and Safety Instructions for the engine, identifying the engine parts and running the engine a few times to gain familiarity sufficient to ensure its safe operation.

We know of a school whose Cheddar engine is demonstrated by technicians rather than by teachers. This seems to be quite a prudent policy in that the engine is always in practised, and thus competent, hands.

The main hazards with steam engines devolve from the type of fuel. Related to the use of natural gas with the Cheddar engine is the risk that the gas is left on for too long a period, or is simply forgotten about. Gas has no conscience! Unlike solid fuel, which ultimately runs out, gas heating has no cut-off system other than from an act of human volition. Although this point is ever so obvious, the engine operator must keep a sharp look-out on time and at water levels. Setting a stop-clock or count-down timer with a 10 minute period when steam is first raised would seem to be a useful extra reminder.

Steam engines do have to be formally inspected once a year by a competent person working to a written system of examination and a record kept. This is a requirement of The Safety of Pressure Systems and Transportable Gas Containers Regulations 1989 [6]. Also helpful, but not required, is a record of any maintenance, repairs or modifications carried out at or between examinations. The competent person can be a school or local authority employee who has been trained to inspect such simple pressure systems.

Model steam engines are relatively small even for what is termed minor plant in the Regulations. When guidance and suggested written schemes were first drawn up for educational employers by CLEAPSS and SSERC, it was suggested that for such items the competent person need not be of incorporated or chartered engineer status. HSE staff of the Education Service Advisory Committee (ESAC) had sight of the various papers and did not object to that advice nor comment on it in any way. More recently we have had more specific enquiries on this question. The matter has again been raised with HSE through the ESAC Secretariat. We await either confirmation or refinement of earlier advice on the interpretation of "competent person" in this context. Further discussion on steam engine inspections is given in this issue as a separate article - Pressure Systems Regulations. A written system of examination has been prepared by SSERC and has already been circulated to Scottish education authorities. CLEAPSS School Science Service took a similar line of action for schools in member EAs in England and Wales.

The Cheddar model reported on elsewhere in this issue is somewhat more complex than those sold as children's toys. Cheddar recommend that their boilers are tested at least every other year in accordance with the Southern and Northern Federation of Model Engineers' specifications. This includes testing the boiler hydraulically. Cheddar provide a testing service for their customers. Notwithstanding what we have written in the preceding paragraphs, it may be prudent to comply with the maker's directions either by returning to Cheddar every two years any steam plant of theirs for testing, or by having the engine tested locally to this specification.

References

1. *Model steam engines*, Safety Notes, Bulletin 149, SSERC, February 1986, pp 6-8.
2. *Model steam engines*, From the Laboratory Safeguards Sub-committee, Education in Science, 116, ASE, 1986, p 15.
3. *Alcohol fires*, From the Laboratory Safeguards Sub-committee, Education in Science, 116, ASE, 1986, pp 15-16.
4. *Management of health and safety at work : Approved Code of Practice (ACoP)*, Health and Safety Commission, HMSO, 1992, ISBN 0 11 886330 4.
5. *Work equipment : Guidance on Regulations*, Health and Safety Executive, HMSO, 1992, ISBN 0 11 886332 0.
6. *Safety of Pressure Systems and Transportable Gas Containers Regulations 1989 : Approved Code of Practice (ACoP)*, Health and Safety Commission, COP 37 HMSO, ISBN 0 11 885514 X.

Hazard	Comments	Preventive and protective measures	Applicability		
Ethanol fires, including unconfined vapour cloud explosion from spirit burners	Ethanol is highly flammable. Its flash point is 12°C. Several types of ethanol fire have occurred : 1. A liquid spirit fire caused by refilling the burner before the flame had gone out. This can turn into a major fire if the liquid in the stock bottle ignites. 2. If a spirit burner is refilled from a plastic bottle via a nozzle before the flame has gone out, burning fuel can be sucked into the stock bottle. 3. If a spirit burner is refilled with ethanol before the burner has cooled down, a large amount of ethanol can evaporate. Given a source of ignition, the vapour cloud can readily catch fire, the fire spreading explosively through the vapour-air mixture. This has been a cause of serious injuries to pupils one metre distant from the steam engine.	Use only solid fuel in a burner specially designed for solid fuel.	C	M	W
		Never attempt to use a liquid fuel in a burner intended for solid fuel.	C	M	W
		Destroy and dispose of any liquid fuel burners.	-	M	W
Gas air explosion	If using a boiler with a gas burner, take care that unburnt gas is not released into the atmosphere. This can happen if the gas fails to ignite, or if the flame is dowsed with excess water escaping from the steam vent or safety valve.	After trying to light the gas, or after any excessive release of steam, always check that the gas is lit by placing a hand momentarily 20 cm above the funnel to detect a hot convection current rising from the flue.	C	-	-
		Do not look for the flame by peering into the funnel, which would be extremely dangerous.	C	-	-
Chemical toxicity of solid fuel tablets	Esbit and Mamod solid fuel tablets contain hexamethylenetetramine (often known by its alternative name hexamine). It is a poison by skin absorption. It has been shown to cause tumours in animals and is believed to be mutagenic. When heated it emits toxic fumes of formaldehyde and NOx. There is not much to choose between hexamine and Meta fuel, which hexamine seems to have replaced as solid fuel. If anything, Meta fuel is slightly less hazardous.	Try to avoid skin contact. Handle blocks with tweezers or tongs. Try to avoid breaking up blocks and producing crystalline debris.	C	M	W
		Ventilate the laboratory.	C	M	W
		To extinguish the tablets, place the fuel carrier in a metal (biscuit) tin and close the lid.	C	M	W
Camping gas	Cheddar engines can be operated off camping gas as well as off natural gas. Different types of burners are needed.	Camping gas is not recommended as a substitute for natural gas because the cylinder is very thin and can readily be punctured.	C	-	-
Fire to clothing or hair	Pupils wearing readily flammable clothing or hair preparations have suffered burn injuries from their clothing or hair catching fire.	Discourage pupils from wearing readily flammable clothing or hair preparations.	C	M	W

Table 1. Steam engine hazards and risk assessments. Code : C = Cheddar engine, M = Mamod engine, W = Wilesco engine. (Continued overleaf)

Hazard	Comments	Preventive and protective measures	Applicability		
Burns		Care is required in handling hot parts.	C	M	W
	The base plate of an engine should always be sufficiently cool in places to handle safely.	Because the Cheddar base plate becomes too hot to handle, it must be mounted on a larger wooden base.	C	-	-
	The flue gas from the Cheddar is dangerously hot.	Do not look into the flue of a Cheddar engine. Wear eye protection when operating it. The eye protection should be of a heat resisting material.	C	-	-
Scalds	During a normal operating cycle, steam and droplets of condensed steam are released from the cylinder, safety valve and funnel. The rate of flow and rate of cooling are such that an adult's skin is unlikely to be harmed. Young children may be more susceptible to injury.	Never attempt to refill the boiler until you are sure there is no pressure left.	C	M	W
	The main steam shut-off valve on the Cheddar is non-captive and therefore can be removed by unscrewing. There is a significant risk of scalding.	Do not open the steam valve more than 4 turns. Affix a warning label on the engine.	C	-	-
Steam boiler explosion	We know of no accident reports in recent years of model steam boiler explosions. Primary protection is afforded by the safety release valve on the boiler.	Before using the steam engine always check that the safety valve (or valves) is in working order by seeing that the movable part is free to operate.	C	M	W
		Replace defective ball bearings, washers and springs. Remove lime-scale deposits.	C	M	W
	The valve and steam outlet can become obstructed with deposits of calcium carbonate or other substances.	Use distilled or de-ionised water unless the water supply is soft.	C	M	W
	If a boiler is overfilled the pressure can reach the release pressure.	Do not overfill the boiler.	C	M	W
	If a boiler runs dry, it can overheat and develop leaks.	Top up the boiler water before running.	C	M	W
		If firing a boiler by gas, take care to turn off the heat when the water reaches the minimum level. Use a count-down timer as an added check.	C	-	-
	Corrosion may weaken a boiler.	Always empty out residual water after use.	C	M	W
	Routine inspection of boiler.	Annually, by competent person.	C	M	W
		Cheddar recommend sending their engine to them once every two years for testing and inspection.	C	-	-
Oil mist	A mist of water and oil emulsion is emitted from the Cheddar and Wilesco engines. This mist is harmful by inhalation.	Ventilate the laboratory.	C	-	W
		Fit an oil trap to the steam exhaust port on the Cheddar engine.	C	-	-
Demonstration safety distance	Pupils sited one metre from engines fired by a spirit burner have been injured by unconfined vapour cloud explosions.	During a demonstration, the class should be seated well back. Three metres is thought to be appropriate.	C	M	W

Table 1. Steam engine hazards and risk assessments. Code : C = Cheddar engine, M = Mamod engine, W = Wilesco engine. (Continued from previous page)

Model steam engines

We report on the safety and other design features of three model steam engines. We also report on their performances. The three engines tested are representative of a wider range of models (Table 1).

It must be appreciated that the safety of the user depends not only on features inherent in the design, but also on the operational procedures. Since a safe system of work rests with the user, it is the matter of a separate article in the *Safety Notes* section of this issue.

A specification for model steam engines intended for the use of children of less than 14 years of age but not under 11 years was recently published by the British Standards Institute [1]. Although the school context differs from that intended by the standard, it provides useful guidance. The specification requires that :

Manufacturer	Product name	Supplier	Order code	Price (£)	Comments
Cheddar	Pipit Steam Plant	Cheddar	10068	128.50	double acting, oscillating valve engine,
		Griffin	XHV-615-Y	155.00	includes base plate, natural gas burner, safety valve, steam stop valve, 2-step drive wheel
	self assembly version	Cheddar	10052	94.75	as above, but supplied in kit form
		Griffin	XHV-610-P	128.00	
	• Pipit Steam Plant with Electricity Generating Set	Cheddar	10077	208.00	as above plus Dynamo & Lighting Kit, Lubricator,
		Griffin	XHV-620-Y	256.00	Condenser/Oil trap
	self assembly version	Cheddar	10079	143.17	as above, but supplied in kit form
	Cheddar accessories				
	Lubricator	Cheddar	10057	22.70	essential, use with Condenser/Oil trap
		Griffin	XHV-625-500E	20.75	
	Condenser/Oil trap	Cheddar	10105	13.75	essential, use in conjunction with Lubricator
	Lubricating oil (steam oil)	Cheddar	10032	1.87	essential
		Griffin	XHV-625-530S	1.85	
	Water level gauge	Cheddar	10098	13.15	essential
	Pressure gauge (imperial)	Cheddar	10101	24.00	recommended, includes syphon that prevents
	Pressure gauge (metric)	Cheddar	10112	24.00	heat damage to Bourdon gauge
	Universal coupling joint	Cheddar	10076	3.96	recommended
		Griffin	XHV-625-520V	4.50	
	Dynamo & lighting kit	Cheddar	10071	26.92	useful
Mamod	• Steam Engine SP4	Griffin	XHV-602-K	61.40	single acting, oscillating valve engine, includes base plate, safety valve, overflow plug, water level, solid fuel burner, flywheel, pulley wheel, spring belt
	Steam Engine SP2	Griffin	XHV-606-J	50.00	more compact than SP4, cylinder mounted on boiler
	Fuel tablets, solid, 450 g	Griffin	S/5700/99	15.25	
	Workshop Unit	Griffin	XHV-605-P	50.00	model line shaft, power press, hammer, polishing mop and grinding wheel driven by above engine
Wilesco	• Steam Engine D10	Irwin	RA3216	64.14	double-acting, fixed-cylinder engine, includes base plate, safety valve, overflow plug, water level, solid fuel burner, flywheel, pulley wheel, spring belt, speed governor
	Fuel tablets	Irwin	RA3217	2.18	
	Steam Engine D16	Harris	Q45045/7	128.29	D16 is a larger engine than D10
	Solid fuel	Harris	Q45050/0	3.08	

Table 1. Descriptions, suppliers, order codes and prices of steam engines. Engines tested by SSERC marked with a bullet • Cheddar offer a 20% discount on orders totalling under £500 and 30% discount on orders of £500 and over.

- the metalwork and moving parts shall be finished so as not to cut the skin or trap fingers;
- the materials used for parts under pressurized steam are resistant to corrosion and fire;
- there are safe lifting points even when the boiler is hot or fired;
- the fuel is solid and that if the fuel carrier is filled to capacity it cannot evaporate more than 80% of the water in the boiler;
- a child's finger cannot be inserted into the furnace;
- the boiler has an indication of the minimum water level and either a means of showing the maximum water level or the provision of an overflow plug;
- at least one safety release valve shall be provided;
- the service pressure shall not exceed 150 kPa (1.5 bar) and the release pressure shall not exceed 200 kPa (2 bar); and
- there is appropriate marking on the engine and a set of working and maintenance instructions.

Two of the engines, those made by Mamod and Wilesco, are marketed as being appropriate for use by children of less than 14 years of age, but not under 11 years. These engines are tested by the manufacturer for compliance with this BS specification. The third model in our test report, the one made by Cheddar, is intended for use by adults. It has not been designed to comply with the BS specification for a child's model.

The purpose of the standard is to specify requirements for a child's model to be used at home in reasonable safety. The standard presumes that the child in control of the engine has a reasonable amount of competence, that an adult should be in supervision - not necessarily directly so, but should know of the whereabouts and circumstances of use and should have control of other children who might be present. Because the supervision of practical work in a school laboratory is far tighter than it usually would be at home, and because model steam engines are usually demonstrated in school by a teacher or technician, non-compliance with the standard should not necessarily be a reason for prohibiting usage in a school laboratory. Indeed we do not have any objection in principle to the use of

Compliance with BS 7328 specification	**Cheddar** Pipit	**Mamod** SP4	**Wilesco** D10
Metalwork and moving parts finished so as not to cut the skin or trap fingers	yes	yes	yes
Critical materials resistant to corrosion and fire	yes	yes	yes
Provision of safe handling points	no, base plate becomes too hot to touch	yes	yes
Fuel shall be solid, provision of fuel carrier, the maximum amount of fuel that can be used will not evaporate more than 80% of the water	no, normally runs off natural gas, but solid fuel burner provided	yes	yes
A child's finger cannot be inserted into the furnace	no, flue from furnace is dangerous	yes	no, vents and furnace entrance might trap child's finger
Boiler has an indication of the minimum water level	no, water level is accessory fitment	yes	yes
Boiler has a means of showing the maximum water level or has an overflow plug provided	yes, overflow plug is standard fitment	yes	yes
Provision of one or more safety release valves	yes, two valves	yes, one valve	yes, one valve
Service pressure is not more than 1.5 bar	no, 3 bar	yes	yes
Release pressure is not more than 2 bar	no, 4 bar	yes	yes, 2.3 bar
Markings and instructions	no	no	no

Table 2. Compliance with specification for model steam engines intended for children of less than 14 years of age (BS 7328 : 1990). *Yes* means compliance. *No* means non-compliance.

adults' steam engines in schools. However depending on the age, competence and behaviour of the pupils, it may be prudent to restrict usage to demonstration only.

