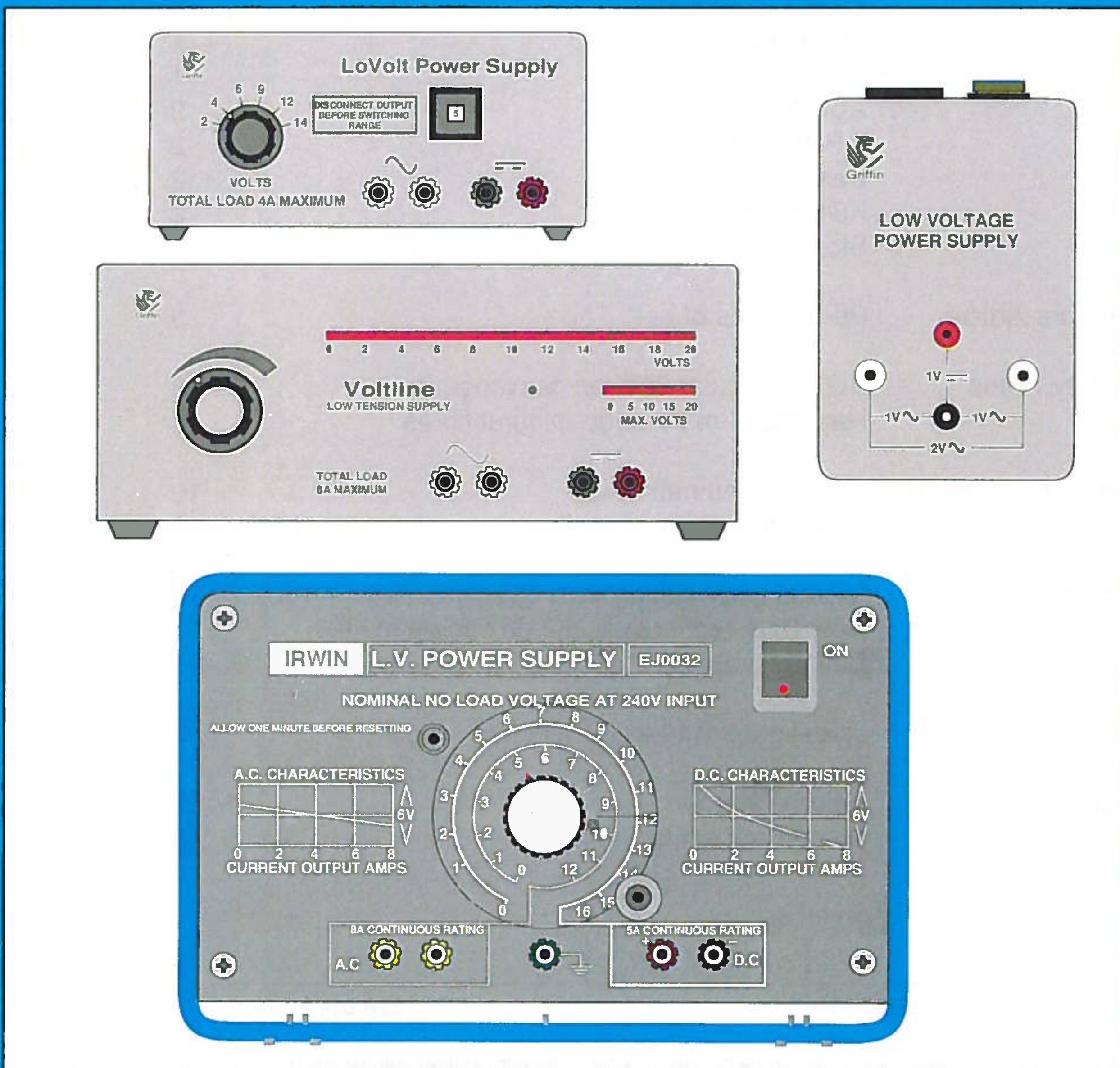
SCOTTISH SCHOOLS EQUIPMENT RESEARCH CENTRE



Science & Technology Bulletin

For: Teachers and Technicians in Technical Subjects and the Sciences

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NEWS AND COMMENT

Apology

We apologise to teachers and technicians as well as our other readers for the non-appearance of a Winter '95/96 issue. Much of the copy had been prepared. Some of it has been revised for inclusion in this issue. It did not however prove practicable to get it to press on a sensible timescale. This was because of a diversion of staff time to other issues which are discussed below.

Future of SSERC

The re-organisation of Scottish Local Government has caused much uncertainty for all concerned. In our case we have experienced great difficulty in obtaining firm commitments from all of the new Unitary Authorities that they would continue to buy in the SSERC service. As a direct result, on the 31st of January the Company known as SSERC Limited ceased active trading. As a Company Limited by Guarantee SSERC Ltd is governed by the Companies Act 1985. The Directors, all of whom are either elected members or senior officers of the Regional and Islands Councils, took a decision intended to avoid the possibility of the Company going into liquidation.

At the time of writing SSERC Limited remains solvent. A number of contractual obligations which remain are being met because they generate income and will improve the financial position of the Company so preventing potential losses. Thereafter the Company is to become dormant. The hope is that its assets, its material and intellectual properties, can be mothballed until such time as a sufficient number of Unitary Authorities give their commitment to buy the service.

We find it hard to see how the new Councils otherwise will be able to meet their twin statutory obligations to inform instruct and train teachers and technicians in health and safety matters and to do so cost-effectively and efficiently. Nonetheless, if the majority do not obtain this service from SSERC the staff team will be dispersed to different employing authorities and the Centre will close permanently. This Bulletin issue thus may be the last for some time, possibly the last ever. It is being published to meet the conditions of a service agreement with Strathclyde Regional Council.

Oh, that research report!

Where were you when somebody last asked : "Where were you when JFK was shot?"? Unless by my undemanding aged-beehive standards you're an educational neonate, you may well recall the sub-question fairly readily. I'll bet though, that if I were to ask "Where were you when they announced the publication of the SCRE Report on *Primary Teachers' Understanding of Concepts in Science and Technology*?" you'd struggle.

I know exactly where I was that morning. A colleague and I were standing in front of a group of Educational Development Staff in Glasgow. We were about to begin a professional development day on safety issues in primary science and technology. This was for a mixed group of primary and secondary practitioners. Some had brought examples of what is laughingly cried 'The Popular Press'. I guess it's called that because few on either side, writers or readers, can stretch to such polysyllabics as newspaper or journalist.

According to the scribblers of the "The X News" and "The Y Journal" primary teachers have been found out. They are a useless bunch of scientific and technological inadequates who know much less than the children they teach (the scribblers must have copied out 'technological' from the report 'cos some of 'em even 'ad it spelled right). Likely, this was just the motivational ticket for all those idle primary teachers out there. But it was less than auspicious for a day about to be devoted to professional matters with folk who had been giving big licks to the promotion of primary science and technology. Some of them were more than mildly miffed. For a while, trap-doors in canoes and motorbike handlebar ashtray attachments were discussed. General gloom pervaded.

There is a cure. Get your hands on a copy of the full report. Read it. Forget the press (with the possible exception of the TESS - which carried a more balanced account and followed it up by giving Professor Harlen space to explain the report's findings). Of course, there are fundamental difficulties in the general readiness of many primary teachers to cope with the science and technology in 5-14 Environmental Studies. But that's more a long standing case of "What's new?". It has to be set against the ephemerality of "What's news?".

The SCRE report has a lot of positive things to say. It suggests ways ahead and it identifies priorities. It is to be welcomed. SCRE is to be congratulated. And so (he keyed in grudgingly) is the SOEID for funding the research. Having paid for the authoritative rediscovery of the right questions, all they have to do now is help fund and promote the answers. If the central response turns out to be better than yet more CD-I disks, I would consider publicly eating one of same - whole.

Now, that would be memorable!

New Director at CLEAPSS

With the retiral of David Tawney, Dr Peter Borrows is taking over as Director of our sister organisation CLEAPSS School Science Service. We wish David a happy, healthy and enjoyable retirement. At the same time SSERC staff welcome Dr Borrows and wish him a fruitful future with the CLEAPSS School Science Service.

ASE Scotland AGM

For its 1996 Annual Meeting ASE Scotland is abandoning its traditional Easter slot. Over the years an increasing number of teachers and technicians have understandably opted for some well-earned R&R at that time. That hasn't done a lot to help boost attendance at the ASE's event. This year the meeting take places over the third weekend in March (22nd to the 24th) in the West Park Conference Centre of the University of Dundee. Would be participants or exhibitors can obtain details from the addresses listed on the inside rear cover of this bulletin issue.

IoB Meeting

Whilst ASE is breaking with tradition, it looks like the Scottish Branch of the Institute of Biology is trying to start a new one. Emulating the Institute of Physics annual shebang they are to stage a cross-sector educational event of their own, possibly with the same venue - Stirling University. The IoB meeting is planned for Tuesday 14th May, 1996. Details are likely to be circulated via the Scottish Science Advisers' Group network.

Damned if they . .

Even I begin to feel for those poor old Government scientists and medical men. If they say one thing, about BSE and CJD for example, they get accused of a cover-up. Then they get equally slated for over-reacting when they send out measured warnings about the possibility of slightly increased risks from certain kinds contraceptive pill. Heads or tails, the media win.

At the root of this problem lie public perceptions of the nature of risk. From that point of view Government and science have had their just desserts. A lack of openness brings loss of trust and, as the The Good Book has it:

"As ye sow, so shall ye reap."

Over a number of years we've banged on in these pages about the need to integrate such matters into science and technology curricula. We've even provided hard examples of how it might be done. The ASE is about to do something about this problem. We understand that a Task Group is working on some Science and Technology in Society (SATIS) materials for this purpose.

Our own advisory, consultancy and training activities have forced us to gain some understanding of the difficulties presented by both professional and public perceptions in the business of assessing risk - individual as well as societal or environmental. In an attempt to stimulate further educational debate we have set out some of the conventional wisdom in the Feature Article opposite.

Kurt but decent

The current Beatles revival has led me back to some of my own heroes of the era. I've recently been re-reading Kurt Vonnegut. John, Paul, George etc. you will recall were at one time 'into Luv' and flowers. Kurt Vonnegut on the other hand took a different stance.

In one of his last works he wrote that :

"Love is where you find it. I think it is foolish to go looking for it and it can often be poisonous. . . . Please - a little less love, and a little more common decency."

Vonnegut trained as a biochemist. He has a lot to teach us scientists and technologists about common decency, about humility with humour, in our own disciplines. As well as being 'one of us'- scientist - as was his brother, he came from a German-American background which included scepticism as a form of religion. Hence his lovely image of the sceptic addressing his prayers :

"To whom it may concern".

Vonnegut's peculiar but penetrating insights into health and safety matters have also impressed.

There is, for example, his anecdote about his brother Bernard which Kurt claimed could have equally been about him:

"Bernard worked for the General Electric Research Laboratory . . . he discovered that silver iodide could precipitate certain sorts of clouds as snow or rain. His laboratory was a sensational mess, however, where a clumsy stranger could die in a thousand different ways . .

The company had a safety officer who nearly swooned when he saw this jungle of deadfalls, snares and hair trigger booby traps. He bawled out my brother.

My brother said this to him, tapping his own forehead with his fingertips: 'If you think this laboratory is bad, you should see what it's like in *here*'."

If you don't immediately appreciate the sheer brilliance of that - ask some unfortunate Safety Officer or Safety Manager what they think it means. But, tread warily.

This was the closest Kurt ever got to writing an autobiography. At the time, Graham Greene claimed that Vonnegut was one of the very best of living American writers. He was surely one of her great champions of 'common decency'. Faced with a choice between his revival and a luvfest, either from The Beatles or anyone else, I know which would get my vote.

Reference

All three quotes are from Vonnegut's prologue to : "*Slapstick or Lonesome no more*", Vintage paperback edition 1991, originally published in 1976 by Jonathan Cape Ltd.

FEATURE ARTICLE

Perceptions of risk

A number of factors which influence both individual and societal perceptions of risk are reviewed. Some limitations of probabilistic approaches are discussed. Arguments are made for the inclusion of some of these ideas in science and technology curricula. A summary list of such ideas is provided.

There are at least three identifiable dimensions to health and safety in education. Firstly there is the business of ensuring a *safe and healthy education* which applies to every activity within, and some outwith, schools or colleges. The management of this aspect has emerged as a major current concern of Scottish teachers. This was given some emphasis in the SOEID summary report of the outcomes from the regional conferences on Effective Learning and Teaching in Science.

Then there is *safety and health education* which deals with many diverse topics - from how safely to cross the road to avoiding AIDS. The third aspect is one which until recently has been almost entirely neglected. This is *education through health and safety.* It uses health and safety topics as contexts in which to pursue some aims and objectives of a general science and technology education.

Hazard and risk

The technical definitions of these terms should by now be familiar to many teachers. This is especially so if in recent years they have had to suffer a COSHH or health and safety management course. In everyday life these words tend to be used as though they were interchangeable. But, in professional usage they each have a definite and distinctive meaning. Hazard is defined as the potential to cause harm. Risk has twin dimensions. One is the probability of that harm being realised and the other is the severity of the ensuing consequences. It is the probabilistic feature of risk which has allowed specialists to assign number so adopting quantitative approaches to its assessment.

RISK = Probability of occurrence x Severity of consequences

Individual and public perceptions

To the health and safety professional a hazard is a hazard and a risk is a risk, as defined above. Lay perceptions tend to shift with context. Individuals, both singly and in groups, shift their judgements on hazards and risks according to particular circumstances. Hazards which are familiar and frequently met tend to be played down. Those which are unfamiliar, or of which one has no personal experience, tend to be looked at askance. They are judged insidious and thus more threatening. This may be particularly marked where a hazard cannot be detected directly with the human senses.

Thus hazards such as ionising radiations, or diseases such as CJD without a definite known causal agent, are perceived as insidious. Secretive hazards are serious hazards. A further complication is the different way in which people view a relatively high chance of harm being done to one individual and a much smaller probability of simultaneous harm to numbers of people in groups, communities or via the environment. There are other complexities such as whether the risk of harm is immediate (acute) or accrues slowly over time (chronic) and whether or not there are any perceived moral or ethical considerations.

All of the above considerations point to a need for technical risk assessments often to be tempered by judgement. Once that point is reached then risk assessment may be as much a political or sociological process as it is a scientific or technological matter. Much of the rest of this article seeks to illustrate these principles with some relevant examples.

Insidious hazards, chronic risks

The results of probabilistic risk assessments may be expressed as frequencies or rates of occurrence. Often they are historic having been calculated from records of past events. For example some risk estimates in everyday living are shown in Table 1.

Event	Probability
All men, aged 35 to 44	1,730
All women, aged 35 to 44	1,145
Accidental (all causes)	240
Road accidents	112
Falls (all types)	110
Domestic accidents	86
Fire	16
Drowning	12
Lightning strike	0.1
Death from CJD	0.5 - 1
Cancer (men and women 35-44)	950
Ionising radiations (doses over and above natural sources)	1

Table 1 Estimated mean risks of death in the UK annual rates per million. (Approximations, various sources not all for same year and thus produced here for illustration only).

The degree of concern exhibited by the public over different causes of fatalities demonstrates the intuitive discrimination exercised between overt or patent dangers and latent hazards. For example, the public discriminates markedly between the patent hazards of road travel or being a pedestrian and latent hazards such as additional radiation dose from 'unnatural' causes. At the same time they may underestimate or even ignore risks from other latent, but 'natural', hazards such as additional exposure to cosmic radiation during numerous high altitude aircraft flights, or of over exposure of the skin to non-ionising radiation such as the UV in sunlight.

Table 1 also puts into perspective the contemporary controversy over a spongiform encephalopathy like Creutzfeldt Jacob Disease (CJD). Leaving aside the presence of any linkage with the bovine spongiform encephalopathy (BSE) casual or otherwise, it can be seen that the overall risk of contracting CJD remains extremely small (about one in a million). This remains so even though the number of reported CJD cases in the UK has increased recently to just under 60 per year from a low base of about 28. With such small numbers of cases, any statistical analysis for correlation or establishing trends is likely to be extremely contentious.

Nonetheless, we can see that the overall risk of contracting CJD is broadly similar to that suggested for cancer from doses of ionising radiation from non-natural sources. Compared with the risks of accidental death in the home or on the roads, both CJD and radiation are apparently almost trivial. They are roughly similar to the risks of death by lightning strike. They are of such low frequency that, had they stemmed from more obvious hazards, they would normally be treated as insignificant by individuals in going about their daily lives.

The public also intuitively distinguishes chronic[1] risks from risks of immediate death or harm (acute risks). Examination of some of the figures in Table 1 against observed individual and social behaviours may confirm this for you. The table should also demonstrate other apparent irrationalities in public perceptions. Some kinds of hazard are apparently weighted to reflect deep seated anxieties about activities somehow seen as 'unnatural'.

Multi-casualty events

It is tempting, once the numbers have been assigned, to equate different expressions of risk. Some workers have even proposed a unit of risk currency [1]. This could be, for example, the risk of premature death from a one in a million contributory chunk of risk - termed a micro-risk. It would seem however that in the eyes of the average citizen (whoever they are) this is misguided. This is most evident when judgements have to be made about single events which, although rare, may have consequences for many people. These are societal or environmental risks. Lay opinion intuitively and selectively gives extra weighting to such risks.

1 Greek : chronos, over time

Take for example a 1 in 1,000 (1×10^{-3}) annual risk of single accidental fatalities. This is fairly typical of one of our more hazardous industries such as offshore oil or gas (the figure here is calculated so as to include only those actually at risk in such an industry). Suppose the total number at risk, from a particular activity, was 1 million and the probabilistic assessment of a single event was as above. There are a number of other ways in which this same nominal frequency or rate of fatal accident could be expressed. For example :

1 fatality per year, per 1,000 at risk
1,000 single (isolated) fatalities each year
1 event every six months, 500 fatalities per event

In theory at least, the total risk is the same in each case. It is likely that the Public, the Press and Parliament would take a different view. This would be especially so if the last figure was applicable to some large scale industrial facility being planned for location in your constituency! NIMBY's are thus both understandable and unsurprising.

The influence of media coverage is not to be underestimated. Table 2 shows just a selection of large scale accident or pollution events which have occurred in the last quarter of this century.

Year	Event	Place	Outcome
1974	Cyclohexane explosion	Flixborough UK	29 deaths
1976	Dioxin release	Seveso, Italy	No acute deaths
1978	Propane fire	Los Alfaques, Spain	215 deaths
1979	Dam failure and flooding	Gujurat, India	ca. 10,000 deaths
1979	PWR meltdown	Three Mile Island USA	1 delayed death (equiv.)
1984	LPG explosion	Mexico	ca. 500 deaths
1984	Methyl isocyanate release	Bhopal, India	2,500 deaths

Table 2 Examples of large scale events in the last twenty years or so.

Be honest - how many of these do you remember? Our guess would be that most people reading Table 2 would recall Flixborough, Seveso, Three Mile Island and Bhopal. How many recall or had even heard of the Gujarat dam failure even though about four times the number of people perished as did at Bhopal?

Needless to say the Press and TV coverage of the Gujarati event was poor.

Social aversion factors

There is little doubt that the public's valuation of risk to individuals may be markedly different from that for risks of large-scale or multi-casuality events. Should the hazards also be seen as insidious, or be ill-understood, then the effect may be yet more obvious. The small 'p' political reality of this discrimination has to be recognised in the overall assessment of acceptable and unacceptable risks. In 1978 Lord Ashby even proposed a rule of thumb guide to levels of public acceptance of risk. He suggested a four point scale. This is summarised and illustrated with examples in Table 3.

Probability	Likely acceptance level
10^{-7} (fatal lightning strike)	*Of no concern to the 'average' citizen*
10^{-5} (fatalities in some years in the construction industry)	*Elicits warnings, causes some concern*
10^{-4} (fatalities in our most hazardous industries, limit of HSE tolerance of risks of industry to the public, road deaths [all causes])	*People become willing to pay to to have the risks reduced*
10^{-3} (HSE maximum tolerable risk levels for workers in any industry)	*Unacceptable to the public and thus must be reduced. Dividing line between the intolerable and what is just tolerable*

Table 3 Estimates of public acceptance or rejection levels of risk. Probabilities are likely annual frequencies with a comparator in brackets.

Figure 1 further illustrates the problem. To the left of line A lies a zone wherein either the likely frequency is so low or the numbers of casualties apparently so small that any combination of rate and consequence bounded by the line is likely to be publicly acceptable. To the right of line B lies a zone wherein the numbers of casualties are always at an unacceptable level whatever the frequency of occurrence. The area between the two lines is a zone wherein actual probabilities matter less than that magic ingredient - judgement. This is where, to a large extent, the science and technology of risk assessment may leave off and politics, public participation and the media all may be brought to bear.

Risks to individuals, for example of AIDS, of CJD or of the release of genetically engineered organisms into the environment, all may stimulate similar responses where numbers of individuals are apparently at risk, the hazard is insidious or poorly understood and, or, the effects are chronic.

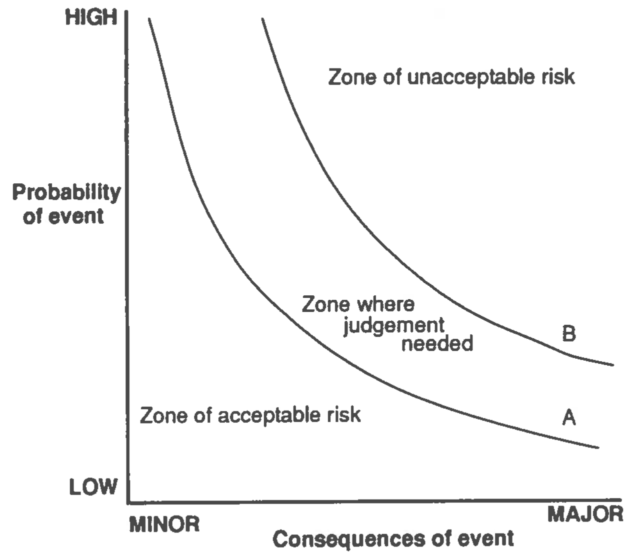

Fig. 1 Uncertainties in risk assessments because of sociological, political and media pressures.

This social or public aversion factor is well recognised. It has even been quasi-quantified for use in assessing risks of large scale plant with potential for multi-casuality events or environmental pollution on the grand scale. Two well known examples were the Nuclear Installations Inspectorate's assessments on Sizewell B and the HSE's two exercises on the siting of refineries and gas storage on Canvey Island [2].

Here attempts were made to quantify or allow for social or public aversion. It was proposed that these kinds of risks had to be weighted according to the degree of aversion. A so-called aversion factor (β) was applied to the consequences side of the risk equation. It is suggested that when $\beta > 1$ the public aversion to risk varies according to $(\text{consequences})^{\beta}$. The risk level can then be defined in terms of equivalent social cost (*ESC*) as follows:

$$ESC = \Sigma\,(\text{probability}) \times (\text{consequences})^{\beta}$$

Figure 2 (overleaf) illustrates the thinking behind this kind of exercise as applied to a nuclear installation and a petrochemical storage complex. Examination of Figure 2 should show that, for these very large scale industrial hazards, the zone of uncertainty may be very wide. In the case of Sizewell B it spans several orders of magnitude. Even an extremely rare event or failure[1] will need further assessment should it be a possible cause of ten deaths or more. Quasi-quantitative devices like social aversion indices may not assist us greatly. Whilst everything possible may be done to arrive at an overall probabilistic assessment which is as rational and objective as possible, making a final decision rests on judgement. Those who argue that a social aversion index is little more than a fudge factor might well attract sympathy. What usually happens in these cases is a judgement which errs mightily on the side of caution.

1 For example - once per 100,000,000 years

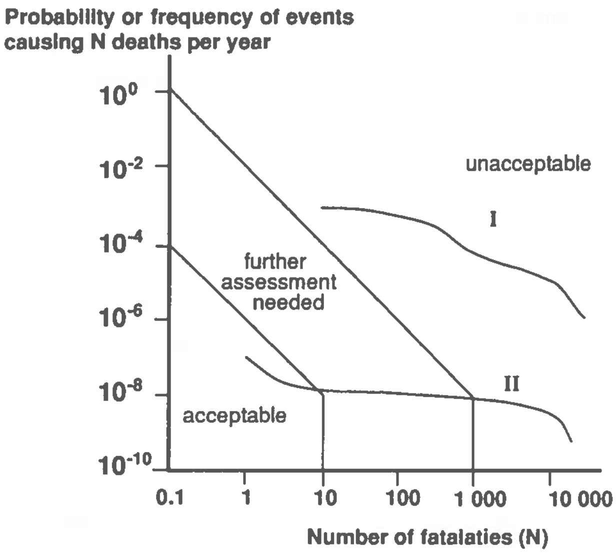

Fig. 2 Suggested criteria for multi casualty accidents, applying social aversion weightings. Curve **I** is based on the HSE's second report on Canvey Island and Curve **II** is for the PWR installation at Sizewell.

The other great dilemma here is that of the proper emphasis to be laid on preventing small but regular numbers of fatalities per year on the one hand, and extremely rare but potentially disastrous events on the other. The former are usually odds-on bets and the latter rank outsiders which may never happen. Many commentators agree that there is little alternative but to deal with them even-handedly. Whilst the latter events may never occur there are usually sound, economic and other business reasons for investment to shorten the odds so far as is reasonably practicable. Large scale events causing loss of lives and damage to property or the environment don't usually do a lot for anyone's corporate image or turnover!

Economic and ethical aspects

When making judgements as to the acceptability of levels of risk from industrial or commercial activities it is entirely legitimate to take into account their probable economic or societal benefits. There have thus been numerous attempts to settle risk assessment matters with the use of economic or cost/benefit analyses. These too are not without their own little snares and traps for the unwary. For example, *human life values* have been calculated by a variety of methods for a range of activities. One approach is to divide the estimated number of relevant fatalities into the total expenditure on prevention or protection for risk reduction (plus any compensation costs of those fatalities which went unprevented).

Not the least of the objections to such an approach is that many people see it as morally or ethically offensive. A more pragmatic objection is provided by the bizarre results yielded by such calculations. These tend to reinforce the earlier thesis that public, media and business always assign their own weightings to different kinds of hazards. These are then reflected in levels of spending in attempting to control the risks. This principle is illustrated in Table 4. The approximate amount spent per year on prevention etc in each sphere of activity is divided by the likely number of fatal accidents or premature deaths each year in that activity. The past expenditure on cervical smears gives us an interesting basis for comparison. This shows again how important an influence can be exerted by media, and thus public, attention.

Other economically based methods have been put forward for cost/benefit analyses of safety expenditure. The whole thing may become somewhat surreal once we begin to take into account the risks presented by the construction and installation of the safety devices themselves. Figure 3 illustrates a typical approach as suggested by the Royal Society. This also avoids any need for ethical judgements on values assigned to human life or to loss of life expectancy.

Basis of calculation	Value of life index
Cervical smear tests (base figure)	1.0
Road safety spend/road deaths	4.5
Safety in agriculture/deaths etc	15
Aviation safety/fatalities	135
Tower blocks, apartments/ fatal falls etc	3,000
Nuclear safety	28,000

Table 4 Value of human life index (as at 1980).

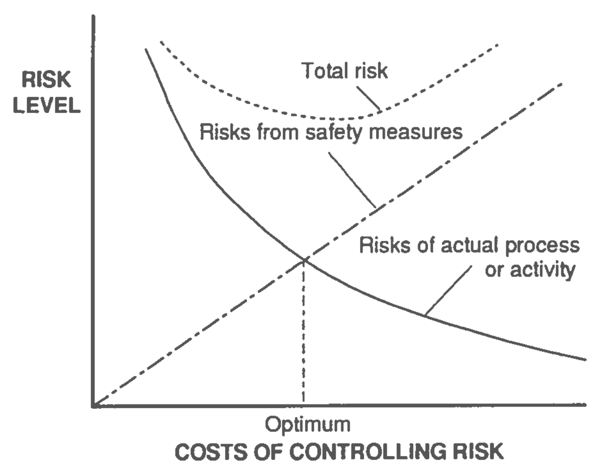

Fig. 3 Royal Society suggestion for taking risks of safety devices or 'improvements' into account.