Compliance with safety specifications is shown in Table 2. Wilesco's D10 engine has vents around the furnace and an unguarded furnace opening into which a child's finger could be inserted and possibly get trapped. There would be no risk of harm were the engine used by a teacher, or even by older children whose fingers would be too large to be entrapped, but younger children might be at risk. The Wilesco D10 engine is not therefore safe for use by young children unless the hazard is specifically pointed out to them, they are suitably competent and are under close teacher supervision.

The standard specifies that the release pressure of the safety valve shall be not more than 2 bar. The 2.3 bar release pressure of the Wilesco D10 engine is a jot more than the specified value. Were we to apply Portia's reasoning, this engine would not comply. However if the 2.3 value is rounded off to the nearest whole number, it would be reasonable to accept that it does.

The Cheddar engine tested by us is called the *Pipit*. The version of the Pipit sold to schools is normally supplied with a natural gas burner, but also includes as standard fitment a tray for solid fuel tablets. The use of solid fuel is safer because of the finite burning time of this type of fuel. However natural gas is a more convenient laboratory fuel. The use of gas is reasonably safe provided the teacher follows a safe system of usage (see Safety Notes).

We are concerned that neither a water level nor pressure gauge are standard fitments on the Pipit. We think that schools buying this type of engine should also buy and fit both of these accessories.

Other Pipit accessories which are recommended to schools are the Lubricator and Condenser/Oil Trap. The Lubricator mixes steam oil with steam to lubricate the moving parts. The Condenser/Oil Trap removes the oil mist that is exhausted with the waste steam and prevents that oil mist being inhaled.

The waste gas venting from the Pipit's funnel is fiercely hot. There is a risk of eye injury because the obvious way of checking that the furnace is lit is by trying to look down the flue. This would be dangerous and the operator therefore ought to wear eye protection. The safe way to check that the fire is lit is by sensing for a heating effect on the back of a hand held momentarily 20 cm above the funnel.

Performance tests

The three engines have been run at least thirty times each. Most of the runs have been under normal operational conditions. Some have been deliberately, and some accidentally, stressful. The unplanned events are interesting because they indicate how an engine behaves when out of control.

Boiler volume	Cheddar (ml)	Mamod (ml)	Wilesco (ml)
Total boiler volume	195	160	160
Water volume at maximum level	175	104	110
Water volume used per firing (typical conditions¹)	135	15	49
(worst case conditions²)	-	73	52

Table 3. Boiler volumes and amounts of fluid used per firing. Code : [1] boiler filled with cold water, 2 tablets Esbit, [2] boiler filled with hot water, fuel carrier packed with solid fuel.

The Wilesco engine typically uses more water per firing than does the Mamod engine (Table 3) - a reflection on the greater efficiency of the Wilesco furnace.

In our comparison of running times (Table 4), the boilers in all three engines were filled with cold water to start with. The furnaces of the Mamod and Wilesco engines were each fuelled with 2 tablets of Esbit solid fuel.

The running times of solid fuel engines can be extended by starting with hot water in the boiler, or, with the Mamod engine, by packing additional fuel into the fuel carrier. Doing both extends the running time of the Mamod engine to about 9 minutes.

By only testing one sample of each type of engine, quality control has not been assessed. There may be some variability of production. If either a Mamod or Wilesco engine were to underperform significantly, then that engine would be virtually useless. There is not much leeway between satisfactory and duff.

Performance	Cheddar Pipit	Mamod SP4	Wilesco D10
Maximum power developed (W)	6	0.6	0.8
Stall torque (mN m)	50	4	5
Stall load on pulley wheel (depends on part of cycle) (N)	5[1] 12[2]	0.8	1.0
Running period (cold water start) (min)	9 - 15	4	10
(hot water start) (min)	9 - 15	6	11

Table 4. Steam engine performance showing maximum power, stall torque, stall load on pulley wheel and running periods. Code : [1] large diameter, [2] small diameter.

Mamod Steam Engine SP4 : This is a single acting engine. The boiler is mounted horizontally. The cylinder and flywheel are mounted on the base plate some distance from the boiler. A pulley wheel is provided for driving external machinery.

The operational time is given in Table 5. After firing the boiler, we usually waited for steam to be released from the safety valve before giving the flywheel a flip to start the engine. At this pressure, the engine always started first time. The operation of the engine was wholly reliable. None of the linkages came loose or separated. No part fractured. The amount of water converted to steam when starting with a boilerful of cold water was only 15 g. This is much less than that consumed by the Wilesco engine. The Wilesco boiler would therefore seem to be much more efficient.

Mamod steam engine	Event time (min)
Boiler fired (cold start)	0.0
Steam escaping	2.5
Engine starts turning	4.0
Engine ceases turning because of fuel exhaustion	8.2
Total running period	*4.2*

Table 5. Mamod steam engine (SP4) : sequence of events between firing the boiler and the limit of operation. Fuel : 2 tablets of Esbit.

Wilesco Steam Engine D10 : This is a double acting, fixed single cylinder engine. Like the Mamod SP4, the boiler is mounted horizontally. The cylinder and flywheel are mounted on the base plate some distance from the boiler. There is a speed governor, connected by a spring belt to the flywheel. A pulley wheel is provided for driving external machinery.

The operational times are better than those of the Mamod engine (Table 6). Using two tablets of Esbit fuel and with a cold water start, the running time is about 10 minutes. By waiting until until steam was released from the safety valve, the engine started readily with a single flip of the flywheel.

Wilesco steam engine	Event time (min)
Boiler fired (cold start)	0.0
Steam escaping	2.0
Engine starts turning	4.3
Drive belt removed	14.0
Engine ceases turning because of exhaustion of fuel	14.5
Total running period	*10.2*

Table 6. Wilesco steam engine (D10) : sequence of events between firing the boiler and the limit of operation. Fuel : 2 tablets of Esbit.

There were however several operational problems :

- The speed governor detached itself from the base plate to which it had been riveted. This happened through wear and tear from two causes. For one, the lugs on the rivets do not seem to be sufficiently large. For another, the sheet metal out of which the base plate is formed is really too thin. As a result, the holes accepting the rivets had become enlarged by wear.
- The screw fitting the crankshaft to the axle of the flywheel worked loose after ten runs. Thereafter it worked loose again periodically.
- The funnel was insecure.

Apart from these mechanical failures, the engine ran well. It started easily every time. The boiler is relatively efficient, generating about 50 g of steam in a firing. Relative to the Mamod engine, the performance is superior in two significant ways, the running time being more than twice as long, and the maximum power developed being 25% greater. In particular, the Wilesco engine is capable of sustaining a reasonably high power output for a much longer period than is the Mamod engine. This is of value when trying to harness the engine to an external load, or attempting to make dynamical measurements.

Cheddar Pipit Steam Plant : Because the base plate is quite small and because the engine gets very hot, we mounted the plate on a wooden board, as recommended to do so by the manufacturers.

The engine has an upright boiler. Water is heated through a central flue, there being water pipes braced diagonally across this to improve the efficiency of heat transfer. As mentioned earlier, it is dangerous to look into this flue when the fire is lit. There is a safety release valve on the top and an overflow plug on the side which must be used when filling the boiler to avoid overfilling.

The engine is a single cylinder, double acting, oscillating valve type, as fitted in some early Clyde steamers causing them to bob from side to side. A second safety release valve is fitted at the cylinder - a spring which holds it against a fixed plate. When the pressure exceeds the release pressure, steam is expelled from the seal between this plate and the cylinder.

There is a valve which can shut off and control the flow of steam from boiler to cylinder. This is usually kept shut when the engine is fired until the pressure reaches the normal running pressure of 3 bar. To start the engine, the usual practice is to wait for steam to force open the release valve at the cylinder block, set at 4 bar, and then give the pulley wheel several sharp flicks.

The engine is lubricated by mixing steam oil with steam in a chamber called the Lubricator. To remove the resulting oil mist, the steam is exhausted through a condenser.

An operational problem met with in running the engine was one of procedural neglect rather than any fault in the apparatus. During the final minute of running, the condenser should be emptied by allowing the exhaust

cont./page 24

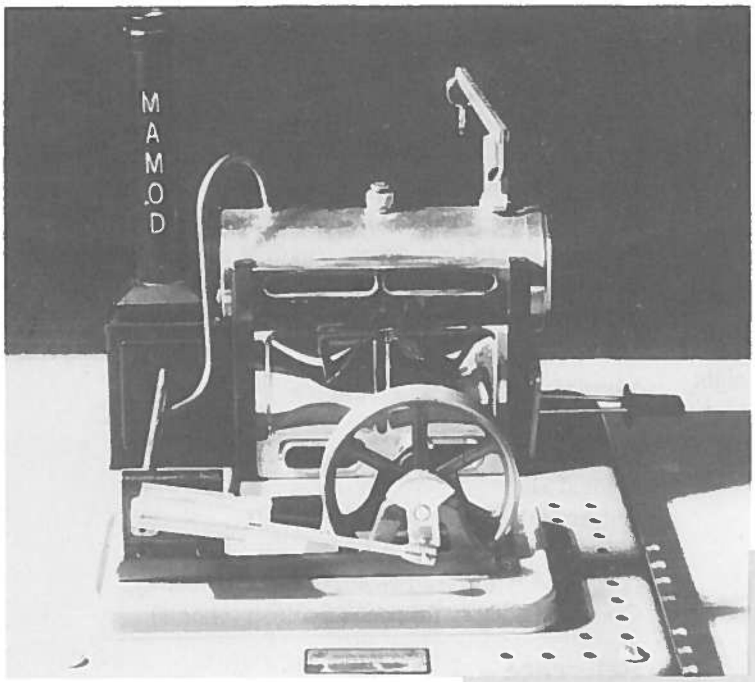


Figure 1 Mamod Steam Engine SP4

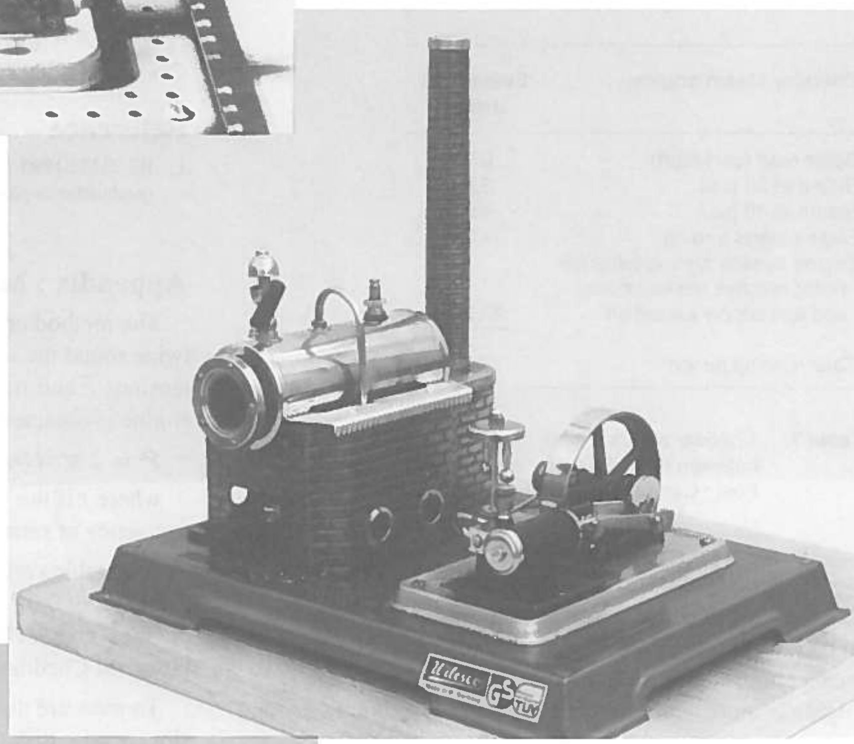


Figure 2 Wilesco Steam Engine D10

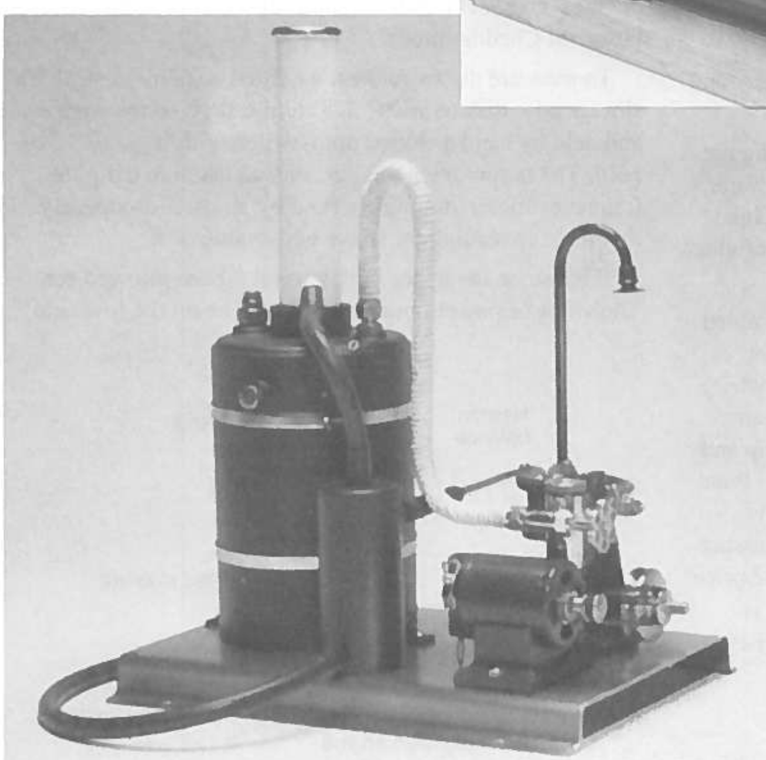


Figure 3 Cheddar Pipit Steam Plant with Electricity Generating Set

steam to flush out its contents. If this is not done then when the engine is restarted the initial high steam pressure can blow the contents of the condenser out through the flue as a shower of oil and water droplets. This is great fun, if not a little alarming! The vehemence of such an expulsion can dowse the furnace. It also makes quite a mess.

Apart from this procedural problem, the engine performed very well. It started reliably. It ran reliably. Depending on the gas flow rate, a running period of between 10 and 15 minutes can be expected (Table 7). A maximum power output of 6 W is obtainable. This is eight times better than that of the Wilesco engine, the next best performer. The Pipit is therefore very capable of driving ancillary machinery and indeed can directly lift, without gearing, a 1 kg load.

Cheddar steam engine	Event time (min)
Boiler fired (cold start)	0.0
Steam at 20 p.s.i.	3.6
Steam at 40 p.s.i.	4.6
Engine starts turning	4.9
Engine ceases turning because water reaches minimum limit and fuel supply turned off	20.2
Total running period	*15.3*

Table 7. Cheddar steam engine (Pipit) : sequence of events between firing the boiler and the limit of operation. Fuel : Camping Gas.

The lesson from the Pipit's procedural problem indicates the need for a safe system of work and for staff to be given training. Although both are required for all steam engines (see Safety Notes), the need with this engine is more acute because of its greater complexity and higher pressure.