Other economic approaches have attempted to set the total costs of accidents (including consequential costs such as loss of production, increased insurance premiums etc) against their probability. Events are grouped according to frequency and cost categories then plotted in a histogram. In this way, a risk line may be drawn to separate the acceptable from the unacceptable events. These methods suffer the same objections on both ethical and practical grounds as those described for assigning monetary value to human life. A one-off major event, however improbable, may prove as fatal for a company economically as it does for its employees or neighbours literally.

There tends to be a preference in the legislative lexicon for risks to be controlled "so far as is practicable" or "so far as is reasonably practicable". To a large extent such phraseology reflects the difficulties inherent in setting simple quantitative or monetary limits to risk reduction.

Summary

The objective, probabilistic assessment of risk is the proper business of science and technology. But, it can never be the sole means of judging the acceptability of any risk. At some point the subjective judgements and attitudes of people - both as individuals and groups - have to be given due consideration. The Council for Science and Society has put this elegantly :

> *"The acceptability of risks cannot be simply derived from a scientific study of quantified probabilities, costs and benefits. The human factor influences the analysis at every point. But fairness in decisions and effectiveness in controls of risk can be approached by the use of scientific methods among others, provided that the diversity of human interests, values and perceptions of risks is always respected."*

Conclusion

This article has explored some limitations of scientific or technological approaches to risk assessment. Public perceptions of levels of risk exhibit varying degrees of subjectivity and occasional apparent irrationality. Others seem rooted in perfectly proper caution. Such caution is understandably exercised when hazards are ill-understood or their effects may only be fully exhibited over the longer term. AIDS, BSE, CJD, ionising radiations, DNA and genetic manipulation all provide notable examples.

Such issues would appear to offer opportunities for science and technology education. Their inclusion in the curriculum should be given serious consideration as part of the current review.

Similarly, there are a number of teachers and others presently developing new approaches to learning and teaching for controversial issues in technology and science. The assessment and perception of risk seem worthy candidates for such research and development.

What concepts related to coping with risk might need to be covered as part of everyone's basic science and technology education? As a starting point for debate we would offer the list shown in Table 5.

1. Define and distinguish hazard and risk.
2. Dimensions of risk
   - probability of occurrence
   - severity of consequence
3. Quantification of risk.
4. Comparison of risks
   - everyday living;
   - occupational;
   - recreational.
5. Nothing is ever without risk.
6. Public perceptions of risk.
7. Acceptability of risk, distinguishing 3 zones
   - unacceptable;
   - tolerable;
   - acceptable (after optimisation).
8. Zone boundaries are dependent on vicarious involvement either by employment or recreation.
9. The related concepts of :
   - exposure limit values;
   - action levels;
   - threshold levels.
10. Influence of risk assessment and measures of the tolerability of risk with examples from:
    - EU Directives;
    - NRPB dose levels;
    - large, complex, industrial plant or widespread environmental application.

Table 5 Suggested risk related ideas for consideration as to their possible inclusion in science and technology curricula.

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SOED Circular 8/95 on carcinogens

The broad purpose and philosophy behind the circular, prepared by SSERC on behalf of the SOED, are explained. The basic risk assessment approach adopted for this advisory document is illustrated with examples.

The above circular concerning the use of carcinogens in schools and colleges was issued recently by the Scottish Office Education Department (now the Scottish Office Education and Industry Department). Because the covering note sent out by SOEID cites SSERC as having prepared this document, we have been the direct recipient of a number of comments and a few complaints on and about Circular 8/95.

To be forthright about it, not a few of these moans seem to arise from a failure to read and study what the Circular actually has to say about the detailed practical aspects of this problem. Other complaints apparently stem from disappointment that the Circular did not spell out the requirements of COSHH and the Carcinogens ACOP in a more legalistic way. Our response to this second type of complaint would be that anyone wanting a line by line legally oriented account could obtain copies of the Regulations and ACOPs and study those. The thrust and purpose of Circular 8/95 is different. Its major intention is to interpret the legal requirements in terms of day-to-day practice in schools and colleges. From other comments we have had, it would appear that it makes a pretty good stab at that target.

Background

Nobody in education likes to see "yet more lists" of apparently proscribed substances, whatever the source of such listings. Twenty or so years ago many educational employers issued lists of banned chemicals thus needlessly and thoughtlessly stopping much interesting and useful practical work.

Some years later COSHH appeared and not a few were heard to sigh and say that this was the beginning of the end of all practical work. However, discerning and thoughtful spirits soon realised that the opposite might well be the case. In fact many of the chemicals which had previously been banned in the seventies by their employers could then be brought back into use. People began to understand the important difference between hazard and risk, realising that it was not necessarily the chemical that had to be restricted, but its mode or scale of use. A highly hazardous substance can pose a miniscule risk to health if handled correctly by informed laboratory workers. The converse is also true. Many chemicals of low toxicity can pose a large risk to health when handled carelessly.

Risk assessment approach

Provided that proper consideration is taken of the risks to health from a substance, under the actual circumstances of use, then valid estimates of those risks can be made and the appropriate control measures adopted. This is the general approach we, and other established educational agencies in the health and safety field, have consistently taken towards the requirements of the COSHH Regulations. There are a number of important reasons for retaining such an approach when considering the risks posed by substances where there are various types of evidence of possible carcinogenicity.

The COSHH Regulations 1994, together with the General COSHH Approved Code of Practice (ACOP) and the specific Carcinogens ACOP emphasise the need to follow the familiar hierarchy of control measures ranging from the preferred option of eliminating the use of hazardous substances and of substitution by less harmful chemicals, through the use of various degrees of enclosure, reduction of time of exposure and of scale of operation down to the use of personal protective equipment as a last resort.

If one of the hazards posed by a particular chemical is its potential carcinogenicity then, when selecting control measures, the use of elimination and substitution must be the preferred option and the first to be considered. Thus it could be tempting, and all too easy, to add to lists of banned substances all those legally defined as being carcinogens (those required by the CHIP Regulations to be labelled with the risk phrases R45 or R49 and those listed in Schedule 8).

Avoiding blanket elimination

In our opinion such a comprehensive extension of prohibition on the use of substances would be very shortsighted and foolish for the following reasons:

- there are many other substances not so defined by the current version of COSHH which are known to have carcinogenic potential. Any rigidly defined list based merely on the requirements of CHIP would overlook them.
- very real educational benefits might be lost by not using some of these substances. This has to be balanced against the magnitude of the risk. Modes and scale of use as well as possible routes of exposure all have to be taken into account.

Some examples should illustrate such points.

In handling any chemical suspected of causing irreversible effects, with varying degrees of evidence for their carcinogenicity or mutagenic potential, the main factors to bear in mind are:

- details of the mode of use;
- possible exposure routes;
- likely duration and, or, repetition of exposure;
- a need for realistic, practical and thus appropriate control measures;
- the specific educational value of the activity.

Mode and route

Potassium bromate(V) is known to be a carcinogen of low potency, but only by the *ingestion* route. It has useful applications in volumetric work. It is almost impossible to see how it can be ingested if normal good laboratory practice is used. We would see little justification for banning a method involving the weighing out of a few grams to prepare a volumetric solution and then titrate aliquots of it. After all pipette fillers are there to be used. Pipetting by mouth has been proscribed in educational laboratories for many years.

Potassium and other dichromates(VI) and other dichromates are known to cause cancer among miners or workers in the electroplating industry. This however is by *inhalation* of dust or aerosols. With a sensible, practical approach potassium dichromate(VI) can be used on a laboratory scale to prepare standard solutions without raising significant amounts of dust, or without forming an aerosol. The compound consists of crystals, often quite chunky. If it were a fine light dusty powder then there might be a strong case for banning its use for volumetric work.

Other uses, of the solution itself, could conceivably generate aerosols, e.g. electrolysis of solutions, or having a gas being generated in the same solution by other chemicals present. Such applications should not be carried out, unless an efficient fume cupboard is available.

In contrast, other harmful aerosols which do not carry the same risk of irreversible effects would not require the same high degree of control (e.g. from acid in a battery undergoing charging). Here the risks from the hazards of corrosive effects (as well as of the *non-COSHH* event of an explosion) might be controlled merely by not carrying out the operation in a confined space and by ensuring a good level of general ventilation.

Stains, dyes and indicators : many of these provide examples of substances not necessarily labelled R45 or R49 in the past, with quite a few not carrying either designation now. Nonetheless some are suspected of carcinogenicity. This may not be a property of the pure substance but the suspicion may arise because of the possibility of contamination with carcinogenic starter materials or by products. Were we to suggest total bans on the use of all such dyestuffs some shelves in biology department stores would be half empty.

The risks with a very few of these dyestuffs are sufficiently significant that their laboratory use has indeed been prevented or curtailed legally (e.g. *o*-tolidine). The control of risks with those others which still find application in education tend to rest on substitution or in controlling scale and modes of use. Substitution is often possible. For example there is evidence that some of the Sudan family of stains may have irreversible effects but as yet there are no such suspicions for others. Of course one has to exercise care and common sense here. The lack of evidence may merely reflect a lack of relevant research.

The principal route of exposure of stains, dyes and indicators is through the skin. Thus control measures tend to rest on preventing contamination of the skin, either by the practical details of the method itself, or as a last but only practicable resort, the use of suitable gloves.

Length of exposure

Circular 8/95 also makes some important points about current views on the nature of tumour inducing mechanisms. It makes the distinction between those carcinogens which are genotoxic and others which are epigenetic producing effects only after prolonged or repeated exposures. For example :

- many of the substances categorised as known human carcinogens have caused tumour formation only after a long and heavy exposure, e.g. fitters or machine operatives whose overalls had been continually soaked in oil.
- chromium or nickel compounds have been banned by some educational employers because of suspected carcinogenicity yet much of the epidemiological evidence comes from the industries cited opposite (under potassium and other dichromates). Again these cases usually involve prolonged exposures rather than the more isolated one-off usage of the laboratory. Ironically some research workers now suspect that it may be that it is contamination of ores with arsenic which lies at the root of some of these cancers in the mining industry.

Chemophobia

It must be one of the tasks of school science departments to help produce well informed and useful citizens (Sorry for bringing up Plato). Those who suffer from an excessive and irrational chemophobia will be of little use to many employers in industry. More importantly, for their own health and safety it is important to recognise that there many hazardous but useful substances that - with sensible controls - can be handled safely.

An irrational response at the laboratory scale of usage is more than incongruous when the world outside school may provide such wide-ranging possibilities of exposure to suspected carcinogens, whether these be to the lead chromate in the yellow lines on road markings which break up into dust, to phenacetin drugs or to the benzene vapour streaming out of the nozzle of a petrol pump hose.

cont./over

Practicability

The arguments set out above, trustfully, have shown that the problems associated with suspected or potential carcinogens and mutagens cannot be solved merely by drawing up yet another list of banned substances. In any event, as Circular 8/95 clearly indicates, there are a number of known human carcinogens whose manufacture, import and use is illegal. The question of their elimination from schools thus does not arise.

The problems stem, as usual, from those grey areas where the quantity and quality of evidence varies and where relative potencies are difficult to establish. An attempt was made for Circular 8/95 to indicate some of the possibly more potent substances likely to be considered for use in schools. It would be impracticable, as well as irrational in view of the nature of the evidence, to eliminate these entirely from schools.

Decisions then have to rest on what is reasonably practicable. That in turn depends on making a valid educational case for continuing usage and combining that rationale with practical measures to control the risks. This approach is familiar to managers in commerce and industry.

Until relatively recently it has not been the practice in education to so seek to balance risks againsts benefits and in turn to balance benefits against the costs - in terms of time and expense - of the necessary control measures.

Conclusion

One of the main purposes of Circular 8/95 is that of especially flagging up certain chemicals suspected of causing irreversible, chronic effects on human health. This is so that we may all stop and especially consider the implications and the necessary control measures before using them at all or in any particular ways.

Some of the adverse comment we have had seems to have stemmed from a failure properly to read the document. It would seem that on first sight of the Circular some science teachers have merely assumed that it must, yet again, mean more bans on substances or processes. This is as unfortunate as it is understandable (given the history of educational health and safety management). But, it happens not to be the case.

It is important to read paragraphs 14 to 23 of the Circular carefully and, in particular, para 18 which sets the scene for a sensible approach to the management of carcinogens.

EQUIPMENT NOTES

Simple pneumatics kit

New *Pr-Mid* range from Polytech 2000 suits 5 to 14 curriculum.

We have recently been introduced to Polytech 2000's Pr-Mid range pneumatic kit, which can be used as an inexpensive introduction to pneumatics and hydraulics in the 5 to 14 curriculum. It will also act as an interesting preface to forces, energy, levers and mechanisms. The two manuals included with the kit give adequate explanations on the principles of pneumatics and levers and linkages. They also offer a number of ideas for working models. Sufficient components are included to carry out the seven investigations described in the manuals.

To allow for some understanding of how each of the components work they are all made from a clear plastic material. There is no need for a compressor as the cylinders work at very low pressures. Two small hand pumps are included. This is all that is needed for most of the investigations. If there is a need for a reservoir in more advanced work there is a non-return valve and cap for use with a large, empty drinks bottle. Air is pumped into the bottle by a bicycle pump, working pressure can be read from a pressure gauge, between 1.5 and 2 bar. In this age of safety there is a pressure relief safety valve which blows when the working pressure is reached. A 2 litre bottle gives sufficient air for about six reciprocating movements of the double acting cylinder. All of this for £39.09 including VAT and carriage.

We believe this kit to be of use at 5 to 14, and are arranging to have it trialled in a primary and a secondary school. A report will follow in a future Bulletin and Primary Newsletter. Polytech were expected to introduce a further working range in January 1996, made from polycarbonate. These will have colour coded working parts to show the operation of each valve and cylinder. The range will include shuttle valves, 3/2 and 5/2 valves, solenoid valves, flow and speed controllers - all to be as competitively priced as the Pr-Mid range.

BIOLOGY NOTES

Microbiology videos

We have received some videos for review. The first of these, *An Introduction to Practical Microbiology*, was obtained from the National Centre for Biotechnology Education (NCBE). It was produced, under the name *Microbewise* by students in the Department of Biological Sciences at Manchester Polytechnic in association with NCBE (£28.50 per copy).

The video, which lasts about half an hour, comes in a plastic book-style case which also contains a thirty five page booklet describing the techniques and principles intended to be illustrated by the video. Additional copies of the booklet are available separately from Manchester Polytechnic or NCBE (see Address List).

Whoever provided the specification for the booklet and video was obviously well-briefed on the day to day practicalities in school and college microbiology as well as on the health and safety aspects. The material is thus pitched at the right levels of work and contains remarkably few mistakes. What errors do occur either visually or in the commentary are all relatively minor. One example is that in all of the shots the work is being carried out on a wooden bench surface without any temporary bench coating in use. Closer examination reveals however that the hardwood bench has in fact been sealed with proprietary hard varnish or sealer (probably a two-pack resin type). It is thus impervious and therefore acceptable.

The techniques covered rarely go beyond the requirements of schools and colleges up to about CSYS or A level. Within that limit the coverage is markedly comprehensive. The techniques shown are soundly based. They comply with the HMI guide advice, ASE's guidance in Topics in Safety and therefore also with those of Education Authority Codes of Practice such as that of Strathclyde Regional Council (widely adopted or adapted by other Scottish EAs).

The second microbiology video is available through the resource sharing facility of the Scottish Science Advisers' Group. It was recorded live during some of the training courses run in Strathclyde for the purpose of training one teacher and one technician per secondary school up to Level 3 (see the Strathclyde Code). The major use for such a video is thought to be as revision for those who have already been on a Strathclyde course or a similar one run by a third party such as SSERC. For more details please contact your local Science Adviser or Science Development Officer (but, if I were you, I'd hurry!).

New DNA technology kit : An interim review

The then imminent launch of a new, joint, NCBE and SAPS kit for the investigation of DNA technologies was heralded in Bulletin 185. We obtained a couple of sample kits in the Autumn of 1995 and have been evaluating them as quickly as the twin pressures of workload and fighting for survival would allow.

As forecast, the new kit covers the Lambda DNA protocol provided for in the original NCBE kit and extends the SAPS plant DNA procedures using mustard or cress to take in two new sets of protocols. These extensions allow for the extraction of DNA from onion and from dried peas. The use of calf thymus DNA has been dropped. The instructions adopt the clear style of largely graphical instructions originally adopted by NCBE. The new kit is, as expected, more expensive than the earlier NCBE version. But then it covers much more work.

In our trials, the Lambda protocol and the cress or mustard DNA extractions and electrophoresis worked as well as ever they did in the original, separate kits. But, we found the other plant DNA procedures to be somewhat less straightforward and convincing than the instructions would suggest. The onion protocol results varied considerably with the type or variety of onions used. We found the described method for removing the precipitated DNA somewhat awkward. For several trials we were unable to get enough onion DNA precipitated by the ethanol to be able to retrieve it by hooking it out on an inoculating loop as described in the instructions. By chilling the glassware in a refrigerator until just prior to use and by ensuring that the ethanol (IMS) was indeed ice-cold we did eventually get to fish out strands of DNA. We found that a glass hook made from a fine tipped Pasteur pipette was superior to the use of the loop as suggested. The suggested method of drying the DNA by using a hair-drier also proved somewhat tricky. We discovered that the DNA could be dried more easily, if more leisurely, simply by leaving it overnight for the ethanol to evaporate off.

The results from running electrophoresis gels with the new plant DNAs, both digested and undigested, also were not always convincing or inspiring. For example, results from electrophoresis runs with undigested pea and onion DNAs were such that it is difficult to know what impression the pupils might form from them. Similarly in several of our trials digested DNA bands could be markedly ill-defined. Having said that, we obtained much improved results when stained gels were allowed to age a while before being re-stained. In a few cases the appearance and resolution of bands continued to improve over several cycles of staining and de-staining.

The principal difficulty we had with the new kit was however, educational rather than technical. Some of the work might appear repetitive and largely uninspiring (just like real DNA analyses?) - especially to some pupils. In view of this possible difficulty we decided to put our other kit out on an extended school trial. We are also in contact with other schools which we know have purchased kits. Once we have had the benefit of their experience we shall report again much more fully (either in this or in some other professional existence).

Meantime, don't let us put you off buying a kit. If you're keen to get some practical work on DNA into your courses then major parts of this kit still provide one of the best ways to do that and probably, at present, the only sensible way.

Biology graphics

Jim Shields, P.T. Biology at Balfron High School, has sent us some samples from his collection of simple line drawings for biology teaching. Jim points out the increasingly difficult time teachers are having in sourcing illustrative material for their classroom resources, assessments and mock exams etc. He has been building up a collection of *Draw!* files for such uses. SSERC is considering marketing these on Jim's behalf once he has suitably classified and organised them with suitable descriptors which will allow the whole collection to be searched using key words. Because they are in *Draw!* format they will run on Acorn Archimedes or A-series machines. They should also be accessible to PC users who have Oak Solutions *Oak Draw for Windows*.

EQUIPMENT NOTES

Laboratory power supplies

In this second article on laboratory power supplies we review products from Griffin and Irwin.

Griffin have in the 1990s completely redesigned their range of power supplies. In 1991 we tested a prototype of the 4 A Voltline (EKR-401-010L), which, like some of their new range, has infrared controlled voltage locking. This unit was found to have been built to a satisfactorily high standard of electrical safety, to be adequately robust and to operate reliably. Very recently we have tested seven other models. They form the bulk of the report below. It is pleasing to record that these three factors - electrical safety, robust construction and reliable operation - are shared by all seven.

The smaller Griffin power supplies are housed in lightweight ABS plastic enclosures. These are sufficiently strong to withstand reasonable mechanical abuse - such as being dropped onto the floor. On continuous full load our soak tests showed that although one or two hot spots can occur these enclosures never become dangerously hot to touch, nor does the plastic ever reach a temperature where it starts to deform.

The larger Griffin power supplies are housed in strong, metal boxes. In shape they are plain. Each side is orthogonal to neighbouring sides. There is generous curvature at corners and no sharp edges. Where separate sheets of metal meet, one folds neatly under the other to prevent there being an aperture, or cutting edge. Perhaps to retain this aesthetically pleasing clean look, no carrying handle, or finger recess, has been provided. Herein lies a problem. Our soak tests on full load recorded hot spots on enclosures of two units which would be high enough to burn fingers. It is foreseeable that someone picking up a unit in that condition could involuntarily drop it, leading either to the damage of apparatus, or injury to a foot or leg (one of the units has a mass of 6 kg). It is for this reason that one of these units has been marked down with a C assessment. There is no other significant safety problem to record.

Three power supplies in the current Griffin range have a novel form of voltage limitation based on an infrared controller. One, the 4 A Voltline, was referred to at the start of this article. Another Voltline model, capable of supplying 8 A, has more recently been tested and is described here. So far as our tests have been able to show, this form of control is completely dependable. It cannot be overridden. Nor can it suffer breakage, which can be the fate of mechanical protection mechanisms.

And so we come to Irwin power supplies. Whereas Griffin have redesigned afresh, Irwin, apart from one exception which we will mention shortly, manufacture a range whose designs go back many years, but have been modified periodically. The one model reviewed here, with continuously variable output (EJ0032), is well tried and tested. It has been on the go for many decades. The Centre has three samples. One dating, we think, from the 60s. Another from the mid 80s. And the one under review obtained in 1995. The specification and basic design stands throughout, but there have been progressive improvements. The present model is safe, reliable, a very fair price, and, we think, reasonably robust. Our only

Product code	Product name	AC voltage (V)	DC voltage (V)	Maximum current (A)	Voltage selection	Voltage locking	Price (£)
Griffin power supplies							
EKR-451-010W	Battery Replacement	-	1.5, 3, 4.5, 6	1	Rotary switch	None	44.10
XKB-370-011V	Low Voltage Supply	1, 2	1	8	4 separate terminals	None	54.50
EKP-141-010E	Multitap Transformer	2, 3, 8, 12	-	8	5 separate terminals	None	84.00
EKR-410-010K	LoVolt Power Supply	2, 4, 6, 9, 12, 14	2, 4, 6, 9, 12, 14	4	Rotary switch	None	76.65
EKR-681-010Y	Voltline Supply	0-20 continuous	0-20 continuous	8	Rotary, continuous	Infrared link	231.00
EKR-286-010K	Single Rail Regulated	-	5, 9, 12, 15	0.6	Rotary switch	None	44.10
EKR-260-010X	Dual Rail Regulated	-	±5, 6, 9, 12, 15	1	Rotary switch	None	81.40
Irwin power supply							
EJ0032	Low Voltage Supply	0-13 continuous	0-16 continuous	8(AC), 5(DC)	Rotary, continuous	Mechanical	86.24

Table 1. Power supplies from Griffin and Irwin reviewed in this article : specifications and prices.

Product code	Product name	Electrical safety	Electrical design	Mechanical design	Operational design	Perform-ance	Protection mechanisms	Assess-ment
Griffin power supplies								
EKR-451-010W	Battery Replacement	A	A	A	A	B	A	A
XKB-370-011V	Low Voltage Supply	A	A	A	A	A	A	A
EKP-141-010E	Multitap Transformer	A	A	A	B	A	B	A
EKR-410-010K	LoVolt Power Supply	B	A	A	A	B	A	A
EKR-681-010Y	Voltline Supply	C	A	A	B	C	A	C
EKR-286-010K	Single Rail Regulated	A	A	A	A	B	A	A
EKR-260-010X	Dual Rail Regulated	A	A	A	A	A	A	A
Irwin power supply								
EJ0032	Low Voltage Supply	A	A	A	A	A	A	A

Table 2. Power supply performance and assessment.

concern rests on the probity of the voltage limitation mechanism. Whilst it seems to be fairly robust, it could conceivably be vandalised. But then, nobody withstood the Huns!

Finally we would like to comment on the Central Source Power Supply (EA3669), about which we understand publicity material has been issued to schools asserting that it has been tested by SSERC. We did indeed test a sample of this new Irwin product in 1995. Whilst it was mainly well engineered, we did uncover a small number of defects, which we reported to Irwin. We understand that Irwin have responded to our concerns by correcting these problems. However we have not yet had an opportunity to test a redesigned model. Until we do, we cannot come to a judgement, pro or anti, about this product.

Test findings

Power supplies are reported on individually on pages 14 to 21. The ABC key used in the summary (Table 2) is explained below. In general it stands for :

A Good B Fair C Poor

Electrical safety :

A Complies fully with IEC 1010-1 as far as our tests are able to indicate, except for some very minor infringements; has no appreciable risk for use in schools.

B Complies in general with IEC 1010-1, but has one or more features where there is a very small risk of harm.

C One or more features present an unacceptable risk of harm.

Electrical design :

A Sound design using good quality components of sufficient strength. Adequate mechanisms to protect against some single fault conditions. Able to meet specified voltage and current outputs.

B Minor weaknesses in design. May not deliver current and voltage to specification.

C Major weaknesses in design. One or several of the following may occur: liable to malfunction; components liable to get destroyed; gross underachievement of performance.

Mechanical design :

A Robust enclosure and parts. Secure fitment of parts. No significant mechanical weakness.

B Minor significant weaknesses identified.

C Major weaknesses identified.

Operational design :

A Controls and outlets clearly and adequately marked. Operation is simple, clear and obvious.

B Minor weaknesses identified.

C Awkward to work with, or misleading to operate.

Performance :

A Electrical outputs perform to specification. Voltage does not fall away steeply with current. Temperature rise is not excessive.

B Significant minor underachievement found.

C Significant underachievement, or excessive temperature rise.

Protection mechanisms :

A Overcurrent and short circuit protection operates reliably and to specification. Adequate protection of primary circuit.

B Minor weaknesses.

C Significant weaknesses. Because of inadequate protection, fault conditions may lead to destruction of parts. Electrical safety may then be compromised.

Assessment :

A Most suitable for use in Scottish schools and non-advanced FE

B Satisfactory for use in above.

C Unsatisfactory.

Griffin Battery Replacement Power Supply EKR-451-010W — *£44.10*

Function : A power supply for Primary Schools in substitution for a battery of 4 dry cells. Offers 4 fixed voltages stepped at equal value intervals. Designed to drive small lamps or motors, or some electronic circuits. Might be useful for introduction to electricity.

Specification : 1 outlet : 1.5 V, 3 V, 4.5 V and 6 V DC, voltage regulated, floating with respect to earth. Maximum current 1 A. Earth terminal not provided.

Circuit : Low voltage is drawn from a step-down isolating transformer through an adjustable switching regulator. Rotary switch selects from a bank of potential dividers to set the regulator's output. The regulator has internal over-current protection. The primary winding is protected by a fuse fitted externally within the IEC chassis plug. The mains switch is double pole and has illumination.

Construction : Lightweight ABS plastic enclosure of adequate strength. Base, top and sides flex slightly with finger pressure. Withstands being dropped on a hard floor.

Electrical safety standard of construction is Class 1 and complies with IEC 1010-1.

Layout and operational markings on top panel are clear and simple.

Because the outlets are sockets they are unable to accept unterminated wire. This is a pity because it would be reasonable to assume that users some of the time would want to work with this type of wire. We think that power supplies designed for Primary schools should be fitted with 4 mm terminals that are able to accept unterminated wire rather than sockets which do not have this facility.