Two other problems occurred. The thread securing the standard lamp fitment sheared and the water in the water level gauge sometimes jammed due to airlocking. This second fault is the more serious. A larger diameter of glass tubing might be the answer.

Cheddar models can be bought either ready assembled or in kit form. There are about 60 parts in the kit, not including screws. We have a letter from a lady school technician advising us that "any competent technician should be able to assemble a kit engine. We had it up and running in about 2 hours." If buying the Pipit Steam Plant with Electricity Generating Set ready assembled, and including as essential extras a water level gauge, pressure gauge kit, universal coupling joint and steam oil, the price direct from Cheddar, including their 20% discount, is £201. The same bought in kit form would cost you £149, a saving of £52.

Summary

Of the two small engines tested, the Mamod SP4 is the more reliable in the sense of not breaking down. The Wilesco is the more useful in the sense of running for a longer period and developing more power. However both engines are overshadowed by the Cheddar Pipit, which was reliable, ran for a decent length of time, develops a reasonably large power and, as the Reverend W. Awdry said of one of his, is *"a Really Useful Engine"*.

Verdict

Cheddar Pipit	A
Mamod SP4	B
Wilesco D10	B

(Code : A = most satisfactory, B = satisfactory, C = unsatisfactory for use in Scottish schools)

Reference

1. BS 7328 : 1990 *Specification for model steam engines and internal combustion engines for models.*

Appendix : Measuring output power

The method comprises wrapping a half turn of thin twine round the engine's pulley wheel and measuring the tensions F and $m\,g$ (Fig. 4). The power output P from the engine is obtained from the expression

$$P = 2\pi r f(m g - F)$$

where r is the radius of the pulley wheel and f is its the frequency of rotation.

A suitable spring balance capacity is 2.0 N with divisions of 0.02 N for testing the Mamod and Wilesco engines, and 5.0 N with divisions of 0.05 N for the more powerful Cheddar model.

To measure the frequency, we fitted a stainless steel 15 slot encoder disk (SSERC 378) to the shaft of the engine and held by hand a slotted opto-switch with logic (RS 304-560). The output from this sensor was taken to a digital frequency meter, double checked by an oscilloscope. By dividing the reading by 15 we get a value of f.

Friction on the upper pulley has not been allowed for. The value of power obtained will thus be on the low side.

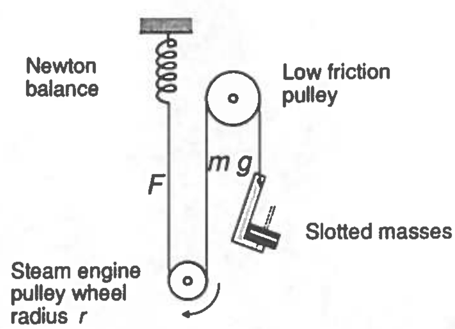


Figure 4 Schematic diagram of apparatus to measure output power of steam engine

Autoclaves

Updated information on one series of models of autoclaves is provided. Recent difficulties over reputed shortcomings in the design of these Prestige Medical devices with regard to the requirements of British Standards, the Work Equipment Regulations and HSE Guidance Note PM73 are discussed.

Portable laboratory autoclaves and sterilisers were last reviewed in Bulletin 172 [1]. Since that time there have been major revisions to some relevant British Standards. Many of those revisions are irrelevant to schools, some confusingly so. But one innovative manufacturer - Prestige Medical - has already modified all of the models in its range of automatically controlled autoclaves (see Table 1). Given that the Pressure Systems etc. Regulations also came fully into force on the 1st of July this year, an article summarising the important points arising from each of these changes should prove timeous.

The results of our evaluation of the 2100/01 were similar to those obtained with the earlier 2075 model (see Fig. 1 opposite). Apart from some minor detail, our conclusions as to the suitability of this device for educational microbiology were as before - very favourable. These innovative and automatic devices gave excellent results in our performance tests. We therefore continued to advise enquirers considering their purchase that they were a good buy.

There are however three specific aspects of either the use or design of these devices which seem to have caused problems for educational purchasers and on which we have had a number of enquiries :

cont./overleaf

Figure 1 Tall form 2075 model reported on in Bulletin 172 and now superseded.

Model and price	Description	Comments
2075	Basic tall form type without pressure gauge but with pressure indicator	SSERC test July 1990 now withdrawn
2100/01 F £460 CA £462 PH £489.30	New basic model but standard height	Tested January 1993, as above, no pressure gauge but with changes to controls and design pressure
2100/02 F £540 CA £550	Extended body version of 2100/01 above, pressure indicator, no gauge	More useful for school use than /01 because of greater capacity
2100/04 F £685 CA £693	Extended plus version as 2100/02 but with pressure gauge and thermocouple entry port	Greater capacity useful, but need for gauge etc. not great enough to justify increased expenditure

Table 1 Key to prices - CA = Charles Allardyce; F = Fisons and PH = Philip Harris
Prices provided for comparison purposes only and merely those available at date of compilation. All net of VAT.

Continued from page 25 :

- Some users have been confused over Prestige Medical's instructions which seem to preclude the use of some models in the 2100 series for the sterilization of liquid media. This seems to arise from a particular interpretation of British Standards.
- We understand that some insurance company inspectors may have been advising educational users that these models do not meet a requirement of HSE Guidance Note PM73. They are then deemed not to pass that particular insurer's written scheme of examination under the Pressure Systems etc. Regulations (see Safety Notes).
- A few users have reported premature pitting of the base of their autoclaves.

Suitability for sterilization procedures

Page 5 of the version of the instructions in English under a section headed DO NOT precludes the use of 2100 series clinical autoclaves for the sterilization of liquids or culture media. We consider that this sits ill with the results of our own tests. Given the nature of micro-biological work in schools and non-advanced FE we are of the opinion that this is an unnecessary proscription on such usage at these levels.

It seems that this section was included because of a strict interpretation of technical requirements within two different British Standards. In our view this is very largely a semantic difficulty rather than a safety problem of any significance. Prestige Medical series 2100 clinical autoclaves have been designed primarily to conform to the pressure vessel and performance requirements of BS 3970 *Sterilising and Disinfecting Equipment for Medical Products;* Part 4 *Specification for transportable steam sterilisers for unwrapped instruments and utensils*[1].

Also relevant however is BS 2646 *: Autoclaves for Sterilization in Laboratories*[2]. It is with BS 2646 that the apparent problem arose. This is because Section 1, Part 1 of BS 2646 defines three basic autoclaving procedures relevant to the needs of laboratories :

Liquids sterilization (Clause 1.3.12) : A process to sterilise a variety of liquids, including culture media, in containers of various types. It further states that because of the heat sensitive nature of some constituents of nutrient media, time and temperature controls should allow the user to select cycle characteristics separately for each load.

Make-safe (Clause 1.3.13) : A process which reduces the microbial content of contaminated material so that it can be handled and disposed of without causing an infection hazard or environmental contamination. Material may include single-use items to be discarded, e.g. plastic specimen tubes and culture plates and/or items for cleaning and re-use, e.g. glass containers and filter assemblies.

1. Eventually there will be no fewer than 11 parts to this Standard : Parts 1 to 5 and A to F.
2. BS 2646 will have 5 separate parts. At the time of writing some of these were not yet published in final form.

Equipment and glassware sterilization (Clause 1.3.14) : A process strictly limited to the sterilization of clean items which do not contain fluids.

Technical consultants to Prestige Medical have so interpreted these definitions as to advise Prestige that basic Series 2100 autoclaves are suitable only for processes covered under clause 1.3.14. and preclude use for procedures under Clauses 1.3.12 and 1.3.13. This was on the grounds that the time and temperature controls on 2100 models are under automatic control and are not adjustable. In our view this advice cannot realistically be applied to use of the 2100 models at school level. Nor should it apply to preparation and disposal procedures which support elementary microbiology in FE colleges.

In the case of sterilization of liquids (1.3.12) the intention of BS 2646 would seem to be either :

- to allow shorter cycles to avoid thermal damage (e.g. caramelisation) to certain heat sensitive media or
- to allow extension of the cycle to ensure sterility in certain difficult media or in single containers of relatively large volume (this second consideration as to extended cycles might also apply to Make-safe [Clause 1.3.13]).

The possibility of thermal damage is not significant for the majority of school work. The other problem of extending the cycle can be dealt with simply in a digital rather than an analogue way. If difficult materials (e.g. contaminated with soil) are to be sterilised prior to disposal then they simply may be subjected to a double cycle. In an educational context the risk of not achieving a sufficient kill of cells and spores by such means is in our view insignificant. Our results with biological (spore strip) tests add weight to that view.

In addition to the above considerations it must be stressed that autoclave procedures are but one set of control measures used in school microbiology to satisfy the requirements of the COSHH Regulations. In Scotland there are also restrictions placed on :

- choice and sources of organisms used;
- nature of culture media;
- types of containment;
- scale;
- levels of work cf. age of student;
- levels of work according to teacher and technician expertise and
- laboratory facilities.

All of these additional control measures are contained within the Code of Practice originated by Strathclyde Regional Council and adopted or adapted since by the majority of Scottish Regional and Islands Councils [3]. Because of these other controls the proscription on use of the 2100 models is entirely inappropriate at this level. A parallel may be drawn with school fume cupboards where the strict requirements of the relevant British Standard tend not to be applied but those of DfE Design Note 29 are deemed adequate.

But what of the Standard to which these autoclaves were originally designed - British Standard 3970 : 1990?

As indicated, the 2100 series were designed primarily to meet the requirements of BS 3970 *: Sterilizing and disinfecting equipment for medical products :* Part 4 *Specification for transportable steam sterilizers for unwrapped instruments and utensils.* The mismatch with typical educational usage should be apparent from this snappy title. It explains why the real market for these devices lies in general medical, dentistry and veterinary practices. It seems it's just our misfortune that they also seem ideal for use in school microbiology!

Unfortunately, several parties have added to this confusion by wrongly interpreting what actually goes on in school and college courses. They have somehow decided that BS 3970 : Part A *: Specification for steam sterilizers for fluids in sealed rigid containers* is the right bit for us mere educational folk. This just gives us yet another problem.

Liquid medical products are often autoclaved in sealed containers so that they then remain sterile through to the point of sale or use. Usually there is a space (the *ullage*) left above the liquid to allow for expansion. During sterilization the pressure of the air in this space is greatly increased. Should the containers be of glass or other rigid material they could be flawed or otherwise weakened. Then if they were handled before they cool to below 80°C or so, they may well explode and cause injuries. Such incidents used not to be rare. Part A of BS 3970 therefore requires that, where liquids in sealed rigid containers are steam sterilized, there must be some means of preventing access to the load until it has cooled below 80°C. This is based on accident histories and is a sensible requirement. It is not quite so sensible when too rigidly applied to other users.

In school and college microbiology, bottles of liquid media are not sealed during autoclaving. Caps of McCartney bottles, medical flats etc. are always slightly loosened so as to allow any air to escape. If that were not the case then the vessels and the autoclave would contain a mixture of air and steam rather than pressurised steam alone. The required sterilization temperature would not then be reached. It is still sensible to advise that, at the end of the cycle, the load be allowed to cool and that the autoclave lid should not be removed until the pressure has dropped to atmospheric or thereabouts. All of that is in the Code of Practice. It is also in the literature which supports the Code. It is not however sensible to insist on an interlock. Nor is it necessary for manufacturer's instructions to insist that an autoclave be allowed to cool overnight before being opened. That makes operational nonsense in the school context[1].

It may be that BS 3970 might yet prove relevant and helpful. This would be in the shape of Part B *: Specification for steam sterilizers for fluids in unsealed vented containers.* Part B has yet to be published. We await it with bated breath since - as the extracts in this article demonstrate - any new British Standard makes a riveting read.

And, when is an indicator a gauge? This may also have you on the edge of your seat. It should. It could mean the difference between a pass and a fail for your autoclave. A number of Scottish EAs are still using specialist inspectors from insurers or their subsidiaries for the inspection of boilers and other pressure vessels (see Safety Notes). It seems that some of these inspectors are leaning heavily on HSE Guidance Note PM73 : *Safety at Autoclaves* as well as using the more recent British Standards (and, as shewn above, they can take their pick of quite a few).

Reports indicate that some insurance inspectors fail the basic Prestige Medical models because they do not have a pressure gauge. According to our reading of the regulatory runes, they don't need one. What they must have is a pressure indicator. They do. It happens to be digital - a red button - and be up for *operating pressure on* and down for *off* or *atmospheric.*

Other nit-picks

Other minor objections have been made to the design features or the operation of this range of autoclaves. We hesitate to bore readers further with yet more technical detail but, so far, these have concerned :

- the proof pressure test level versus the destructive test pressure;
- the final safety feature which is the lid gasket blow-out pressure compared with
- the maximum pressure the lid flanges will withstand before failure etc.

At present none of these objections have stood up to scrutiny. We will let you know if and when they do.

Pitting of the vessel is the one potential problem reported to us which we do take most seriously. A handful of users have reported obvious pitting of the base of 2100 series autoclaves after only a few years' use. We have examined the first such example reported to us and thereby confirmed that this pitting had indeed been both obvious and potentially serious - the pits in some cases being well over 1 mm deep. It was also established that the vessel had been cleaned out after each use. Sometimes premature corrosion is caused by acids from mould growth in spilled culture media lying undetected under the trivet. This was not the cause in this example.

It transpired that the school had habitually used ordinary tap water in the autoclave. The Prestige Medical instructions are explicit on the need always to use distilled or deionised water. Some, but very few, tap waters apparently contain material which may hasten corrosion of the base of the aluminium pressure vessel. In many areas no problems arise from the use of tap water to generate steam.

1. For example, see more recent versions of the instructions for autoclaves made by Dixons and sold by mainstream educational suppliers. Should that advice be heeded it would only be possible to deal with one or two loads in a school day.

Prestige however counsel caution and advise the use of distilled or deionised water. That advice we just happened slavishly to follow. We have used deionised water from the outset. Our two Prestige Medical autoclaves have been very heavily used. To date they show no signs of premature corrosion.

Summary

The Work Equipment Regulations lean heavily on technical standards for detailed specification of what is suitable equipment for supply and use at work. In the UK that means referring to BS or BS EN documents. The *Safety Notes* section of this issue carries a fuller discussion of this matter. Educational applications are not usually specifically catered for in technical standards. There may thus be a mis-match between operational needs and detailed technical requirements. Autoclaves for school use and British Standards 3970 and 2646 provide classic examples of this problem.

It is ultimately for the employer and the user of such equipment to ensure that such usage is acceptably safe and without risk to health. Some British Standards now contain provision for the user to supply information to the supplier or manufacturer on the limits of their equipment usage (see Section 6 of the Health and Safety at Work Act as amended and the relevant Consumer Protection legislation which deals with the duties of suppliers of equipment when it is "properly used").

Standards for autoclaves provide but one example. Only when the exact mode of use is known can the performance of an autoclave be validated for any particular purpose.

As a result of our performance tests, digging into standards as described and taking into account COSHH related measures we conclude that : These Prestige Medical clinical autoclaves are suitable for the sterilization of media and other materials both for preparatory and disposal purposes as described in the Code of Practice for microbiology in schools at Levels 2 and 3. What matters for that purpose is that these devices provide acceptable control measures to limit microbiological risks. We are satisfied that these autoclaves meet that requirement.

References

1. *Autoclave review*, Bulletin 172, SSERC, January 1992, pp 22-30.
2 *Guidance Note PM 73 : Safety at autoclaves*, HMSO, HSE Plant and Machinery Series, August 1990, ISBN 0 11 885557 3.
3. *Safety in Microbiology : A code of practice for schools and non-advanced further education* (and supplement for post 16 student work at level 3), Strathclyde Regional Council, 1989.

Centrifuges

A general description of the Work Equipment Regulations is given in the Safety Notes section of this issue (see page 10). This related article seeks to provide a more specific account of the practical application of these Regulations to one type of laboratory equipment.

If you are buying a new centrifuge or have bought one after the 1st of January 1993 then all of the *Provision and Use of Work Equipment Regulations (PUWER)* will apply to it, both what we call the *software* and the *hardware* parts. The former deal with managing systems of work. The hardware parts relate to the design and construction of equipment.

If your centrifuge was bought or acquired before that date and provided that it is safe in use then only the 'software' aspects apply now and you have until 1st January 1997 to implement the other sections by upgrading the centrifuge.

Upgrading may be a viable option if the centrifuge is neither too old nor worn and if it is capable of effecting the separations needed. For example, it may not have a high enough speed of rotation to be capable of some of the separations which might be needed, such as the spinning down of isolated mitochondria. It may be capable of other procedures - such as spinning down extracted DNA or isolated chloroplasts - but not within a time scale convenient for student practicals.

Software aspects : Regulations 1 - 10

The main requirements for the employer here are that he has to ensure that:

- The piece of equipment selected is suitable for the intended purpose and will be operated only with the loads and speeds as specified by the manufacturer (Regulation 5).
- It is maintained in efficient working order (Regulation 6). The Guidance on PUWER states that where inadequate maintenance can cause equipment to fail in a dangerous way, a more formal system of planned maintenance is needed.
- Those who use the centrifuge and those who supervise or manage its use must :

  - receive written instructions and information pertaining to the use of the centrifuge (Regulation 8). Such information can be given orally, but highly detailed information should be in writing. (The manufacturer's operating instructions and recommendations for servicing and maintenance may make up the bulk of such provision.)

  - receive adequate training in the use of the equipment (Regulation 9).

Hardware requirements : Regulations 11 to 25

These require the employer to ensure that there are means of avoiding contact with dangerous parts (ie, those which are moving, sharp, hot, cold or at hazardous voltages) or which may in the event of catastrophic failure eject parts.

Several of the Regulations in this section concern general means of controlling access to such hazards and systems for emergency shutdown. Details particular to centrifuges are to be found in BS 7687: *Safety requirements for electrical equipment for measurement, control and laboratory use* - Section 2.20: *Specification for laboratory centrifuges*, which has to be read alongside the relevant general standard which is : BS EN 61010-1: *Safety requirements for electrical equipment for measurement, control, and laboratory use*. When examining centrifuges HSE Inspectors are likely to base their judgements on these two Standards.

Some of the main ways in which such controls are to be effected so as to meet the requirements of BS 7687 are described below:

- The lid interlock must prevent the motor from starting before the lid is locked in a closed position and hold the lid in that position until the circumferential velocity of the rotor assembly has fallen below 2 m s^{-1} (Section 7.2.101).
- Furthermore the locking mechanism is to remain unreleased in the event of a power failure and is to be capable of being opened subsequently only by the use of a tool. In addition most modern centrifuges are fitted with a braking system to reduce the time of waiting for the rotor to stop. There is an exemption for smaller centrifuges as defined below where this full interlocking system may be replaced by a simpler power-interrupt switch on the lid (often a microswitch). This simply de-energises the motor as soon as the lid is slightly opened, allowing the rotor to gradually slow down.
- The enclosure must be of sufficient strength and integrity to enable it to contain any parts of the rotor in the event of catastrophic failure.
- Mechanical parts such as motor spindle, rotor head and trunnions for swing out buckets must be reliable, of good design and be well maintained.

Upgrade or replace?

The above requirements might seem enough to force us into making a quick decision to go for replacement. However the cheapest centrifuges which meet all of the requirements of the new British Standard cost between £450 and £500 and a small amount of work on your bench centrifuge may enable it to meet the minimum provisions of the Standard.

Exemptions for smaller centrifuges include permitting the fuller interlock system to be replaced by the simpler power-interrupt microswitch provided that :

1. The lid has a catch to keep it closed and there is fixed beside the catch a warning label stating that the lid should not be opened until rotation has ceased.
   (If there is insufficient space for such a label, the general warning label for caution defined in ISO 3864 [a yellow triangle with black border bearing a black exclamation mark in the centre] is considered acceptable.)
2. The rotational frequency of the rotor assembly does not exceed 3600 rpm.
3. The energy at maximum rotational frequency when fully loaded does not exceed 1 kJ;
4. The maximum centrifugal force does not exceed 2000 *g*.
5. The largest rotor assembly diameter does not exceed 250 mm.
6. The power can be disconnected by a switch which is independent of the lid position.
7. There is means of visual access to the rotor assembly when the lid is closed in order to permit observation of rotation.

All seven conditions must be met before the relaxation applies.

If your centrifuge is more recent than an F or G registration (prefix not suffix!), does not have too many miles on the clock and has only had one careful driver, then upgrading is a realistic option. After all you will probably find your existing centrifuge meeting many of the above conditions. Or it could be modified fairly easily.

The information on conditions 2, 4 and 5 is often in the manufacturers' specifications. To the best of our knowledge most centrifuges sold for schools have a rotational energy less than 1 kJ, but if in doubt the original supplier or manufacturer should be able to help.

Only two jobs remain which may or may not be difficult depending on the actual construction of the centrifuge. There may physically be insufficient room for the switch to be fitted; otherwise it should be a fairly simple task for a competent person. The window in the lid may be a problem and we are looking into possible methods of fitting these.

It is very important that the strength of the lid and its integrity are not reduced. Any adaptation will very much depend on the particular construction of the lid. For example, some lids are of pressed steel and fairly flat. A hole 10 mm in diameter may then be cut out just off-set from the centre and a dot of paint in a contrasting colour placed also off-centre on the top of the rotor so that it can be seen through the window. Such a window is best made of a small piece of polycarbonate rod machined so that it is in the shape of a plug. This is then held in the hole both by a friction fit and by epoxy resin. Alternatively a flat sheet of polycarbonate, 2 cm square and 3 mm thick, can be attached across the hole using four bolts.

We are a bit puzzled by the need for a window since the movement of the rotor is fairly obvious from the sound. A much louder noise generated by the turbulent air is heard the instant the lid is slightly opened. In fact the working group who drew up the Standard cited this as one of the three reasons for not requiring a full interlock on the lid of less 'energetic' centrifuges.

Their other arguments were that :

- the air flow is such that dangling objects such as ties tend to be deflected away from the rotor and out of the lid; and
- that by the time the catch is released and the lid fully opened, most of the rotational energy has been dissipated due to the action of the power interrupt.

The HSE inform us that whilst they prefer to see the fully interlocked controls they have no power to insist on "more than the minimum standards being met". If older models with lower levels of prevention and protection by hardware means are used, then it is necessary to compensate with an increased amount of training and supervision of persons using the centrifuge. This is an example of the *Hierarchy of measures* in the PUWE Regulations.

Additional, germane requirements in the BS are for :

- handles to be fitted if the centrifuge weighs more than 18 kg;
- rotors and buckets to be marked to ensure they are used only in the machine for which they were made and matched - this is unlikely to be a problem in a school where there may only be one sample of any one model.

Other Regulations

As when working with other laboratory equipment, work with centrifuges may involve several other sets of Regulations. For instance, *COSHH* risk assessments will be needed if substances hazardous to health are handled. In common with other portable electrical appliances, a centrifuge will, under the *Electricity at Work Regulations*, need regular testing as per Guidance Note GS 23. We don't think that the noise levels of wee centrifuges will be anywhere near 85 dB, but if they were, the *Noise at Work Regulations* would bite.

	Requirement or inspection item	Pass condition
1.	relevant operating instructions	available
2.	normal electrical safety checks as per GS23	passes inspection or has been recorded as having done so
3.	bowl	free of corrosion and is sound
4.	lid and hinge	free of corrosion and are sound
5.	press against rotor or spindle	movement no greater than when new *
6.	bucket trunnions	no excessive play and corrosion free
7.	rotor head (may be left hand thread, consult manual)	good fit on spindle, can be well secured
8.	load up and run	smooth in action, not excessively noisy
9.	buckets	clean, corrosion free, rubber seals fitted
10.	*power interrupt models only*	
(a)	lid catch	holds lid securely
(b)	notice to user on lid "Do not open until rotor has stopped"	present in good condition, legible
(c)	independent switch	can switch off motor when lid closed
(d)	lift lid slightly with motor running	power interrupt works, motor de-energises
(e)	window in lid	clear and secure
(f)	mark on rotor	visible through window
11.	*interlocked models only*	
(a)	plug in and switch on	motor won't start till lid is closed
(b)	switch off motor	lid cannot be opened till rotor has virtually stopped (< 2 m s^{-1})
(c)	simulate power cut whilst motor is running by switching off at the 'wall'	lid cannot be opened until rotor stops and then only with the aid

Table 1. Typical routine checks for centrifuges, to be carried out by a suitably competent person.

* Note that the motor and spindle are often mounted on shock-absorbing elastomer. However it is easy to distinguish between movement resulting from the elastomer being compressed and stretched and that due to play resulting from wear and tear.

Maintenance

Regulation 6 of PUWER, BS 61010 and BS 7687 Section 2.20 all require that equipment be adequately maintained. One way to meet such requirements would be to follow the manufacturer's recommendations as to the frequency and the type of servicing. Many suppliers recommend two services per year and this is clearly sensible for research labs which may use their centrifuges continually. However this is excessive for schools and many FE users who might use their centrifuges less than a dozen times a year. It is of course open to the owner or user of a centrifuge to consult with the manufacturer or supplier and agree on a sensible frequency of maintenance based on the estimated rate of use.

Many of the modern bench-top centrifuges are virtually maintenance-free apart from the replacement of worn brushes in the motor. After a lot of heavy use there may appear a small increase in the play between the spindle and the rotor, but this measurement is one for the trained centrifuge engineer.

In our opinion a competent school technician could carry out a simple visual inspection at the same time as the GS23 electrical safety tests are carried out. The list in Table 1, column opposite, is not seen as a set of definitive requirements, but merely as an *aide memoire* for such a system of checks. Many of the items in this suggested checklist are those which any sensible user would cast an eye over everytime the equipment is set up for use. Certain apparatus may need different or additional inspections and tests.

Tachogenerator applications - Part 2

Continuing the ever-expanding number of ideas for the, if-it-moves interface it, tachogenerators or, 1001 ideas for CSYS Projects. As promised we get on our bike, balance our wheels, get in the swing and experience of bit of wind! There is also information on a simple voltage-reduction circuit and news of a cheaper motor which is good enough for many of the applications.

1. Bike Dynamics

The car dynamics techniques described in Bulletin 181 [1] can be just as easily applied to bicycles. Stick a tacho and propeller on the bicycle handlebars (Fig.1), cut down the voltage, feed the output to a datalogger and reasonable traces describing the motion of the bike through the air can be attained. Use copious amounts of Blu-tak moulded around the motor thence round the handlebars to provide a reasonable fixing point. Ignore the strange looks you get from people who think you have a turbo-prop bike and just make sure you keep your hands and brake cables away from the blades. We have some super 3-bladed, discreet black plastic props., (Surplus Item 801, 32p) which are perfect for mounting on the 2 mm shaft of a 9 V ex-cassette motor (Surplus Item 802, only £5 each, 20 left). Fig. 2 shows the voltage output vs. frequency to be linear over a wide range (V = 5.796 x frequency (kHz)). In the lab a 15 slot encoder disc was fitted to the shaft of another motor which was used to drive the tacho and the output from a slotted opto-switch fed to a frequency meter.

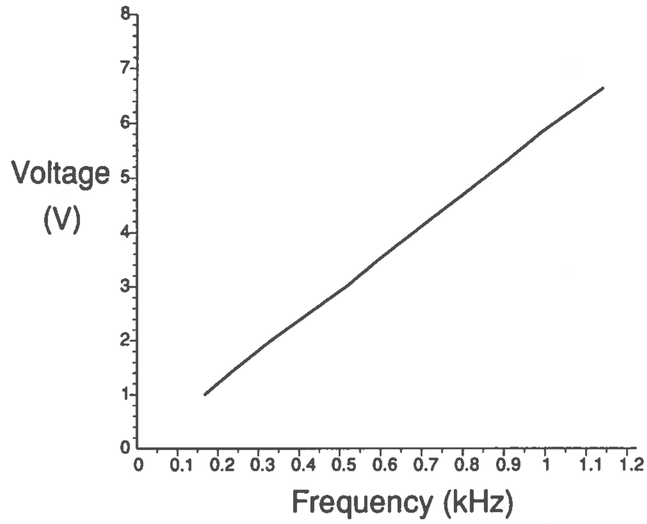


Figure 2 Voltage output vs. frequency of rotation for motor

Although the principle of voltage reduction is all too simple we provide our working circuit here as a schematic (Fig.3). As mentioned previously [1], we need this circuitry to reduce the voltage to a range which the datalogger can cope with (usually 0-1 V).

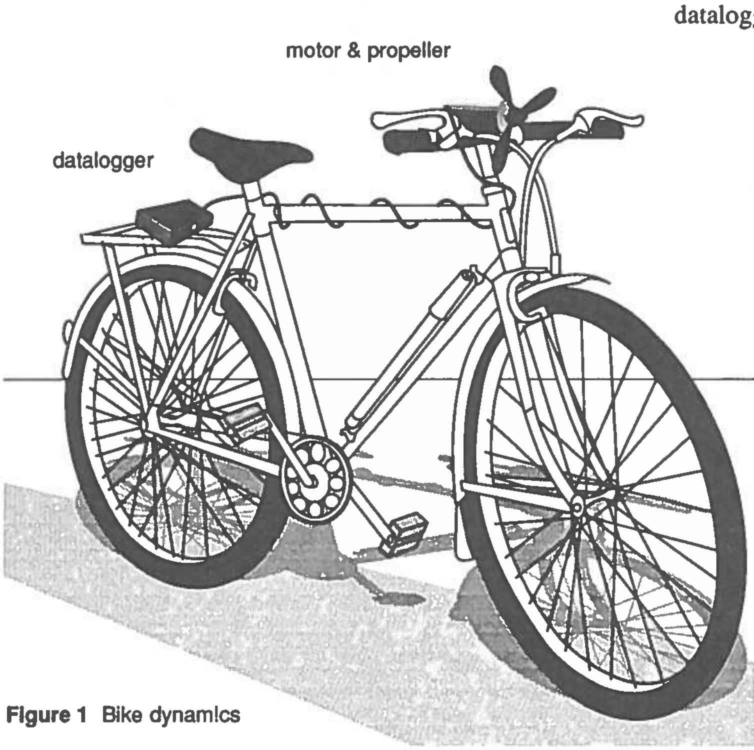


Figure 1 Bike dynamics

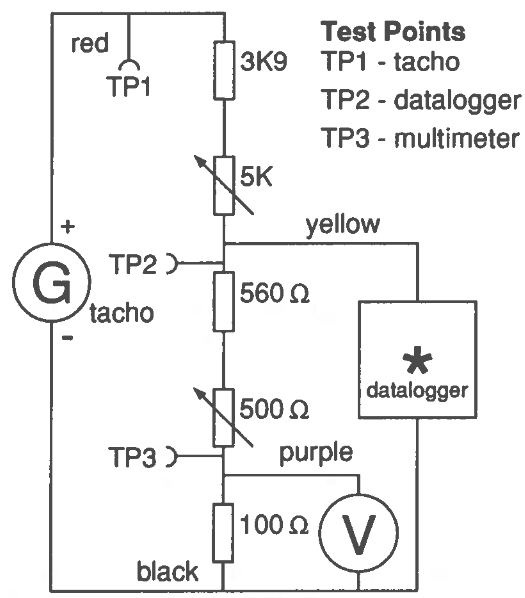


Figure 3 Voltage reduction circuit. We have included an additional output for direct connection to a multimeter (logger input/10) for direct display of 'mV' calibrated to represent mph/kmph etc.