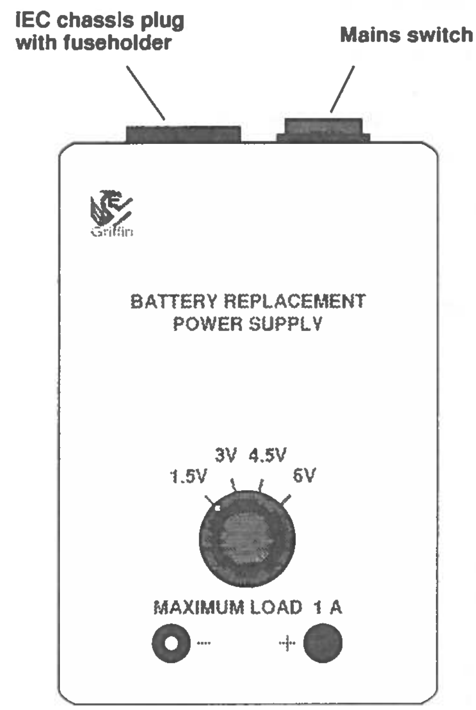
Performance : Voltage values are within 0.2 V of nominal settings with very little drop in value with rise in current. Currents of 1.0 A can be drawn continuously at any setting. The maximum current lies between 1.4 A and 1.5 A, limited automatically. The output is protected against short circuiting.

Because the power supply has a switched mode operation, it generates high frequency noise at about 50 kHz. The typical peak to peak value is 10 mV open circuit rising to 30 mV at 1 A. It is unlikely to upset any load.

The maximum temperature rise of the enclosure is about 30°C, which is tolerable. However there are two tiny hot spots on 6 mm diameter metal studs which might prove uncomfortable on delicate fingers. The temperature rises by 47°C on these spots. Because of the very small area of contact, injury is unlikely.

Verdict :

A (Very satisfactory subject to reservation about type of outlet)



Enclosure : Pale grey ABS plastic. Dark grey markings.
Dimensions : Width 99 mm, depth 155 mm, height 78 mm.
Weight 0.6 kg. No carrying handle. Not stackable.
Detachable mains cord with IEC connector. Fused IEC chassis plug.
Overcurrent protection : fuse on primary, electronic regulation on output.
Outlets : 4 mm insulated sockets, accepts 4 mm plugs, does not accept unterminated wire.

Griffin Low Voltage Power Supply XKB-370-011V *£54.50*

Function : This power supply has been designed for use with the Westminster electromagnetic kit.

Specification : 1 V or 2 V AC, or 1 V DC full wave rectified. Current 8 A at these voltages. Outlets floating with respect to earth.

Circuit : Low voltage is drawn from a step-down isolating transformer. The primary winding is protected by a fuse fitted within the IEC chassis plug to allow external access. The mains switch is double pole and has illumination. Overload protection on secondary winding relies on very low voltage generated and on resistance of conductors.

Construction : Lightweight ABS plastic enclosure of adequate strength. Base, top and sides flex slightly with finger pressure.

Electrical safety standard of construction is Class 1 and complies with IEC 1010-1.

Layout and operational markings on top panel are clear and simple.

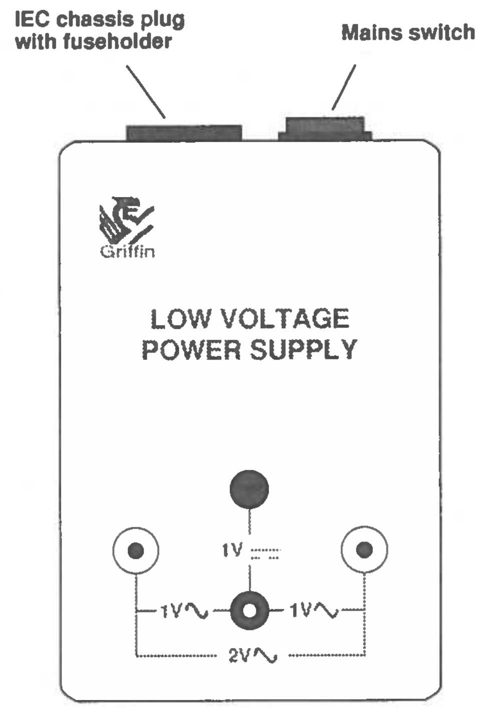
Outlets are 4 mm terminals that can accept unterminated wire or 4 mm plugs.

Performance : Voltage values are reasonably close to nominal settings. Unit can supply a current of 8 A continuously on both AC and DC outlets without the temperature rise being excessive (19°C on enclosure and 29°C on transformer mounting studs).

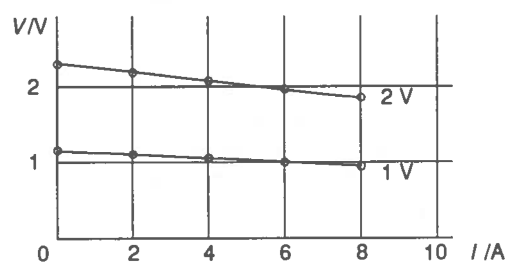
The voltage output versus current slopes are significantly better than that found on many other types of educational power supply.

Verdict :

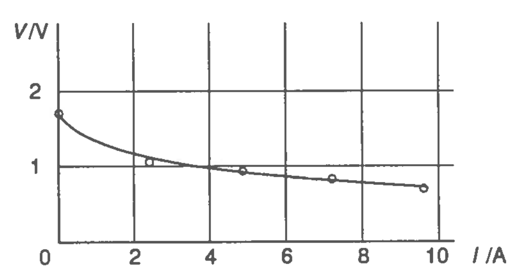
A (Very satisfactory)



Enclosure : Pale grey ABS plastic. Dark grey markings.
Dimensions : Width 99 mm, depth 155 mm, height 78 mm.
Weight 0.9 kg. No carrying handle. Not stackable.
Detachable mains cord with IEC connector. Fused IEC chassis plug.
Overcurrent protection : fuse on primary, secondary circuit gives inherent protection against overload.
Outlets : 4 mm insulated terminals, accepts 4 mm plugs and unterminated wire.



AC outputs



DC output

Griffin Multitap Transformer EKP-141-010E *£84.00*

Function : Multitap AC supply.

Specification : Outlets at 0, 2, 3, 8 and 12 V. The following values can be selected dependent on combination of outlet: 1, 2, 3, 4, 5, 6, 8, 9, 10 and 12 V. Maximum current 6 A continuous or 8 A for periods up to 1 hour. Outputs not referenced to earth.

Circuit : Low voltage is drawn from a step-down isolating transformer with 5 taps on to the secondary winding. The primary winding is protected by a fuse fitted externally within the IEC chassis plug. The mains switch is double pole and has illumination.

Construction : Strong 2-piece metal enclosure. Class 1 electrical safety standard of construction. Complies with IEC 1010-1 on electrical safety.

Whilst the front panel markings are clear, a linear arrangement of sockets in ascending order of voltage would simplify the task of obtaining different potential differences.

Performance : Output voltages agree with settings. Lower than average voltage drop-off with current.

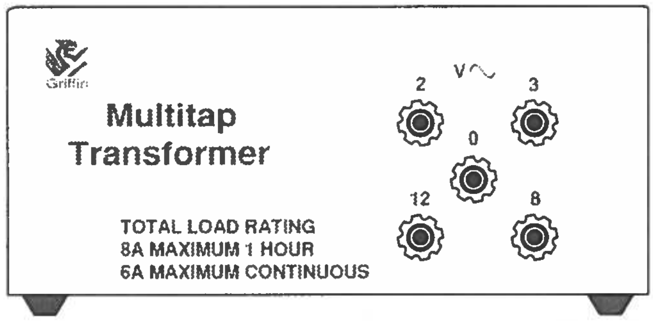
Able to deliver 6 A continuously on each setting and 8 A on each setting for periods of an hour. Because the only form of overload protection is the fuse on the primary supply and the inherent resistance of conductors, it is possible to draw a current greater than the specified maximum. For instance we drew 12 A continuously for 30 minutes after which time the supply was switched off because of the emission of some noxious and offensive vapour. However this internal self-heating did not appear to be excessive. There was no sign of damage to either the insulation or to conductors. We therefore formed the opinion that the supply seemed able to withstand gross overloading because of the inherent resistance of conductors and because of its general robustness.

Maximum temperature rise on enclosure after continuous operation at 6 A is 25°C; at 12 A it is 36°C.

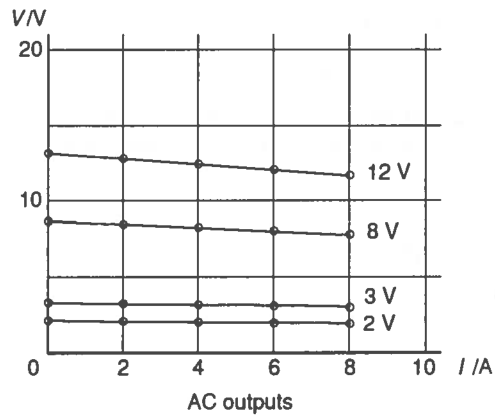
Verdict :

A (Very satisfactory, but see comment below)

Comment : There is a lack of protection on the secondary windings necessitated by the design. A thermal trip on the primary supply would mitigate against some forms of overload abuse.



Enclosure : Light grey stove-enamelled steel. Dark grey markings.
Dimensions : Width 173 mm, depth 185 mm, height 82 mm.
Weight 3.0 kg. No carrying handle or aid. Stackable.
Detachable mains cord with IEC connector.
External mains fuse on IEC chassis plug.
Overcurrent protection : fuse on primary.
Outlets : Shrouded 4 mm insulated sockets, accepts 4 mm plugs including shrouded plugs, but not unterminated wire.



Griffin LoVolt Power Supply EKR-410-010K *£76.65*

Function : General purpose laboratory supply with switched voltage settings.

Specification : Outputs of 2, 4, 6, 9, 12 and 14 V AC and DC from separate pairs of shrouded sockets. Maximum current 4 A. No locking mechanism on voltage selector. Outputs not referenced to earth.

Circuit : Low voltage is drawn from a step-down isolating transformer with 8 taps to the secondary winding. The DC output is full wave rectified. There is no smoothing. The primary winding is protected by a fuse fitted for external access within the IEC chassis plug. The mains switch is single pole and has illumination. The secondary winding has thermal cut-out protection.

Construction : Strong 2-piece metal enclosure. Class 1 electrical safety standard of construction. Complies with IEC 1010-1 excepting clause 9.2 (temperature tests).

The bridge rectifier was found to be wrongly connected to the DC socket outlets resulting in the output having reverse polarity. This is presumed to be just a careless production fault.

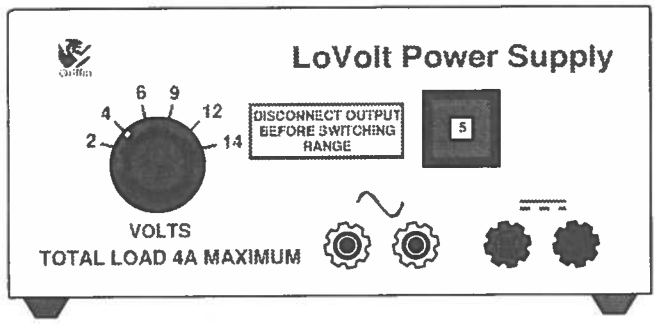
Performance : Output voltage values register with switch settings. The drop off of voltage with current is slightly greater than average.

The thermal cut-out operated efficiently. It conducts 4 A continuously, trips within a second of a shorted output and trips within a few seconds at 7 A.

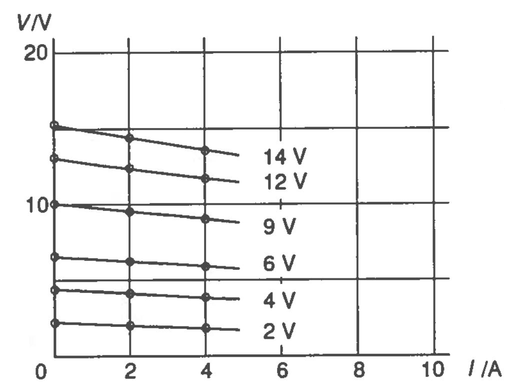
If the power supply is run under full load for a long period of time, self heating is excessive. There is a hot spot on the base by the stud fastening the bridge rectifier to the enclosure. Typically the cut-out limits the temperature rise at this spot to 40°C, and to 32°C on the rest of the base. This means that the product does not seem to comply with the requirements of IEC1010-1 regarding the maximum permissible temperature of a metal surface. We use the phrase *does not seem to comply with* because these requirements are subject to differing interpretations. However the defect might not be very significant. Because there is no carrying handle, the normal way of picking up and handling the unit is by gripping the base. If this is at or above 55°C it is foreseeable that the supply could be involuntarily released with a risk of injury to someone's foot and damage to the supply. In mitigation, the load clearly has to be removed and the mains supply disconnected before the apparatus can be transported. Once the load has been disconnected, the hot spot quickly equilibrates with the temperature of the rest of the base.

Verdict :

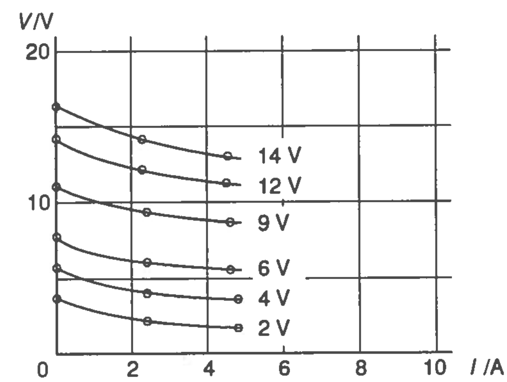
A (Very satisfactory except for its temperature rise)



Enclosure : Light grey stove-enamelled steel. Dark grey markings.
Dimensions : Width 173 mm, depth 200 mm, height 82 mm.
Weight 2.4 kg. No carrying handle or aid. Stackable.
Detachable mains cord with IEC connector.
External mains fuse on IEC chassis plug.
Overcurrent protection : fuse on primary, thermal cut-out on secondary.
Outlets : Shrouded 4 mm insulated sockets, accepts 4 mm plugs including shrouded plugs, but not unterminated wire.