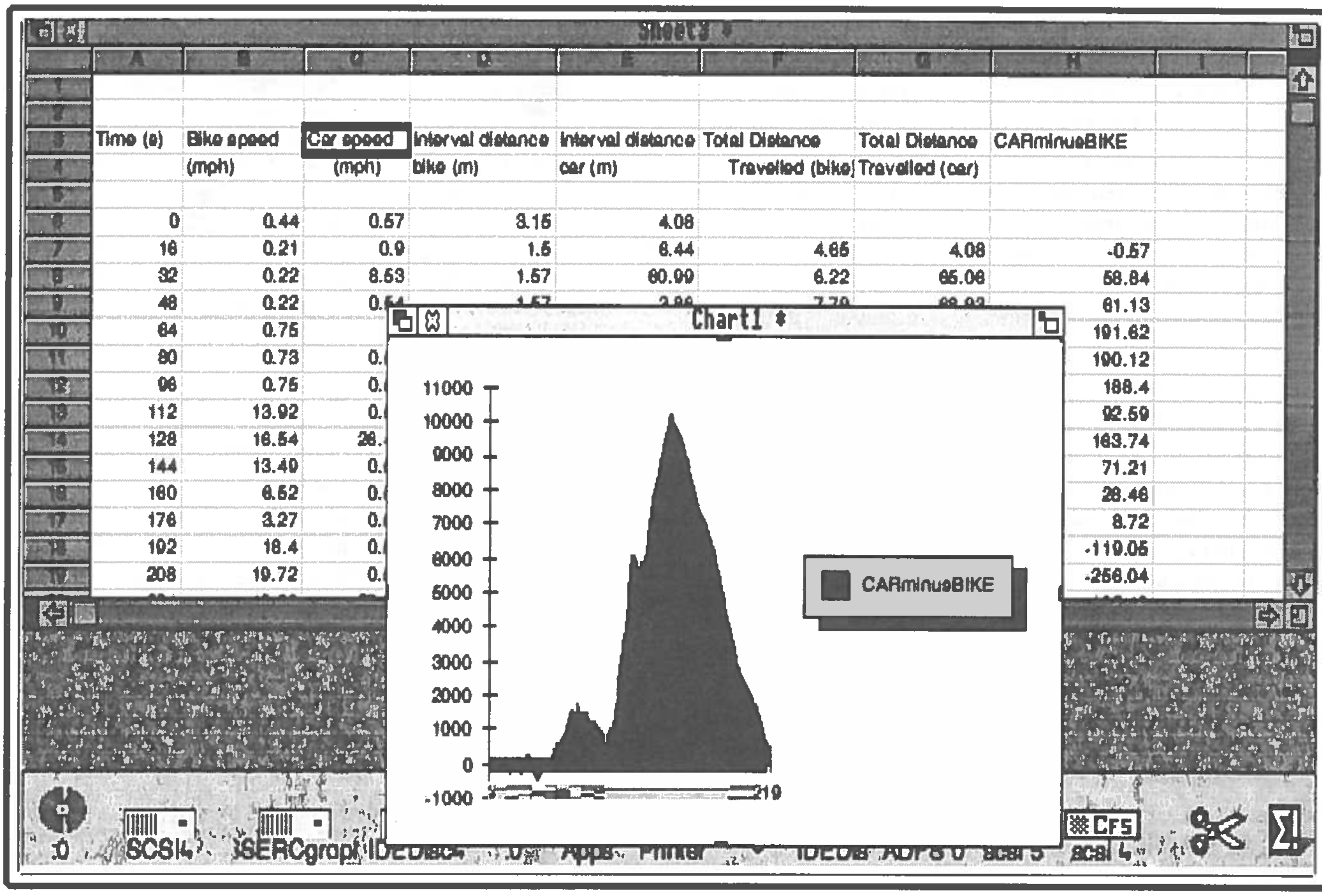


Figure 4 Eureka spreadsheet has built-in presentation facilities which can be used to display the recorded data in interesting ways

Now to the interesting bit - the data - Edinburgh to Rosyth on an 18 speed mountain bike (have you seen Edinburgh pot-holes?) powered by a reasonably fit, but extremely tired, 40 year old. The obvious question is how does the bike compare with the car over the same journey? Fig.4 shows some data compared on a Eureka spreadsheet. Chart 1 is the distance travelled by the car (see Bulletin 181, p10-12) minus that travelled by the bike (in metres). It is apparent that up to about half the total distance i.e. the outskirts of Edinburgh, the car is in the lead by only 1 km. The average speed of 23 mph for the car compares not too favourably with almost 15 mph for the bike (Fig.4). Even if car users had a second Forth Road Bridge to go over I doubt whether their average speed would increase by much!

Do try out this technique on any other vehicles (yachts, microlites, humans on roller/ice skates, hang-gliders etc. - at your own risk) and send us samples of your data, Arc preferably or CSV files, and the problems/solutions you encountered. Why not rig up a tacho with friction wheel rubbing on the bike tyre for *real distance* and compare it to the *wind distance*. Try plotting the latter vs. the former for journeys on calm days and windy days mostly into the wind and then with the wind. The *wind distance* seems a better measure of how much energy you have expended in cycling. Fig.6 opposite shows the apparent distance on a journey, mostly with the wind, was 82% of what may be expected in calm conditions. Does this mean I used 18% less energy in getting to SSERC? The reverse journey, mostly into the wind that same evening was 12% more than expected. This definitely needs more investigation. Happy 'birreling'!

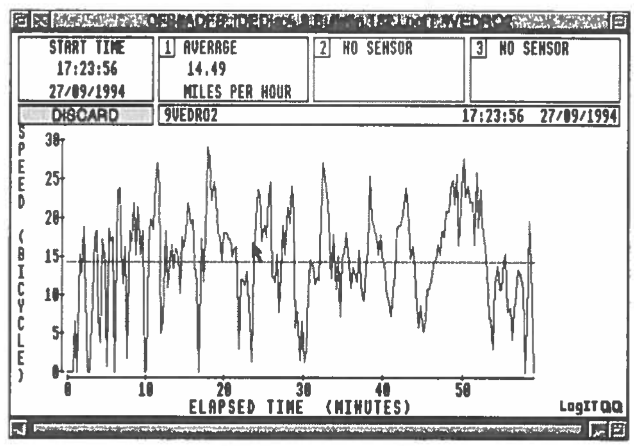


Figure 5 LogITLink used to display bike journey & average speed

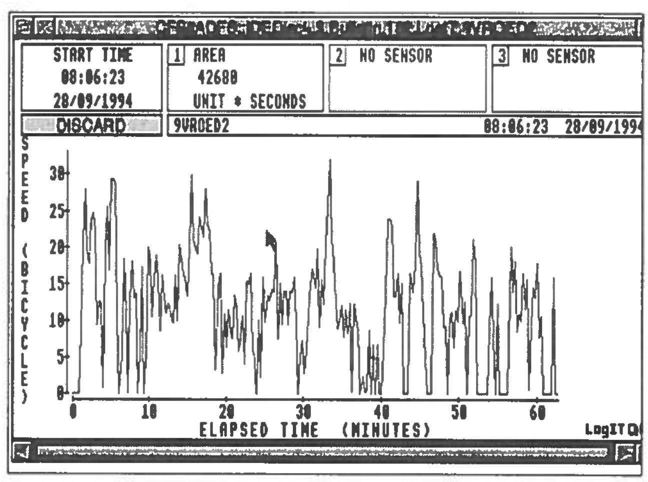


Figure 6 Rosyth to Edinburgh with a SWW wind

2. Wheel Balancing

No, this is nothing to do with John Major's relations, unicycles or the like. Anyone who is unfortunate enough to have had their car fail the MOT test or lugged a spare wheel to Kwik-Fit, Smiley or back-street rip-off merchant will know that the price you pay for your rubber bears scant relation to the advertised prices. "Would you like your tyres balanced sir?". Those brave enough to say "No" are treated to horror stories about uneven tyre wear, ruined suspension and uncontrollable wobbles at 50 mph.

If "Yes" is the answer then it is a difficult choice to either partake of the disgusting free coffee purveyed in the sub-tropical customer waiting-room or to quietly kick your heels whilst watching the 16 year-old tyre technician, up-to-the-elbows in glaur, as he (or she) wrestles with the tyre balancing machine. Red lights blaze out how bad the imbalance is and therefore how disastrous your driving life would have been without the discrete dod of lead delicately hammered into the rims.

To show the principles in the lab you need no more than a tacho with any large (approx. 8 cm) diameter wheel attached and a few blobs of the ubiquitous Blu-tak (Fig.7). The 75 tooth gearwheel shown is part of the Unilab/Test-bed) Precision Gear System and is available in packs of 20 (Cat. No. 874.004, £8). However, any buggy-type wheel will do so long as it fits securely on the tacho spindle.

Depending on the voltage output characteristics of the tacho, you may need to voltage divide the output to suit your datalogger or interface. In the examples shown here we logged the data on the DL plus datalogger and transferred the data to Datadisc PP on the Archimedes. You may equally well use a simple analogue interface.

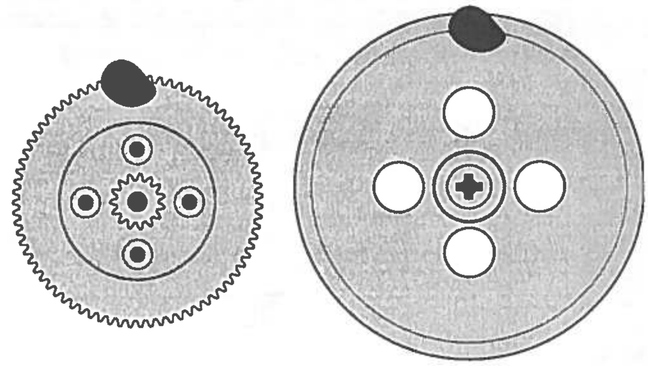


Figure 7 Plastic gearwheel or buggy-type wheel with Blu-tak

First spin the wheel with nothing attached and then log and save the voltage. Add a blob of Blu-tak to the rim and spin again. Now place another roughly similar sized blob diametrically opposite and spin again. If it is balanced the *wiggle factor* on the trace will decrease. Adjust the size of blob until a straight line results. Compare the blob masses.

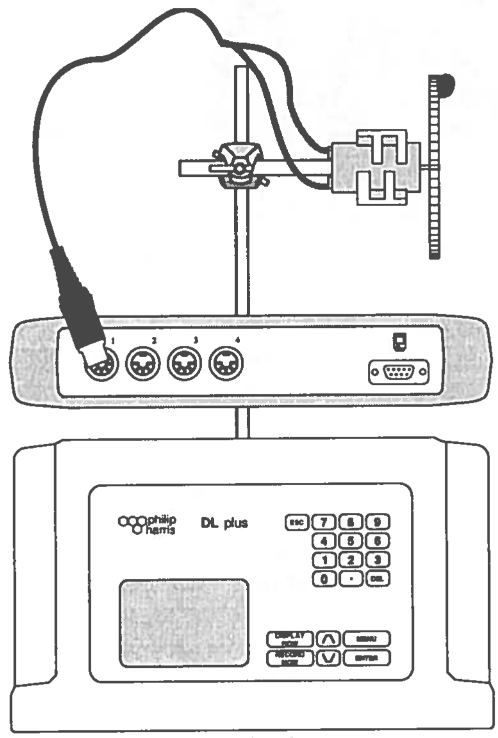


Figure 9 Apparatus for wheel balancing

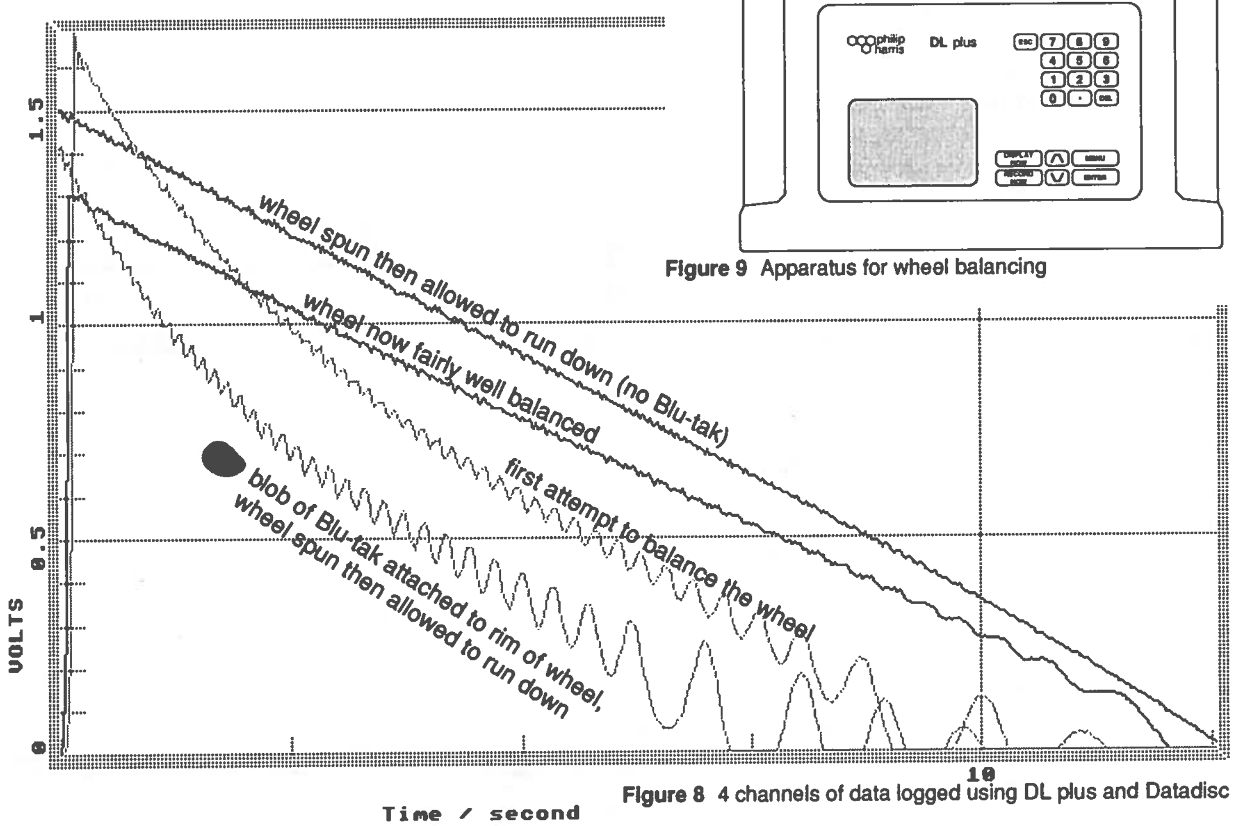


Figure 8 4 channels of data logged using DL plus and Datadisc PP

3. Damped Oscillations

This is an extension of the Wheel Balancing technique used in section 2. This time our blob of Blu-tak is fixed on the end of a wooden arm which is attached to the wheel in pendulum fashion by two more pieces (Fig.10). The arm can be of any material really as long as it can be fixed securely to the wheel.

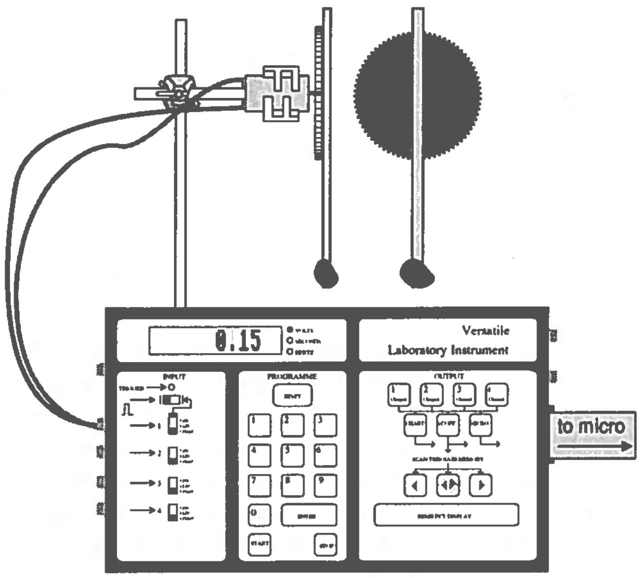


Figure 10 Apparatus for damped oscillations

In this experiment we used VELA since it can log bipolar voltages - plus or minus to you and me. Connect the output from the tacho to the channel 1 inputs and set the input scale to ±0.25 V. Log for 40 seconds on Program 2 - i.e. enter <02 40, ENTER, START>. As soon as possible spin the wooden pendulum to complete a number of revolutions then allow it to swing to and fro until stationary. The letters <O-P> appear on VELA's display when logging is finished.

The data can either be downloaded to Datadisc Plus/ PP/Pro and saved (Fig.11) or viewed immediately on an oscilloscope connected to VELA - press <RESELECT DISPLAY, Channel 1, SCOPE>.

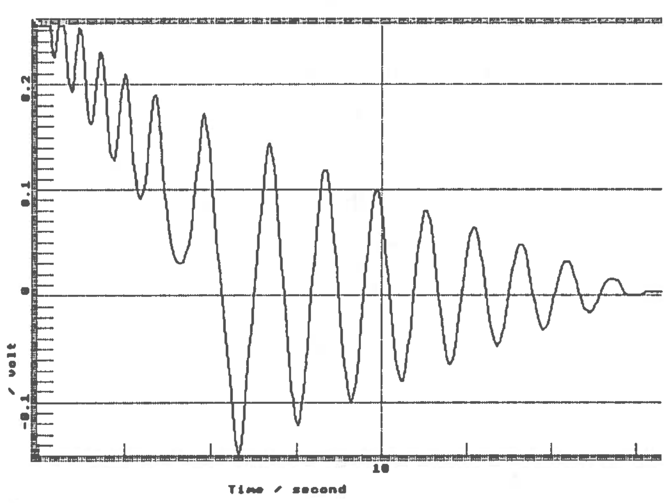


Figure 11 Spinning pendulum then damped oscillation

Remember the trace shown on Fig.12 is the velocity of the system and not displacement as may have been encountered in other experiments used to demonstrate damped oscillations. Have a look back at pages 11 and 13 in Bulletin 182 to see how to derive displacement and acceleration data respectively from your velocity vs. time graph. Suggest what the displacement and acceleration graphs would look like before you plot them.

Looking at the graph some interesting questions arise - is the period of oscillation the same when the pendulum spins and then swings? How would you describe the damping of the maximum speed in the positive direction throughout the course of the experiment? Is it the same as the damping in the opposite direction?

Now try altering the mass of Blu-tak and, without spinning this time (Fig.12), let the pendulum swing back and forth from just off the vertical position. Try also fitting a longer arm etc. etc.

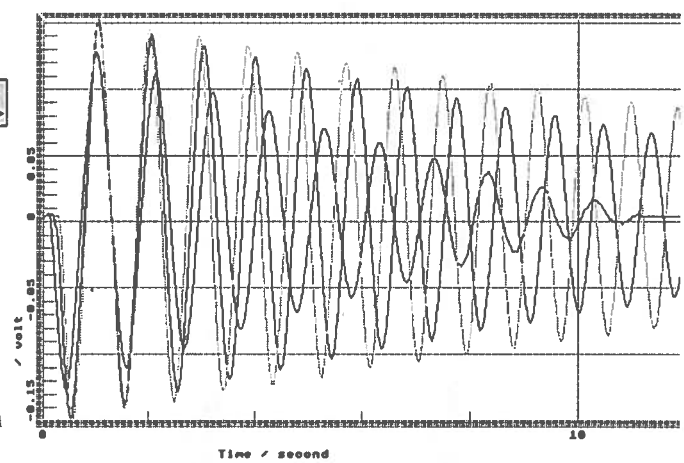


Figure 12 Damped oscillations - altering the mass

As a final twist why not have a bit of fun and display an X-Y plot of one damped oscillation against another. Now try and explain that one! (Fig.13). With the graph displayed press <J> to join the dots (or not).

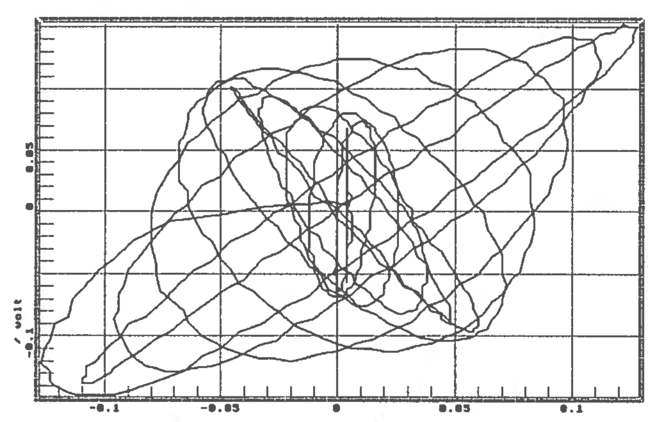


Figure 13 Putting a damper on Lissajou?

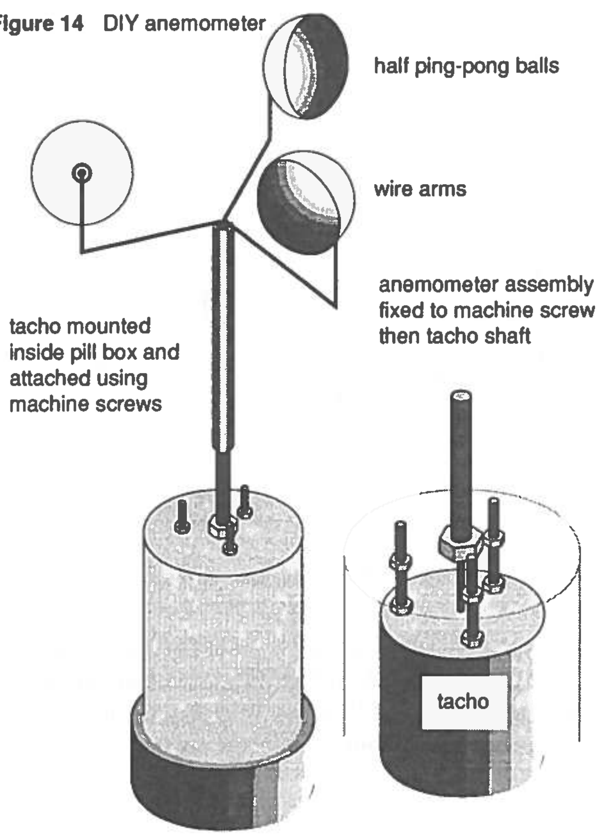
4. DIY anemometer

Is there nothing you can't do with a tachogenerator and a bit of imagination? Comments and answers on a post-card to ....

In this application we forego the propellor and build something that looks like the real thing - well almost. In the best *Blue Peter* tradition you need a plastic pill box (49 mm diam. x 75 mm height, available at your friendly-neighbourhood pharmacy), 3 ping-pong balls, a wee wire coat-hanger and a tachogenerator (Surplus Item 802, £5).

First cut three ping-pong balls along the seam and drill a clearance hole in each of three hemispheres. Make three, 120 mm lengths of wire for the arms and fashion 2 right angled bends at about 40 mm from the end of each (Fig.15). At one end make a loop through which a wee machine screw (3M on our assembly) & nut can attach the cup. The anemometer shaft can be made of plastic, wood or metal. If the rod you use is pretty true you can drill a 2 mm hole in one end to accept the tacho shaft and at the other a hole which will take three of the wire arms.

Figure 14 DIY anemometer



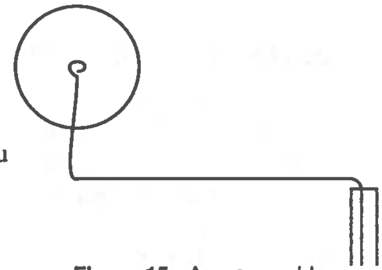


Figure 15 Arm assembly

At this stage, stating what seems to be blindingly obvious but is easy to get wrong, make sure the cups are all facing the same way and the assembly will produce a positive voltage when the wind blows. With the help of a protractor, ensure the 3 wires are set at 120° to each other. Use *Araldite* to fix them in position in the shaft. We used a brass machine screw as an intermediate link between the cup assembly and the tacho shaft. This can have a hex or countersunk head. A bolt, not fully tightened down, helps to keep out rain.

This tacho has 3 small tapped holes around its shaft. These can be used to fix it to the pill box. Drill a 2 mm hole in the centre of the pill box base. Push the tacho shaft through a piece of card and, with a pencil, locate the tapped holes and push the point through. Use the 2 mm drill to centre the card template on the pill box base and mark the positions of the fixing holes. Drill clearance holes in the pill box for 3M fixing screws. Drill out the centre hole to 6 mm.

Put a nut on each 3M fixing screw and fix to the tapped holes on the tacho and tighten the nut fully on to it (Fig.14). Cut the head from each machine screw. Push the tacho through the pill box until the its shaft and threads sit proud of the base. Fix securely by tightening down another nut on to each fixing screw (Fig.14). Drill a 4 mm hole in the side of the pill box. Feed the output wires through and affix 4 mm sockets.

Make sure the top half spins freely and there is no contact with the pill box. Check the voltage output is OK with a multi-meter. Add a voltage divider if it is necessary to reduce the output. The output can be calibrated easily by taking a short car trip on a windless day. Drive at a series of constant speeds and note the voltage output each time. When you have applied this calibration to your software you are ready to log wind speed. See Fig.16 for a typical trace over a period 3 days.

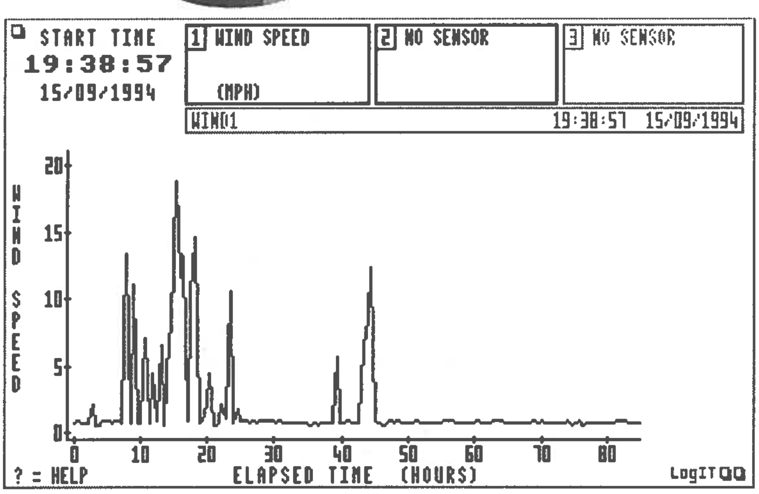


Figure 16 Typical output from DIY anemometer measuring wind speed

Tachogenerator applications Part 3

There wasn't quite enough space in this issue to include the one-piece apparatus for demonstrating constant acceleration, constant speed and constant deceleration or the techniques for measuring *g*.

The story will thus continue in the Winter issue.

Reference

1. *Tachogenerator applications Part 1*, p 9-15, SSERC Bulletin 181, Summer 1994.

Machine Safety

Some aspects of safety in the design of work equipment are suggested as possible contexts for teaching and learning in technology courses. The article attempts to put to positive educational use concepts behind some of the *preventive and protective measures* required by the Work Equipment Regs.

In recent Bulletins we have described the need to discuss health and safety issues with pupils and students as and when they arise naturally in the course of day to day learning and teaching. And, we would go further and suggest that a preferred approach is to exploit such opportunities mainly so as to further their understanding of basic ideas in science and technology.

Safe shall be my going[1]

We can all become more than a little disenchanted with yet another circular on Health and Safety, COSHH or British Standards, particularly those penned in soporific prose. A notable exception to this style is the BSI publication Safety of machinery [1]. To all those who have this publication but have never read it - dust it off! It is well worth a read or even just a look at the informative drawings. Dull of soul would they be who did not so glean a few ideas for project work. There are too many good things to list in this short article but a couple that seem worth bringing to the attention of those involved in technology education are detailed in the ensuing paragraphs.

We provide two examples of electrical and pneumatic safety circuitry that could be introduced at S2 or Standard Grade, perhaps as an introduction to logic tables. They require a little thought to understand, allow a modicum of progression and may even engender in both teacher and pupil an interest in safety technologies. Remember that, in any power operated guard interlock system, should there be a failure of any part or a failure (or interruption) of the power supply, it should not be possible to run the machinery.