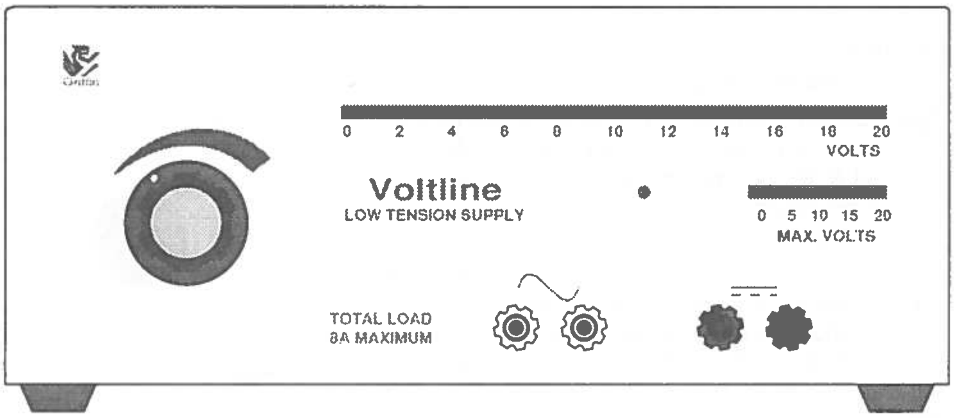


AC outputs



DC outputs

Griffin Voltline Variable Low Voltage Power Supply EKR-681-010Y *£231.00*



Enclosure : Light grey stove-enamelled steel. Dark grey markings.
Dimensions : Width 252 mm, depth 215 mm, height 110 mm. Weight 6.3 kg. No carrying handle or aid. Stackable.
Detachable mains cord with IEC connector.
External mains fuse on IEC chassis plug.
Overcurrent protection : fuse on primary, electronic regulation on output.
Outlets : Shrouded 4 mm insulated sockets, accepts 4 mm plugs including shrouded plugs, but not unterminated wire.

Function : General purpose laboratory supply with voltage range controlled by infrared link from remote key. Output voltage continuously variable up to limit of operative range.

Specification : Continuously variable voltage outputs of 0 V to 20 V AC and DC from separate pairs of shrouded 4 mm sockets. Four range limits : 5 V, 10 V, 15 V and 20 V. Maximum current 8 A AC, 6 A DC, or 8 A DC for periods up to 1 hour. Voltage output indicated on upper LED bar display; range shown on lower LED bar display. There is electronic protection against overloading and short circuiting. Outputs not referenced to earth.

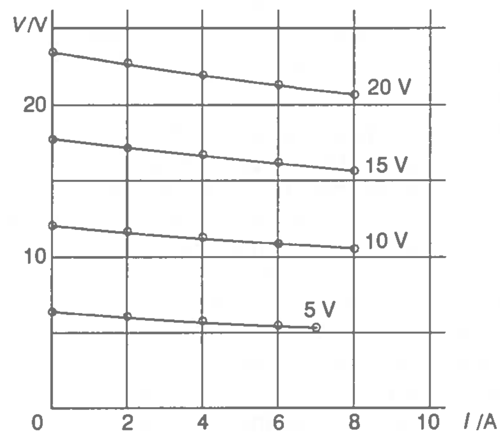
Circuit : The control knob operates a variac transformer which applies a variable voltage to a step-down isolating transformer. Relays operated by the range selection controller connect the output to different taps on the secondary winding. The output is fed through a shunt from which a signal is fed back to the controller to limit the current and operate the bar display. The DC output is full wave rectified. There is a small amount of smoothing, only significant at very low currents. The primary winding is protected by a fuse fitted for external access within the IEC chassis plug. The mains switch is double pole and has illumination.

Construction : Strong 2-piece metal enclosure. Class 1 electrical safety standard of construction. The enclosure base shows some slight distortion from handling and carriage due to inertial forces from the massive isolating transformer. Except for this point and temperature rises, apparatus meets with IEC 1010-1. The total weight of the unit exceeds 6 kg.

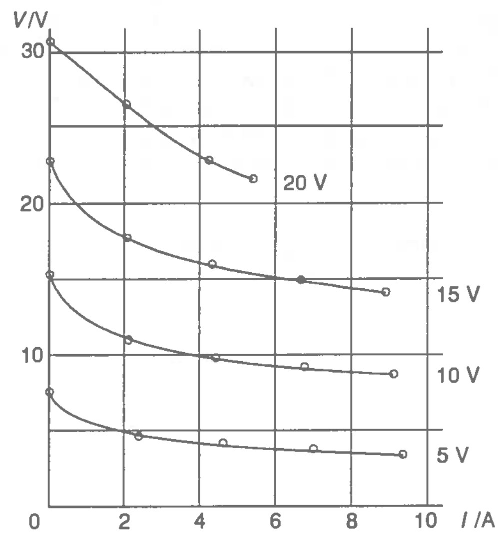
The layout and markings on the front panel are a little obscure. It is not self evident that the top bar graph indicates output voltage, or the bottom graph indicates the operative range. The voltage control is not marked, and nor is the infrared photodiode.

Performance : The Voltline cannot be operated without the infrared controller. The range of the beam is about 10 cm. At power-up the output voltage is 0 V. On each operation of the IR controller, the output limit switches from 0 V to 5 V, 0 V, 10 V, 0 V, 15 V, 0 V, 20 V, 0 V, etc. In the event of a short circuit or overload the protection circuitry switches the output limit to 0 V at the beginning of the control cycle. The teacher thus has to be notified of every instance of overload. This gives the teacher tight control over usage.

Output voltage values do not register closely with range settings. AC values can be up to 20% high. The drop off of AC voltage with current is lower than average for power supplies. DC values are about 50% high at 0 A to about 10% low at 8 A, there being an enormous drop off of DC voltage with current.



AC outputs, variable control on maximum setting



DC outputs, variable control on maximum setting

However because the voltage is shown on the indicator the user can adjust the control knob to set voltage at the required value.

The Voltline can supply a continuous current of 8 A DC at 10 V and 8 A at most other settings for short periods. The temperature rise over much of the enclosure ranges between 20°C to 30°C depending on situation, which is acceptable. However the rise on that part of the back panel to which the rectifier is bonded is up to 70°C. In effect it means that a person lifting the apparatus could make skin contact with a metallic surface whose temperature is 90°C. This is unacceptable.

Verdict :

C (Not satisfactory because of dangerous enclosure temperature. In most other respects it is very sound, but is expensive.)

Griffin Regulated Power Supply, Single Rail EKR-286-010K — *£44.10*

Function : Bench supply for digital electronics with switched voltage settings.

Specification : Outputs of 5, 9, 12 and 15 V DC voltage regulated. Maximum current 600 mA. No locking mechanism on voltage selector. Output not referenced to earth.

Circuit : Low voltage is drawn from a step-down isolating transformer through an adjustable switching regulator. Rotary switch selects from a bank of potential dividers to set the regulator's output. The regulator has internal over-current protection. The primary winding is protected by a fuse fitted externally within the IEC chassis plug. The mains switch is double pole and has illumination.

Construction : Lightweight ABS plastic enclosure of adequate strength. Base, top and sides flex slightly with finger pressure.

Electrical safety standard of construction is Class 1. Complies with IEC 1010-1 in respect of electrical safety.

Layout and operational markings on top panel are clear and simple.

Performance : Voltage values are within 0.2 V of nominal settings with very little drop in value with rise in current. Currents of 600 mA can be drawn continuously at any setting. The output is protected against short circuiting and overloading.

Because the power supply has a switched mode operation, it generates high frequency noise at about 50 kHz. The typical peak to peak value is 10 mV open circuit rising to about 25 mV at 600 mA. We have operated sequential logic off the supply and did not experience any difficulty.

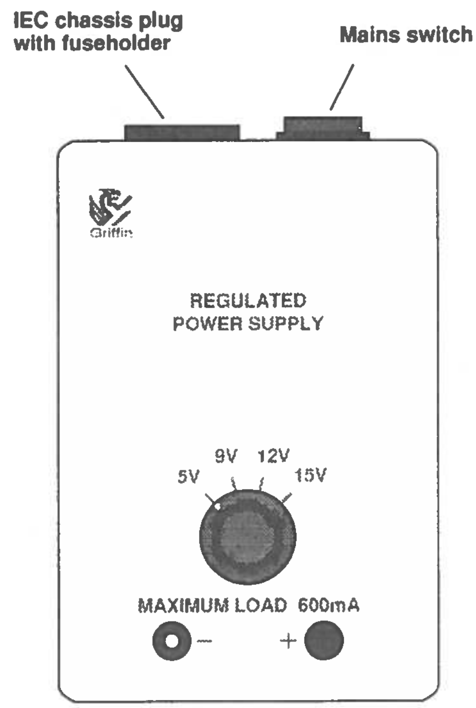
The maximum temperature rise of the enclosure is 40°C, which is tolerable. However there are two tiny hot spots on 6 mm diameter metal studs which might prove uncomfortable on delicate fingers. Because of the very small area of contact, injury is unlikely.

Verdict :

A (Very satisfactory subject to reservation about temperature rise)

Comment : We are puzzled over the choice of output voltages, there being little call for either 12 V or 15 V single rail supplies. If 3.3 V were provided instead then the unit would be capable of supplying low voltage logic devices.

Because the voltage can be mis-set there is a consequent risk of damage to logic devices. Some teachers may prefer to use a supply with a single fixed voltage to avoid mishaps through having the wrong supply voltage.



Enclosure : Pale grey ABS plastic. Dark grey markings.
Dimensions : Width 99 mm, depth 155 mm, height 78 mm.
Weight 0.6 kg. No carrying handle. Not stackable.
Detachable mains cord with IEC connector. Fused IEC chassis plug.
Overcurrent protection : fuse on primary, electronic regulation on output.
Outlets : 4 mm insulated sockets; accepts 4 mm plugs; does not accept unterminated wire.

Griffin Regulated Power Supply, Dual Rail EKR-260-010X *£81.40*

Function : Bench supply for electronics with switched voltage settings. Dual rail supply for powering bi-polar circuitry including op-amps.

Specification : Outputs of ± 5, 6, 9, 12 and 15 V DC voltage regulated. Maximum current 1.0 A. No locking mechanism on voltage selector. Outputs not referenced to earth.

Circuit : Low voltage is drawn from a step-down isolating transformer through adjustable switching regulators. Rotary switch selects from a bank of potential dividers to set the regulators' outputs. The regulators have internal over-current protection. The primary winding is protected by a fuse fitted externally within the IEC chassis plug. The mains switch is double pole and has illumination.

Construction : Strong 2-piece metal enclosure. Electrical safety standard of construction is Class 1. Complies with IEC 1010-1.

Layout and operational markings on front panel are clear and simple.

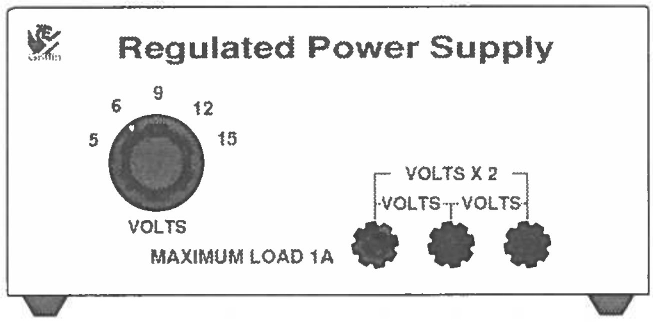
Performance : Voltage values are within 0.2 V of nominal settings with very little drop in value with rise in current. Currents of 1000 mA can be drawn continuously at any setting. The outputs are protected against short circuiting and overloading.

Because the power supply has a switched mode operation, it generates high frequency noise at about 50 kHz. The typical peak to peak value is 3 mV open circuit rising to about 20 mV at 1000 mA. We have operated sequential logic off the supply and did not experience any difficulty.

The maximum temperature rise of the enclosure is 23°C, which is acceptable.

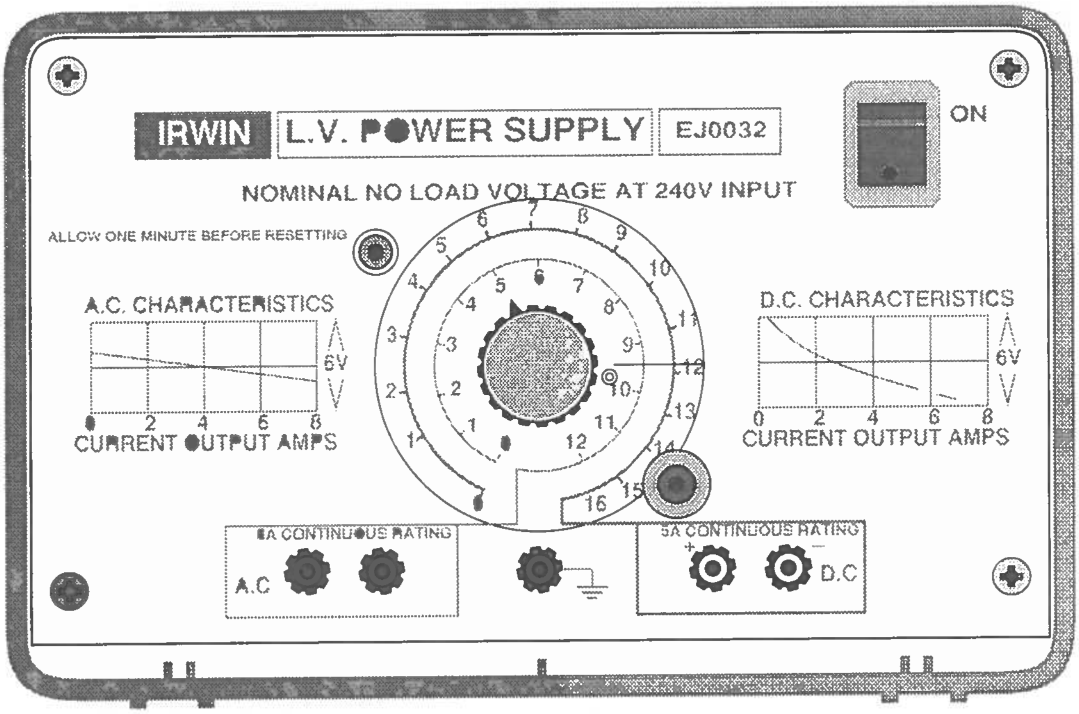
Verdict :

A (Very satisfactory)



Enclosure : Light grey stove-enamelled steel. Dark grey markings.
Dimensions : Width 173 mm, depth 200 mm, height 83 mm.
Weight 2.1 kg. No carrying handle or aid. Stackable.
Detachable mains cord with IEC connector.
External mains fuse on IEC chassis plug.
Overcurrent protection : Fuse on primary, electronic regulation on output.
Outlets : Shrouded 4 mm insulated sockets, accepts 4 mm plugs including shrouded plugs, but not unterminated wire.