Caution is the parent of safety[2]

In its simplest forms the design of a pneumatic or electrical interlock can be arranged so as to actuate the switch in one of two ways - in either a negative or a positive mode. One easy way to show this electrically is to use microswitches. In our diagrams the actual electrical connections have been deliberately omitted for clarity. Each in any case should be a straightforward wiring project. Fig. 1 summarises the simple logic of a microswitch, describes one type (SSERC Item 723) and the relationship of the output pins to the internal contacts.

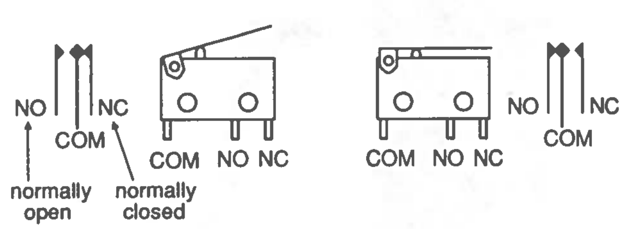


Figure 1 The simple logic of a microswitch

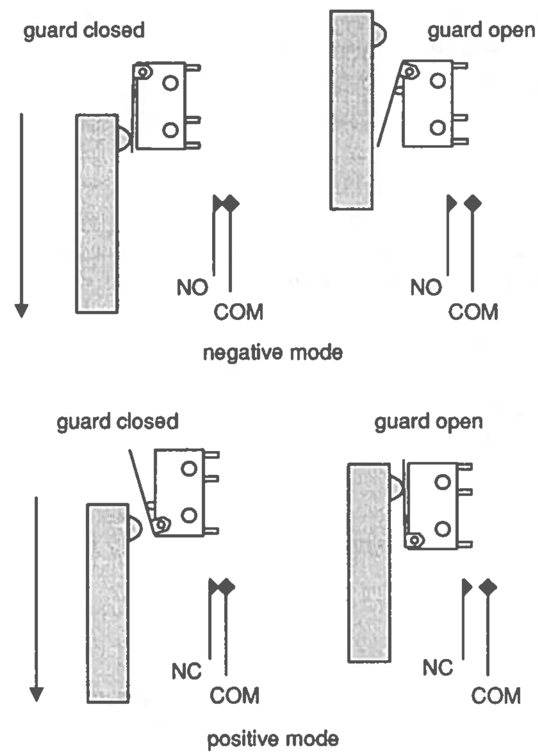


Figure 2 Switch operations in positive and negative modes

From Fig. 2 it should be apparent that a system in negative mode is easily over-ridden, Problems could arise if contacts welded or if the return spring were damaged. The positive mode is a safer system but it still relies on the return spring and on proper maintenance of the system.

How could this interlock system be improved? Fig. 3 gives one answer. Maybe this should be offered as a problem solving exercise to the class after some discussion on various aspects of safety in the use of machine operated tools and equipment? This opposite mode method should give a higher standard of safety. But, what would happen should the top switch fail? What would be the consequence if the contacts in the lower switch were to weld? Some method is required of monitoring the state of the switches. Could this provide a progression into the use of LEDs as signal lamps?

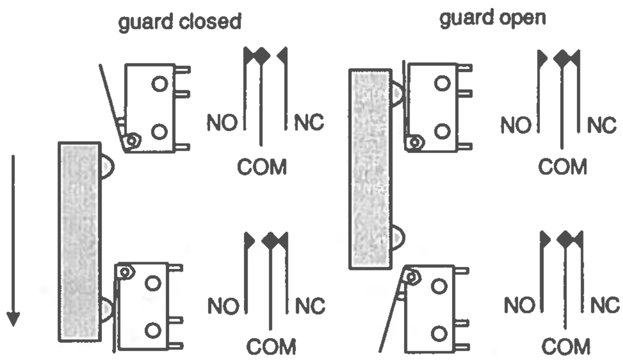


Figure 3 Switches mounted in opposite modes

Fig. 4 shows a stylised version of how such an interlock system could be configured. It should be noted that in a workshop situation the power to the motor would be fed through a contactor or power relay, and not directly through the microswitch.

Much is made in schools in any introduction to pneumatics, and rightly so, of the hazardous aspects of air at high pressure and the forces involved. A favourite project is the use of 2/3 valves to simulate a guard system for some unspecified piece of machinery. The point of the exercise, apart from the obvious one of learning the basics of pneumatic circuitry, may be to give a simple introduction to AND gates or safety. For example, how can we keep the operator's hands away from the working area?

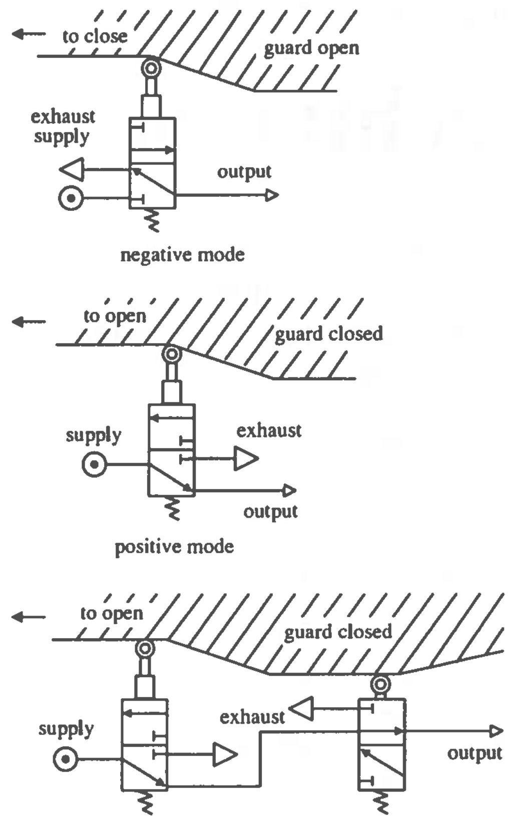


Figure 5 A better, pneumatic system replaces the microswitches. It uses positive and negative modes. Is this a failsafe system?

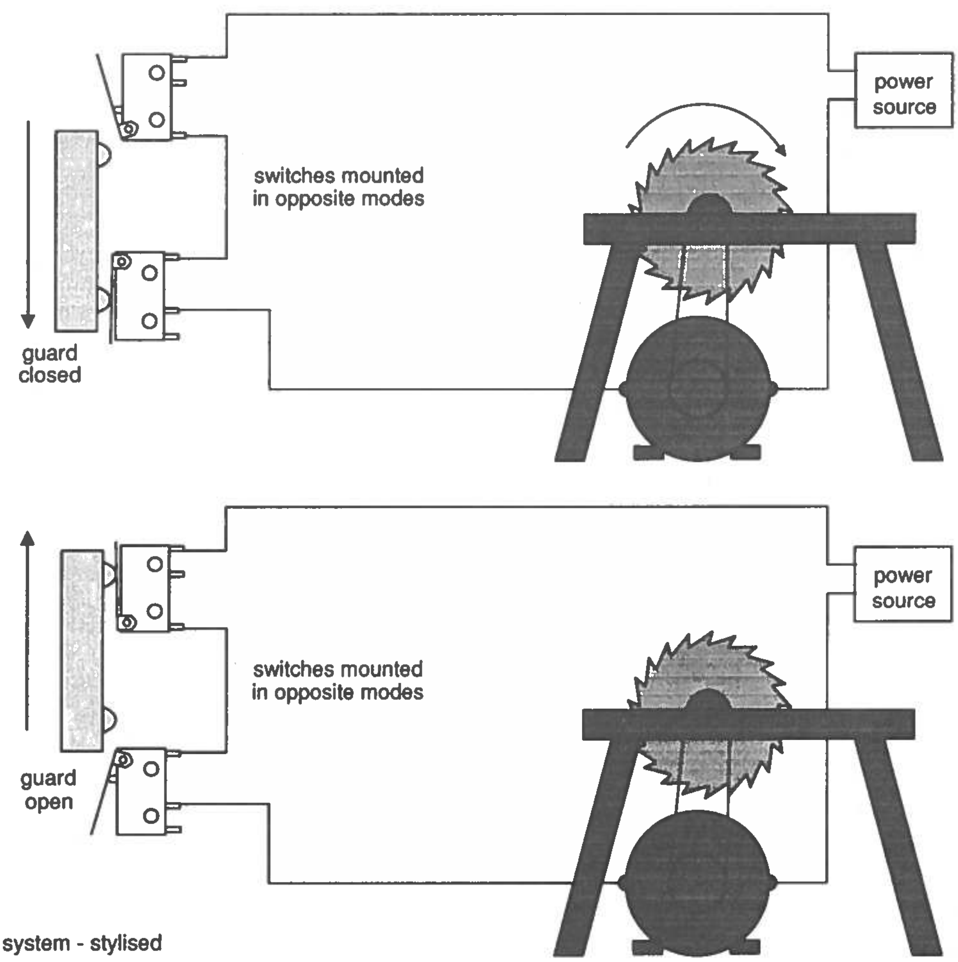


Figure 4 Interlock system - stylised

Although the preceding examples are not related to specific machinery, it should be a simple matter in a technology department to relate them to a relevant machine room or production line system.

Safe they all safety's lost[3]

Failsafe is a word we all may utter but it is a term no longer used by B.S.I., The phrase now in use is "failure to danger is minimized". The idea behind this move away from such a previously accepted expression is to try to change our thinking on safety. Can a failsafe system ever be wholly safe? History is littered with the debris of ships that could not sink, of heavier than air machines that could not crash, of space shuttles that were the ultimate in safety and of sundry sawyers who will never again order five pints with one hand.

Who keeps no guard on himself is slack[4]

Safety need not be a boring, merely time consuming, subject. Nor should we reject aspects of the curriculum we feel may be too hazardous. What we can do is to have everyone concerned with work that may be deemed parlous to look positively at ways of minimizing risks and dangers. And to enjoy.

Reference

1. *BS 5304 British Standard code of practice for; Safety in machinery : 1988*, British Standards Institution.

Acknowledgements - quotes and aphorisms

1 and 3 Rupert Brooke, New Numbers No 4 Safety.
2 Proverb, Anon.
4 George Herbert, a cleric of the 17th century.

Distinguishing glass types

Now you see it, now you don't, or a simple means of distinguishing between soda and Pyrex glass.

This is an old trick, but performed now with new solvents. A piece of Pyrex or borosilicate glass (refractive index 1.474) becomes invisible or nearly so when immersed in a liquid with the same refractive index. Generally various chlorinated hydrocarbon solvents which had refractive indices close to that of Pyrex glass have been used in the past, In Bulletin 59 the use of trichloroethene was recommended.

Hawick High School contacted us as some of these solvents are no longer available. In addition since they wanted to use the technique as part of class work and not just for purposes of identification, it was also important that less hazardous materials were used.

Of a wide range of solvents scanned none had the required refractive index and it was necessary to try mixtures of solvents with refractive indices bracketing a value of 1.474. A suitable substitute was a 50/50 mixture by volume of cyclohexane and benzyl ethanoate. You can probably fine tune it a little by 'titrating' with a known piece of Pyrex glass as the indicator. If the mixture is kept for any length of time in the open it will become slightly richer in the less volatile benzyl ethanoate and may need a little topping up. Storage in a stoppered bottle should make evaporation negligible. Our panel considered the Pyrex to be more invisible in the mixture than in the trichlorethene whilst the soda glass was clearly seen in both liquids.

Hazcons

This mixture has the advantage of being much less toxic and, unlike the trichloroethene, is much less readily absorbed through the skin. The Occupational Exposure levels are:

trichloroethene	MEL	100 ppm (8 hr TWA) and 150 ppm (15 min STEL) with Sk notation
cyclohexane	OES	100 ppm (8 hr TWA) and 300 ppm (15 min STEL)

benzyl ethanoate has not been assigned an OES.

There are three main reasons for preferring the cyclohexane/ benzyl ethanoate mixture. Trichloroethene has been assigned a MEL (Maximum Exposure Limit), which means that not only should you not exceed the 100 ppm level, but it is legally required to get the concentration of vapour as low as is reasonably practicable. This really means using a fume cupboard. Secondly it is much more likely to reach that level of 100 ppm on account of its higher volatility; it has a vapour pressure of 100 mm at 32°C compared with 100 mm at 61°C and 1 mm at 45°C for the cyclohexane and the benzyl ethanoate respectively. (It is strange that vapour pressures are so often given for widely different temperatures.) Thirdly trichloroethene is more toxic and is readily absorbed through the skin. In addition a splash of it in the eyes may cause damage whereas the other two are irritants.

Cyclohexane is a very safe solvent if used with reasonable care, having both very low acute and chronic toxicities, since it is rapidly metabolised to cyclohexanol and its conjugates, which are readily excreted. In common with many hydrocarbons it does exert a narcotic effect if the vapour is inhaled in high concentration and is flammable (flash point -18°C). However once made up the mixture will be much less flammable, benzyl ethanoate having a flash point of 95°C. Both trichloroethene and benzyl ethanoate are reported as having caused cancer in animals. Trichloroethene reacts with alkalis to give dichloroethyne, which is spontaneously flammable in air and with aluminium to produce carbonyl dichloride.

Controls

- Use the above 50/50 mixture by volume of cyclohexane and benzyl ethanoate in place of the trichloroethene.
- Prepare the mixture in a well ventilated laboratory or in a fume cupboard using nitrile gloves and wearing eye protection.
- Store in stoppered bottle and label *"Flammable"*.
- If possible dip unknown glass into the bottle rather than pour the contents out into a beaker.
- Ensure absence of nearby sources of ignition.

Checking for soda glass

It is also possible to check for soda glass (refractive index 1.511 to 1.512) by using either of the following two mixtures, again 50/50 by volume:

ethyl benzoate and benzyl ethanoate, or
ethyl benzoate and methyl 2-hydroxybenzoate.

Here it is the turn for the soda glass to disappear and the Pyrex remain visible. The panel were now divided on which of the two solvent mixtures were the best. Viewing against a dark background makes the distinction easier than holding it up to the light or window.

As an aside this little topic could easily be expanded into an interesting project about intermolecular forces related to the changes in volume and refractive indices of mixtures.

Hazcons

The two new solvents used here are not classed as flammable having higher flash points (85°C and 101°C) and are much less volatile (vapour pressures of 1 mm at 40°C and 1 mm at 54°C). So inhalation is much less of a problem and the materials are certainly not flammable at room temperature. Both can irritate the eyes. Methyl 2-hydroxybenzoate is reported as possibly being mutagenic and teratogenic and harmful if ingested. A 30 cm^3 dose has been reported as being fatal in an adult. How many of us old rugby players used to rub lashings of this stuff (alias methyl salicylate or Sloan's Linament) onto our sore knee joints? The 2-hydroxybenzoate has a very persistent aroma and if you do not like it then use the first mixture.

Controls

- Wear eye protection and during preparation wear nitrile gloves.

Hydrogen spectrum

Observing the visible lines of the Balmer series in atomic hydrogen

The only inexpensive spectral source of hydrogen on the educational market is the Geissler tube (Table 1). This is a long glass tube whose central portion is narrow bore and whose end sections, which hold the electrodes, are of stouter girth. The tube is normally run off an EHT d.c. supply. This note comments on some of the difficulties in trying to see lines in the Balmer series.