Irwin Low Voltage Power Supply with continuously variable output EJ0032 *£86.24*



Enclosure : Blue inpact resistant plastic case with protective cowl. Dark grey aluminium front panel. Light grey markings.
Dimensions : Width 285 mm, depth 173 mm, height 180 mm.
Weight 3.7 kg. Carrying fold in lid. Stackable.
Attached mains cord with wrapping studs.
Overcurrent protection : Anti-surge fuse, thermal circuit breaker with external reset, and replaceable thermal fuse (all 3 devices sited between supply inlet and primary winding).
Outlets : 4 mm insulated terminals, accepts 4 mm plugs or unterminated wire.

Function : Power supply for general laboratory use.

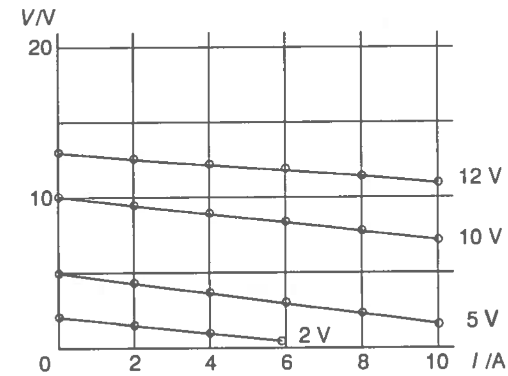
Specification : 0-13 V AC continuously variable at currents of up to 8 A; 0-16 V DC continuously variable at currents up to 5 A. Locking mechanism on voltage selector. Supply outputs not referenced to earth. Earth terminal provided. Some smoothing of DC output which is only effective at low currents.

Circuit : The control knob operates a variac transformer which applies a variable voltage to a step-down isolating transformer. The DC output is full wave rectified and smoothed, this only being effective at low currents. The primary winding is protected by three devices : anti-surge fuse, thermal cut-out and replaceable thermal fuse. Both fuses can only be reached by opening the enclosure. The mains switch is double pole and has illumination.

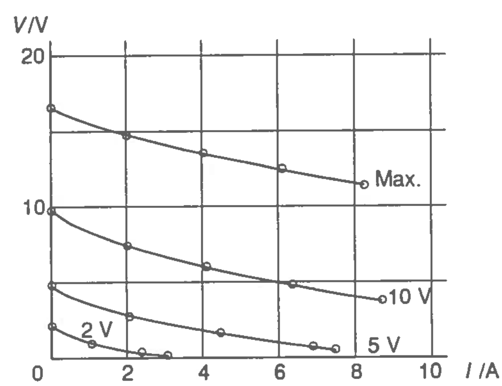
Construction : Strong 2-piece composite enclosure. Electrical safety standard of construction is Class 1. Complies with requirements of IEC 1010-1.

Layout and operational markings on front panel are clear and simple.

The voltage limit mechanism consists of a perspex disk mounted on the voltage control. There is a brass stud attached to this disk against which a projection on the knob hits. The disk is secured by tightening a large knurled nut by hand, or by an Allen key.



AC outputs against rotary knob positions



DC outputs against rotary knob positions

Performance : The supply performs to specification. The maximum temperature rise of the enclosure is 18°C, which is very reasonable.

Verdict :

A (Very satisfactory, and at a good price)

DISCUSSION PAPER

Investigations in the Sciences

Bulletin 185 [1] carried an account of the conclusions of discussion on Practical Investigations at a special workshop held during the 1995 ASE Scotland Annual Meeting. Since then this topic seems to have become something of a mini *cause celebre*. The Scottish Science Advisers' Group (SSAG) have been engaged with this subject, especially with the difficulties of the assessment of investigations. Simultaneously, we understand, the SEB's various Science Panels have been discussing these same issues.

The paper published here was prepared by teachers and members of the advisorate in Borders Region. Its original purpose was to stimulate and inform debate within that Authority. Subsequently the paper has been circulated more widely, principally through the Scottish Science Advisers' Group (SSAG). It is being published by SSERC mainly to stimulate further discussion and debate on investigations both as valuable aids to learning and as assessable elements of science courses. What follows is a largely unedited version of the full paper as originally drawn up by the Borders group.

Investigations in the sciences

A prime aim of the paper is to provide an alternative model for Practical Investigations. The paper is intended to address some of the problems apparent in the use of such investigations in the science subjects. The following basic premises should be borne in mind while considering the further points made:

- investigative practical work by pupils in science should be a major priority of any course;
- assessment of investigative practical work should not dictate the science curriculum of any course;
- trust in teacher internal assessment is an important part of any investigations' evaluation;
- there should be progressive development of investigative practical work; elements this would involve include:
    - group to individual work
    - group to individual interviewing (with an oral report at S6)
    - type of investigation becomes increasingly more complex
    - development of some skills e.g. measurement/ accuracy
- at the base of any progressive developments should be the 5-14 Environmental Studies science strands.

The existing model

Teachers across Scotland are very concerned about Standard Grade Science investigations. Some of their criticisms are listed below:

- investigations not standardised across the sciences (there is disharmony);
- the assessment of the investigations is very time consuming;
- there is no progression from S1/S2, and into S5/S6;
- teachers find them burdensome and, by extrapolation, this must also affect the pupils.

A proposed new model

There are two major starting points for this model:

(i) CSYS Sciences Project - these projects have a good press. Teachers and students enjoy them and hold them in high esteem.

(ii) Reporting on investigations should have its developmental roots in the 5-14 science strands.

The proposed model is described in the following series of text boxes.

S6

¶ A 20 hour project organised and carried out by the individual pupil*.

¶ Assessment based on a written report and an oral assessment by a visiting teacher.

(*Higher Still - Advanced Higher recommendation)

S5

¶ Two investigations (similar to existing PPAs in Chemistry or equivalents in Biology and Physics).

¶ Investigations carried out by individual pupils, who also evaluate their own work towards improvement.

¶ Written report and interview by class teacher of pupil about the report. Redrafting of one report allowed.

¶ Investigations to be more stringent than in S4. e.g. there would be a much greater emphasis on accurate measurement.

¶ Type of investigation could be based on the good PPAs from existing higher courses.

S4

¶ Two investigations (similar to existing good examples of investigations for Standard Grade).

¶ Carried out by individual pupils.

¶ Written report required by individuals. Style of report based on the 5-14 science strands.

¶ Mini interview of each pupil based on their written report. (Teacher may use check list related to 5-14 strands statements)

¶ Pupils suggest improvements for their investigations (self evaluation)

S3

¶ Two investigations, but early in S3 the investigation would be done in groups but with individual reports. Report in the style of 5-14 science strands. Group would be interviewed together on their report.

¶ In late S3 there would be an investigation performed by individuals. Each would write a 5 to 14 style report. Teachers would use a mock/ demonstration type interview as a learning situation for the class.

S1/S2

¶ Three investigations over the two years.

¶ Carried out by groups and with group reports initially leading to individual reports by end of S2.

¶ Reports based on fleshed out 5-14 strands headings.

(e.g. planning :

- what were you trying to find out?

- how were you going to do the investigation?)

¶ At S2 level there would be group interviews for the written report.

General points

1. Suggested timescales :

S6 Project	20 hours
S5 Investigations (2)	10 hours
S3/S4 Investigations (4)	10 hours
S1/S2 Investigations (3)	10 hours

2. Note that investigations are only part of the practical work in years S1-S6. It is proposed however that the investigations are to be the only assessable part of practical work relevant to any external assessment i.e. S4-S6.

3. Care will have to be taken with the types of investigation used. In particular S5 investigations will have to be considered carefully as Highers are still the main entrance qualification for Universities. Item Banks of good investigations should be created for all levels S1-S5.

4. Some thought will have to be given to investigations that can be carried out using books or IT facilities only.

5. Possibly more discussion will have to follow in weighting factors for the practical element of SCE examinations. The table below shows the existing and proposed revised weightings for Knowledge and Understanding (K&U), Problem Solving (P.S.) and Practical Skills (Prac.).

	Existing	Proposed
K&U	33%	40%
P.S.	33%	40%
Prac.	33%	20%

Table 1. Weightings for the various assessable elements of SCE Science examinations (Existing) with suggested adjustments (Proposed).

Endpiece

It is re-emphasised that all of the above ideas have been set merely to initiate, stimulate and inform discussion on investigative work as a tool for learning and teaching. Comments on or constructive criticism of any of these suggestions will be welcomed. In view of the uncertainty surrounding SSERC you are advised to send comment directly to the Acting Senior Adviser, Borders Council (see Address List inside rear cover).

Renfrew Division of Strathclyde have also done a great deal of useful work on investigations in 5-14 Environmental Studies and which should be available via SSAG.

1. ASE (Scotland) Annual Meeting Practical Workshops, Bulletin 185, SSERC, 1995.

Hazards of man-made mineral fibres

About 20 years ago the use of asbestos products was discontinued in laboratory science because of the danger to health which had by then become evident. Ceramic fibres, a type of man-made mineral fibre (MMMF), were substituted. This article reviews recent evidence that ceramic fibres may also be carcinogenic, assesses the risks and advises on control measures.

The article briefly examines the hazards of ceramic fibres and the "wools" and glass filaments and suggests a strategy for their use. Some other fibrous materials, though not considered here, are also under varying degrees of suspicion. They include :

- organic man made fibres, e.g. "Kevlar" (polyaramid fibres). However "Nomex" (the meta polyaramid) has not been shown to cause adverse health effects of this type. There is only very weak evidence to link carbon or graphite fibres with tumour formation.
- inorganic fibres, e.g. silicon carbide; attapulgite (mineral used as an absorbent for oils and as cat litter); gypsum.

Rockwool, slagwool, glasswool (in this article collectively called *wools*) and ceramic fibres have been widely used in laboratories for some years. In the seventies materials based on ceramic fibres were put forward as a substitute for asbestiform minerals which were about then officially declared to be potent carcinogens. Their dangers had been common knowledge for many years before that. At a particular meeting in 1976 some sceptical souls, including myself dared to question whether this new replacement might possibly also turn out to have similar effects. We were batted on the head by an "expert" and told that that was a silly question since the dimensions of its fibres were quite different from those of asbestos, therefore ....

The precautionary approach

It now seems that the theory isn't as simple and that other factors besides the fibre diameter and length matter. There is now mounting evidence [1] [2] that ceramic fibres, also called refractory ceramic fibre (RCF) cause cancer and mesothelioma in experimental animals. This has not been observed in epidemiological studies on work exposed persons. Two lengthy studies will come to fruition in the next two years.

Some workers in the field of occupational hygiene consider that it is only a matter of years before containers of ceramic fibres carry the skull and cross-bones hazard pictogram. For this reason we feel it is sensible at this stage to pursue a precautionary approach. This basically means substitution, where possible, with a less harmful alternative and, where that is not possible, control measures to limit the possibility of dust formation should be undertaken.

Some fibrous materials are used or manufactured in conjunction with organic binders which will do much to reduce dust formation, but there can then be other hazards from some of the binders themselves, e.g. methanal. Another example is the laying up of a glass reinforced plastic (GRP) (or fibreglass) sheet; the glass filaments used here are considered to have very low carcinogenic potential though causing severe irritation of skin, eyes and upper respiratory tract. A greater risk to health can come from the solvents and resins used. Later sanding or sawing of the cured product can create high levels of dust containing the resin and small pieces of glass fibre.

Hazards of ceramic etc. wools

MMMF are assigned a Maximum Exposure Limit (MEL) of 5 mg m^{-3} or 2 fibres ml^{-1} (both time weighted averages referenced over 8 hours). This means not only that this aerial concentration must not be exceeded, but also that there is a requirement to reduce it further to as low a concentration as is reasonably practicable.

None of the fibre types mentioned above are assigned the Risk Phrases R45 or R49 or R40 Category 3 carcinogen, but other authorities officially recognise their carcinogenic potential. The International Agency for Research in Cancer (IARC) classify them as follows :

Ceramic fibres	Group 2B
Wools - rock, slag or glass	Group 2B
Glass filaments	Group 3

Group 1 : The agent is carcinogenic to humans. This term is only used when there is sufficient evidence of carcinogenicity in humans.

Group 2A : The agent is probably carcinogenic to humans. This term is used when there is limited evidence of carcinogenicity in humans and sufficient evidence of carcinogenicity in animals.

Group 2B : The agent is possibly carcinogenic to humans. This term is generally used when there is limited evidence of carcinogenicity in humans in the absence of sufficient evidence of carcinogenicity in animals or it may be used for substances

Table 1. Fibre properties and the relation to carcinogenic potency (taken from Rossiter).

	Carcinogenic potency	Structure	Diameter (μm)
Erionite	Highest	Crystalline	<0.5
Crocidolite		Crystalline	0.1-2
Amosite		Crystalline	0.1-2
Tremolite		Crystalline	0.1-4
Ceramic fibres		Amorphous	1-3
Chrysotile		Crystalline	0.02-1.5
Anthophyllite		Crystalline	2-6
Special purpose fine fibres		Amorphous	0.1-3
Slagwool		Amorphous	4-9
Rockwool		Amorphous	4-9
Glasswool		Amorphous	2-9
Glass filaments		Amorphous	6-15
Gypsum fibres	Lowest	Crystalline	2

for which there is inadequate or no evidence of carcinogenicity in humans and there is sufficient evidence of carcinogenicity in experimental animals.

Group 3 : The agent is not classifiable as to its carcinogenicity to humans.

Like any classification with only a few bands the IARC one is a bit crude. In a more recent paper Rossiter [2] places thirteen fibrous substances in order of carcinogenic potency (Table 1). Ceramic fibres are fifth from the top, below crocidolite or blue asbestos and amosite or brown asbestos, but above chrysotile or white asbestos. Slagwool, rockwool and glasswool are much lower. Glass filaments and gypsum fibres have only a low potency.

All the naturally occurring mineral fibres are crystalline and can easily split along the length of the fibre to give the even more dangerous, thinner fibres. But the man-made fibres are amorphous and cannot split along the fibre. Generally they have a low carcinogenic potency, but the ceramic fibres are an exception to this rule.