The first thing to realise is that it is never easy seeing Balmer lines with this apparatus because the gas within the tube contains a mixture of atomic and molecular hydrogen. The α line stands out on its own. However the other two lines which may also be visible, the β and γ lines, are superposed on bands of molecular hydrogen.

The performance amongst tubes is variable. In some, the β and γ lines stand out prominently against the molecular bands. In others, the molecular bands and atomic lines are of comparable intensity.

Item	Supplier	Stock number	Price (£)
Geissler tube, hydrogen	Griffin	XFU-200-050C	25.15
	Harris	Q63010/1	16.91
	PASCO	SE-9461	19.00
Geissler tube holder	Griffin	XFU-204-520N	17.20
	Harris	Q63050/2	30.63
Geissler tube holder and power supply	PASCO	SE-9460	133.00
Balmer lamp	Leybold	451 13	381.89
Balmer lamp, deuterated	Leybold	451 41	380.00
Power supply for the Balmer lamps (451 13/41)	Leybold	451 14	558.37

Table 1. Suppliers, part numbers and prices of hydrogen spectral lamps and specialised power supplies. Geissler tubes from Griffin and Harris should be operated off an EHT supply delivering about 3 kV.

The variability in quality of tubes is fairly random. Hydrogen may possibly diffuse into electrodes, resulting in poorer quality with age. However new tubes do not consistently perform any better than old tubes. Experience shows that some new tubes can have an atomic spectrum which is less prominent than that in some old tubes. In fact, replacing a tube is hit or miss. So, if you have a tube that reveals the Balmer lines, you can count yourself lucky!

Apart from Geissler tubes, the one other hydrogen spectrum source we know of is made by Leybold, the German physics equipment manufacturer. Leybold have specially prepared their Balmer Lamp so as to give an atomic spectrum free of the band spectrum associated with molecular hydrogen. Leybold also sell a deuterated variant of this lamp. Both lamps operate off a specially designed power supply. The cost of a lamp and supply is around £940 (Table 1).

Summary

In order to measure the visible lines of the Balmer series in hydrogen, which is a suggested activity in the CSYS Physics syllabus, the only apparently reliable source we know of, going by its specification, is Leybold's Balmer Lamp. It is a matter of chance as to whether a Geissler tube produces a clearly visible line spectrum.

Acknowledgements

Information on the performance of Geissler tubes was supplied by Ronal Brown and Robbie Stewart of the Strathclyde University Physics Department.

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.

New 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

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

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

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

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

621 Miniature motor, 1.5 V to 3 V d.c., open construction, ideal for demonstration, dimensions 19 x 9 x 18 mm, double ended output shaft 5 mm x 1.5 mm dia. 20p

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

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

773 Tachometer (ex equipment) £2.25

625 Worm and gear for use with miniature motors, nylon worm and plastic gear wheel. 35p

802 Motor, 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

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

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

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

Precision motor stock

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

786 Precision motor with attached but electrically isolated tachometer, 0.15 to 12 V d.c., no load current 20 mA and 5,700 r.p.m. at 12 V, stall torque 96 mNm, 13 segments. Overall body length including tachometer 99 mm. Output shaft 19.5 x 4 mm dia. Back EMF constant 2.1 V/1000 r.p.m. Offload output voltage from tachometer 11.73 V d.c. with 12 V applied to motor. £15

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

Miscellaneous items

791 Propeller, 3 blade, to fit 2 mm shaft, blade 55 mm long. 45p

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

790 Buzzer, 3 V. 55p

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

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

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

313 Thermostat, open construction, adjustable, temperature range +10° to +65°C. Rated at 6 A, 250 V, but low voltage switching also possible. 60p

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

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

753 Submersible pump, 6 V to 12 V d.c., 8 litres/min., 0.6 bar, dry operation protected. £5.50

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

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

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

781 Toggle switch, panel mounting, 2 Amp rating, SPST, mounting bush 0.468 inch, flattened white 10 mm lever. 35p

782 Toggle switch, panel mounting, 3 Amp rating, SPST, mounting bush 0.468 inch, flattened black 18 mm toggle. 50p

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

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

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

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

742 Key switch, 8 pole changeover. 40p

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

688 Croc clip, miniature, insulated, red. 5p
759 Ditto, black. 5p
788 Crocodile clip leads, assorted colours, insulated croc. clip at each end, 360 mm long. £1.35

741 LES lamp, 6 V. 15p

770 LES lamp, 12 V. 15p

690 MES lamp, 6 V, 150 mA. 9p

691 MES battenholder. 20p

692 Battery holder, C-type cell, holds 4 cells, PP3 outlet. 20p

730 Battery holder, AA-type cell, holds 4 cells, PP3 outlet. 20p

729 Battery connector, PP3 type, snap-on press-stud, also suitable for items 692 and 730. 5p

724 Dual in line (DIL) sockets, 8 way 5p
760 14 way 7p
776 16 way 8p

716 3-core cable with heat resisting silicone rubber insulation, 0.75 mm² conductors, can be used to re-wire soldering irons as per Safety Notes, Bulletin 166. Per metre. £1.35

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

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

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

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

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

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

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

752 Shandon chromatography solvent trough. £1.00

803 Test tube rack, used. 10p

804 Evaporating basin, porcelain, 80 ml capacity. £1.00

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

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

Components - resistors

328 Potentiometer, wire wound, 15 Ω, linear, 36 mm dia. 30p

737 Ditto, 22 Ω, lin., 36 mm dia. 30p

329 Ditto, 33 Ω, lin., 36 mm dia. 30p

330 Ditto, 50 Ω, lin., 40 mm dia. 30p

420 resistors, 5% tolerance, ¼ 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, 470K, 680K, 1M0, 1M5, 2M2, 4M7, 10M. Per 10. 6p

421 DIL resistor networks, following values available: 62R. 100R, 1K0, 1K2, 6K8, 10K, 20K, 150K. Per 10. 30p

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

Components - capacitors

695 Capacitors, tantalum, 4.7 µF 35 V, 15 µF 10 V, 47 µF 6.3 V. 1p

696 Capacitors, polycarbonate, 10 nF, 220 nF, 680 nF, 1 µF, 2.2 µF. 2p

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

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

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

Components - semiconductors

807 Schools' Chip Set, 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 kΩ at 25°C, $\beta = 4200$ 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 ±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 µm to >14 µm, recommended blanking frequency range of 0.1 Hz to 20 Hz. The sensor is sealed in a low profile TO39 can with a window optically coated to filter out wavelengths below 6.5 µm. Data sheet supplied. For application see SG Physics Technical Guide, Vol.2, pp 34-5. 50p

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 µm 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 µm 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

Other components

We also hold in stock a quantity of other electronic components. If you require items not listed above please let us know and we will do our best to meet your needs, or to direct you to other sources of supply.

Items not for posting

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

747 Quickfit vented receiver, 10 ml. 20p

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

Chemicals

NB : chemicals are named here as described on supplier's labels. We have recently added about fifty other chemicals to our stock but have neither the space nor the time to complete a full listing here. Please send for a complete list of substances and prices.

667 250 g urea 25p

668 500 ml dodecan-1-ol. 50p

670 500 g Keiselguhr acid, washed. 25p

672 500 g Magnesite native lump. 25p

673 250 g manganese metal flake, 99.9%. 50p

676 500 g quartz, native lump. 25p

677 100 g sodium n-butyrate. 25p

678 500 g strontium chloride AR. 25p

681 Zinc acetate (ethanoate) AR. 25p

682 2.25 litre ammonia solution. 50p

685 500 ml n-decanoic Acid (Lauric acid). 25p

712 Smoke pellets. For testing local exhaust ventilation (LEV) - fume cupboards and extractor fans, etc. 50p

SSERC, 24 Bernard Terrace, Edinburgh, EH8 9NX;
Tel. 031 668 4421, Fax. 031 667 9344.

Allardyce Health Care Ltd., 6a Castle Street, Dundee DD1 3AA; Tel. 0382 28411 or 0382 22523.

British Standards Institution, Linford Wood, Milton Keynes MK14 6LE; Tel. 0908 220022.

Cheddar Models Ltd., Sharpham Road, Cheddar, Somerset BS27 3DR; Tel. 0934 744634, Fax. 0934 744733.
- also see supplier's address - Griffin.

Data Harvest (Educational Electronics), Woburn Lodge, Waterloo Road, Linslade, Leighton Buzzard, Bedfordshire, LU7 7NR; Tel. 0525 373666, Fax. 0525 851638. [Manufacturer - VELA]

Dee-Organ Ltd; 5 Sandyford Road, Paisley, Renfrewshire, PA3 4HW; Tel. 041 889 7000, Fax. 041 889 7764. [Source of safety signs and labels - Centrifuge article. See also Seton and Signs & Labels Ltd next column].

Engineering Initiatives Programme : Project Executive - Charles Wilson, Scottish Engineering, 105 West George Street, Glasgow G2 1QL; Tel. 041 248 3030, Fax. 041 204 1203.

Fisons (Griffin & George) Limited, Bishop Meadow Road, Loughborough, Leicestershire, LE11 0RG;
Tel. 0509 233344, Fax. 0509 231893.

Philip Harris Education:

2 North Avenue, Clydebank Business Park, Clydebank, Glasgow, G51 2DR; Tel. 041 952 9538;

Lynn Lane, Shenstone, Lichfield, Staffordshire, WS14 0EE; Tel. 0543 480077, Fax. 0543 480068.

Irwin-Desman Limited, 294 Purley Way, Croydon, CR9 4QL; Tel. 081 680 2058, Fax. 081 681 8429.

Leybold Ltd., Waterside Way, Plough Lane, London, SW17 7AB; Tel. 081 947 9744 Fax. 081 947 0210.

Mamod - see supplier's address - Griffin.

Neighbourhood Engineers, Project Manager :
Hamish Stears, The Engineering Centre (B30), Napier University, Colinton Road, Edinburgh EH10 5DT;
Tel. 031 452 8585, Fax. 031 447 8046.

PASCO Scientific, Admail 394, Cambridge CB1 1YY;
Tel. 0345 626055, Fax. 081 570 2682.

Prestige Medical, PO Box 154, Off Clarendon Road, Blackburn, Lancashire BB1 9UG; Tel. 0254 682622, Fax 0254 682606.

RS Components Limited, PO Box 99, Corby, Northamptonshire, NN17 9RS; Tel. 0536 201201, Fax. 0536 201501.

Seton Ltd; Department R, PO Box 77, Banbury, Oxon, OX16 7LS; Tel. 0295 269955, Fax. 0800 526861.

Signs and Labels Ltd; Latham Close, Bredbury Industrial Park, Stockport, Cheshire SK6 2SD;
Tel. 061 494 6125, Fax. 061 430 8514.

Technology Enhancement Programme (TEP) :

TEP Regional Adviser - Mr Michael Bedworth, 4 Hawesmead Drive, Kendal, Cumbria LA9 5HD;
Tel. & Fax. 0539 735901.

Unilab Limited, The Science Park, Hutton Street, Blackburn, Lancashire, BB1 3BT; Tel. 0254 681222, Fax. 0254 681777.

University of Glasgow, Archives & Business Records Centre, 13 Thurso Street, Glasgow G11 6PE;
Tel. 041 330 5515, Fax. 041 330 4158.

Wilesco - see suppliers' addresses - Harris and Irwin.

TEP

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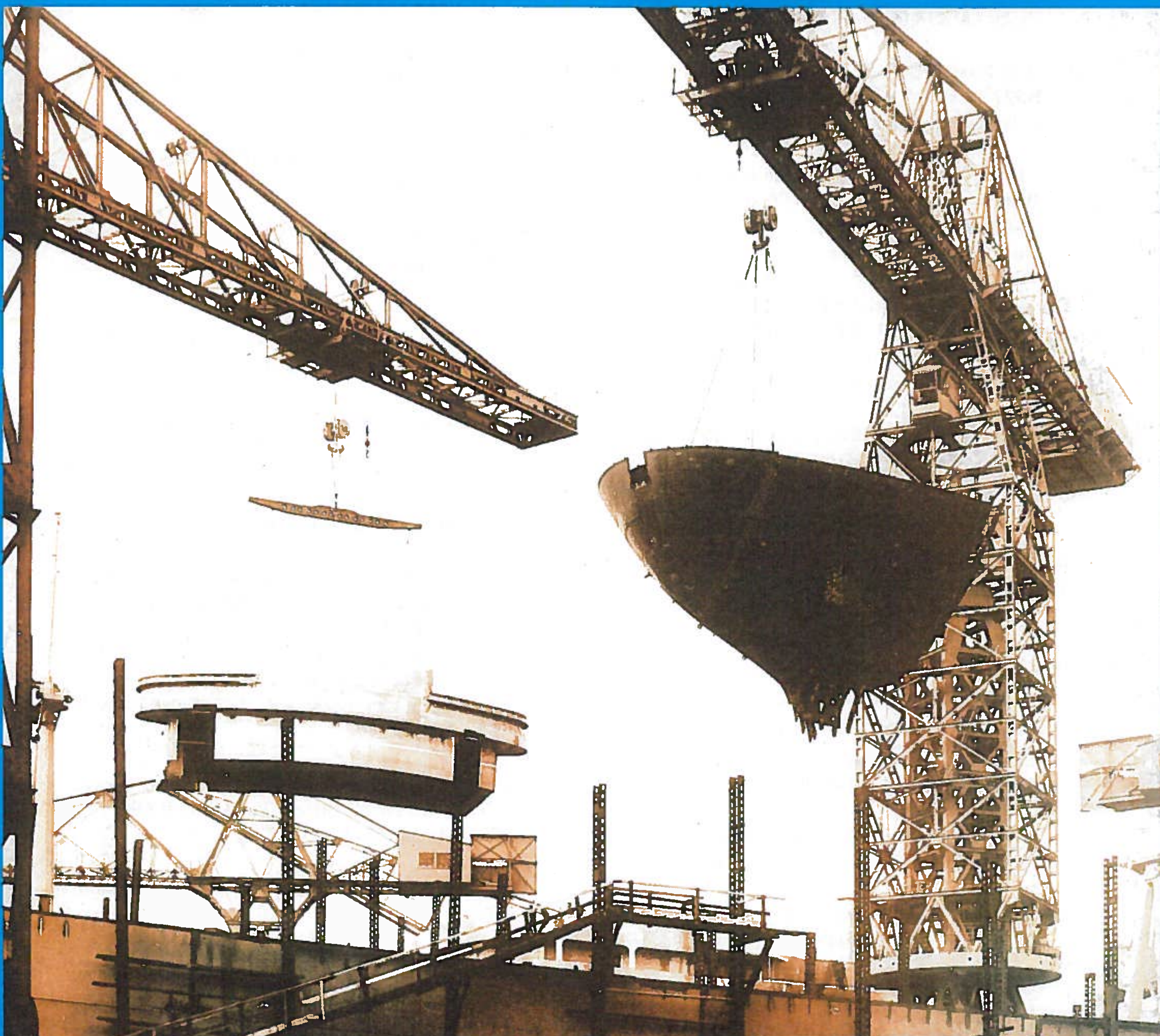

For further information on TEP services and products

contact: Technology Enhancement Programme
The Engineering Council
10 Maltravers Street
London WC2R 3ER