The wools are generally made by spinning (similar to a centrifuging process for making candy floss) and have nominal diameters in the range 2 to 9 μm. This process has poor control over the diameter. Glass filaments are made by drawing, a process similar to that used for making wire where the filament is continuously stretched over a series of capstans. This method of manufacture offers good control over the diameter of the filament produced. Drawn filaments are made with diameters between 6 and 15 μm. Note that what is typically sold as glasswool in the usual schools' laboratory suppliers' catalogues is in fact manufactured by drawing and will tend to have a larger and constant diameter. For example Merck's glasswool has a diameter of 9 μm. Ceramic fibres are often made by spinning and have smaller diameters, generally between 1 and 3 μm. All of these are amorphous, but the ceramic fibres tend to become crystalline if heated at high temperatures (1200°C and above) for lengthy periods of time. The fine cristobalite and mullite crystals formed are more toxic than the original ceramic fibre.

Health effects

Irritant effects

Fibres with diameters greater than 4.5 to 5 μm such as rockwool, slagwool, glasswool and glass filaments can produce a non-severe dermatitis and irritation on skin and eyes, all of which are short lived.

Carcinogenic effects

Human studies : The effects of exposure in the manufacture and use of insulation wools (rockwool, slagwool and glasswool) in the "earlier technological phase" of the industry show mixed results. Studies in the USA and Europe showed an increased level of lung tumours, but the European study showed a lack of statistical significance. Exposures would have been higher in the "earlier technological phase" than now. The results are confounded to an unknown extent by the use of pitch and bitumen and by smoking.

For glass filament no increase in mortality or incidence of lung cancer has been established.

No epidemiological data is yet available for refractory ceramic fibre workers. The difficulty is that most of those workers will also have been exposed to asbestiform fibres.

Animal studies : These show that the probability of tumour formation was relatively high for fibres with diameters less than 1.5 μm and lengths greater than 4 μm and very low for drawn glass; other factors such as durability or persistence in the lung fluid, iron content and surface chemistry also influence the potency. Certain types of ceramic fibre are as potent as crocidolite in inducing mesotheliomas upon peritoneal injection.

Although the results of animal experiments can provide a warning flag there is always some doubt on the validity of extrapolating results from animal experiments to humans because of (i) the exceedingly high doses administered, (ii) interspecies differences, (iii) the mismatch between life expectancies of test animals and humans and the relationship of this to the latency period of many illnesses. Furthermore in some of the tests a known number of fibres are injected directly to a site in the lungs. It is likely that in the case of fibres with larger diameters no more than a very small fraction of this amount would reach that site by inhalation, simply on account of the fibres being large diameter and therefore not being respirable. Additionally with larger diameter fibres it is unlikely that high aerial concentrations would be formed.

Exposures in schools

In all the uses of the fibres in schools very few would give rise to dust formation. Some typical applications might include:

- use of heat resisting mats and surfaces;
- use of ceramic centred gauzes;
- wrapping insulation round glassware, e.g. of a fractionation column for distilling off a less volatile component - the actual use is not so bad, but the wrapping and unwrapping of the sheet or matting may release some fibres;
- loose plugs in the mouths of tubes or flasks, for example
  - to keep small fragments of potassium manganate(VII) being ejected; or
  - of a conical flask with ammonium dichromate(VI) in a contained version of the volcano experiment;
- as absorbent for liquid in Arculus "wet asbestos" method, for example
  - fibre to hold medicinal paraffin to crack it;
  - water to generate steam to react with magnesium;
- packing to hold second reagent in the Arculus method, possibly
  - magnesium ribbon for reaction with steam;
  - zinc granules for reaction with oxygen generated by heating potassium manganate(VII) at the end of the tube; it is essential to keep the metal from accidentally mixing with the powerful oxidising agent;
  - a catalyst in the middle of a tube, e.g. alumina to bring about dehydration of alkanols;
- support for platinum catalyst (sold as platinised Kaowool or platinised ceramic fibre);
- laying up GRP with layers of resin and glass filament and possibly abrading the surface of the cured product to smooth it.

We have not measured the aerial concentrations for any of these activities, but have made comparisons with results for particular processes, such as insulating roof spaces, given by the HSE in Guidance Note EH46 "Man-made mineral fibres" [3]. From this we estimate that the levels reached for all the above activities, except the abrading of GRP resin, would be very low, and far below the MEL. We have consulted the HSE and their Employment Medical Advisory Service (EMAS) who agreed with this conclusion. They further pointed out that

(i) the amounts were very small and if carefully handled then the fibre count would almost certainly be so low as to be immeasurable;

(ii) the time of exposure was very short and when averaged over the 8 hour day the TWA concentration would be even lower.

Control measures

In general

1. Ceramic fibres should be substituted where possible by a less hazardous replacement, possibly by the wools or, better still, by drawn glass filaments.
2. Substitution may be impossible in some cases, say because the process has to stand a sustained high temperature, which may be well above the softening point of a putative replacement. In that case the ceramic fibre can probably be used with care to avoid raising any dust.
3. Substitute rockwool and slagwool by drawn glass filaments. Being coarser fibre the latter is a poorer absorbent.
4. Handle the materials with tongs; the wools and the filaments in particular are very irritating to the skin. Wear gloves and eye protection. After being strongly heated the fibres will be dried out and have a greater tendency for bits to break off and escape into the air. When cleaning out test tubes, etc. it is a good idea to dampen the wodge of fibre or even immerse the tube under water and dispose of the material wet.
5. If the application is as a reservoir for a liquid from which a vapour is to be generated, a ball of scrunched up filter paper may make a perfectly good substitute.

There have sometimes been problems with rockwool and slagwool when they were heated in contact with potassium manganate(VII) or other strong oxidising agents. Traces of oxidisable impurities which may be present in some samples react violently with the oxidising agent. Strongly heating a batch of the fibre in air beforehand in a fume cupboard will remove them by oxidation.

Most of the wools are limited to a maximum useful working temperature of about 450°C though a few specially formulated ones will withstand 800°C. We find in practice that glasswool inside a test tube can be roasted without sagging. The ceramic wools are usually limited to a maximum temperature of 1300°C, though those with a high alumina content can be used at 1600°C.

Specific examples

Heat resistant mats and ceramic centred gauzes : If the mats are hard and in good condition continue to use them; replace if broken or fraying. Replace gauzes with damaged centres immediately and have a rolling programme to replace sound ones with stainless steel, non-centred gauzes

Insulation round fractionating columns : Carry out the wrapping and its removal in a fume cupboard.

Loose plugs in tubes : Non-absorbent cotton wool is fine for :

- the mouth of conical flasks in the marble chips and hydrochloric acid on a balance method;
- the mouth of a test tube to prevent any small fragments of crystals being ejected from iodine crystals, but glasswool should be used for potassium manganate(VII) or the volcano in a conical flask (ammonium dichromate(VI)) as these powerful oxidants react vigorously with cotton wool.

Arculus "wet asbestos" method : Relates to wodge of mineral wool packed into the bottom of a test-tube and soaked in a liquid which, when heated, evolves vapour. For the reactions of steam with magnesium, iron or zinc substitute glasswool or, better still, scrunched up filter paper. In fact paper has a bigger capacity for liquids than glasswool or ceramic wool. It will only char when all the water or other liquid has been driven off; clearly there is no point in heating a dried reservoir. Ethanol (for dehydration) and liquid paraffin (for cracking) can be treated in the same way. Paper is very suitable for most such operations apart from those using oxidising or corrosive reagents.

Arculus method : Relates to separating reagents in a tube with a wodge of wool. Cotton wool is unsuitable where the reagent, e.g. zinc, is being oxidised by oxygen generated by manganate(VII) at the end of the tube. Use glasswool for this situation. In some cases the separator is not needed; e.g. alumina catalyst or broken porcelain does not adversely react with ethanol in the "reservoir". Simply place the alumina well down the tube in a neat wee conical heap and keep the tube clamped in a horizontal position.

Platinised ceramic fibre catalyst : Used in Contact Process and in Ostwald Process. Once the catalyst and its support have been placed in the "catalytic reaction chamber", a side-arm test-tube in the case of the Ostwald Process and usually a combustion tube in the case of the Contact Process, it should simply be stored in that tube between annual outings. Pack the "reaction chamber" with the catalyst in a fume cupboard. Wear gloves and eye protection for this operation. Place a pad of glass filament wool at either end of the length of platinised ceramic wool used in the Contact Process to help contain it.

GRP work : Wear eye protection and gloves. Stipple the resin on a layer of glass mat with a brush. Many ready made mats release very little fibre, which in any case is very coarse and not easily disseminated. A well ventilated room is needed on account of the release of phenylethene vapour (styrene). Machining, drilling or sanding of the cured product requires local exhaust ventilation.

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TECHNICAL TIPS

Soluble starch

What is the best type of starch?

Recently we had an enquiry on the type of starch best used for various teaching purposes. This was from a school which had old stocks of starch located not only in a central store but in a number of small lab based caches. Whilst all of these stocks were labelled 'starch' it seems that not all of them were necessarily easily made up into 'solutions', nor were they all suitable for different enzyme experiments or food testing. Although this is an apparently simple and straightforward matter, the purchase of suitable types of starch for school biology or chemistry applications is in fact quite a tricky business. Much of the information on which to base a cost-effective purchase is only to be found in older texts such as the Nuffield Teachers' Guides (first, unrevised, versions). In giving advice to the school we realised that the information might well be of interest to others.

The main requirement for merely testing for starch itself is that the starch in question be easily 'dissolved' (in fact it doesn't form a true solution but a colloidal suspension or sol). For this purpose any soluble starch would probably do. Similarly, where enzymically catalysed hydrolysis of starch is studied, merely by monitoring the rate of disappearance of starch as substrate (using the starch-iodine reaction), then any contamination by reducing substances is not critical; neither in the starch nor in the amylase which you use.

The complication comes when you wish to test starch for the absence of reducing sugars. This could be by means of one of the classical wet reagents such as Benedict's or Fehling's or by the use of test strips such as Clinistix or the Diabur test. Equally, such contamination could be a problem where the rate of hydrolysis of starch was to be monitored by estimating the rate of appearance of glucose using such wet reagents or test strips. For these applications a starch which is not only soluble but is also completely free of reducing sugars would be the ideal type (e.g. Lintners for diastase estimation). The major snag here is relative expense. A compromise would be a less expensive form of starch not completely free of reducing substances but where the level of such contamination is low enough for it not to be detected by either the wet methods or the test strips (in practice this seems to be < 0.2% or so).

As the school making the enquiry had discovered the hard way, it is probably an unnecessary operational complication to have several different kinds of starch in the department. The answer is to settle on one type and (as usual) the final choice comes down to money. In our own work we have tended to use inexpensive BDH GPR (general purpose reagent) grade soluble starch from BDH (now available from McQuilkin/BDH) Cat. No. 30264 4K at £13.60 for 500 g. Our sample is some seven or eight years old now. It is not reducing sugar free but we have established that any contamination with reducing substances is insufficient to give a positive result with either the traditional wet reagents or the usual test strips. As to more sensitive, colorimetric, procedures we aren't sure that there might not be some interference.

Most of the standard texts recommend Analar grade for all such uses. Surprisingly, this is not as dear as you might think. For example, McQuilkin/BDH's Analar grade soluble starch (Cat. No. 10271 3R) is ca. £10 for 250 g. This grade still contains some reducing material (quoted as < 0.2% [as glucose]) but in practical trials we were unable to detect any effect on either a Benedict's or a modified Fehling's test. Nor was there any discernibly positive result with either Clinistix or Diabur glucose test strips. However, if you want to be absolutely certain that your soluble starch is reducing sugar free you might wish to consider using either Philip Harris' soluble starch free from reducing sugars - Cat. No. S81495/1 at £4.22 for 500 g or their soluble starch (Lintener's) for the determination of diastase activity - Cat. No. S81505/0 at £9.99 for 250 g.

Beware too in enzyme experiments of using any amylases which are contaminated with reducing sugars. Bulletin 179 went into that problem in some detail [1]. Finally, if you want a rapid result for the action of salivary amylase on starch try adding sodium chloride to a 1% w:v starch solution so as to reach a final salt concentration of about 0.1% w:v.

Diabur test strips

Mention of these as an alternative to Clinistix was made in the technical tip above. We are grateful to staff at NCBE for first putting us on this alternative test for glucose. The mechanism of Diabur strips is probably not all that different from that of Clinistix (see ref.[2] for an account of this). What is obviously different is the chromagen system which is used to produce the various colours correlated with varying concentration of glucose. In Clinistix the chromagen is a very small amount of ortho-tolidine. This system is basically qualitative and gives the familiar pink for a negative result with three deepening shades of purple (light, medium and dark) denoting increasing concentrations of glucose. The system can be crudely calibrated however, by a laboratory user, against known standard concentrations.

With the Diabur-Test 5000 system for glucose the range of colours is very different and much wider. A negative result is denoted by a primrose yellow whilst a range of estimated concentrations between 0.1% to 5% (w:v) is indicated by a pale green through to a dark sage green and on to deepening shades of blue (a twin colour pad system coming into operation beyond 1% (56 mmol per litre). We have written to the German manufacturers of Diabur strips in attempt to discover the nature of the colour system which we suspect might be chromate based. To date the only responses we have managed to elicit have been a couple of Material Safety Data Sheets (MSDSs) stating that the product offers no significant risks when used as directed.

As with the Ames range of 'Stix' products (eg Clinistix, Albustix, and Hemastix), Boehringer produce a range of Diabur products for testing urine and like the 'stix range they are available from local pharmacists (although in some instances they may be a special order). Costs are broadly comparable also. Fifty Clinistix strips currently cost about £4.85 over the counter and fifty Diabur Test 500 Glucose strips are £3.57.

Discerning and diligent readers will have spotted that some kinds of test strips may each contain tiny amounts of a suspected carcinogen. If that worries you, and you haven't already done so, we suggest that you read the article beginning on page 8.

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HSE Books, PO Box 1999, Sudbury, Suffolk, CO10 6FS;
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