SCOTTISH SCHOOLS SCIENCE

EQUIPMENT RESEARCH

CENTRE

Bulletin No. 117 December, 1979

Contents

Introduction	- carcinogenic hazards	Page 1.
	- cost index	1.
	- holiday closing dates	1.
Chemistry Notes	- carcinogenic hazards in school science	1.
Cleapse Reports		7.
Biology Notes	- care of WPA oxygen electrodes	8.
Trade News		9.
In the Workshop	- safety modification to a microscope illuminator	10.
Address List		12.

Introduction

We include in this bulletin the second of our articles from the ASE Safety Committee, Materials and Processes Group, possible carcinogenic hazards in school science. We think it right to do this despite its appearance already in Education in Science because although it is possible to over-react to school hazards they cannot be over-publicised. To give point to this, the current issue of a scientific journal has an experiment involving two substances which the carcinogenic hazards article does not want to have even in the same room. The substance is bis-CME, which was the subject of a hazards article in Bulletin 85, <u>four years ago</u>.

* * * * * * *

Our cost index, which is sampled twice yearly in May and November, and for which the base line is 100 in May, 1974 is now 235. This is an increase of 20% over the past year, and 7.5% over the past six months.

* * * * * * *

During the holiday period the Centre will be closed on 24, 25 and 26th December, and on the 1st and 2nd January, 1980. It will also be closed on the two Saturday mornings 22nd and 29th December.

Chemistry Notes

1.0 INTRODUCTION. A large number of chemicals are nowadays widely believed to be carcinogenic, including some that are found in schools. There is a danger that the emotive nature of cancer will cause relatively remote risks to be exaggerated compared to more immediate hazards from fire, toxicity and so on and the purpose of this article is to present the known facts about such of these chemicals as are likely to be found in schools and suggest precautions in their use.

In this discussion, eight types of carcinogen are considered: (1).

1. Aromatic hydrocarbons
2. Aromatic amines
3. Azo compounds
4. Nitroso-compounds
5. Direct alkylating agents
6. Radioactive substances
7. Miscellaneous organic compounds
8. Inorganic compounds.

There is, of course, a list of known potent carcinogens, largely of type 2, published by the DES, SED (2) and elsewhere. These should certainly not be used or kept in schools. See the summary.

1.1 TOXICITY AND CARCINOGENICITY
Toxicity and carcinogenicity are two of the more serious effects that chemicals may exert on the human body. However, whereas toxic effects are often manifested immediately and are thus readily understood, dangerous carcinogenic effects are only seen in the long term and it is less easy to make a rational estimate of any risk. (The same, of course, applies to CHRONIC toxic effects which may at first go unnoticed).

Many carcinogenic chemicals are also toxic. Chemistry teachers in schools should be used to handling safely toxic substances such as mercury salts or chromates and should also be aware of the considerable dangers of some chemicals newly regarded as toxic such as benzene or some of the halogenated hydrocarbons. Some of these toxic chemicals are now also regarded as carcinogens and indeed for some it may be that carcinogenic effects are consequent upon long-term toxic effects, as with benzene, where chronic exposure may lead to leukaemia as a result of the damage benzene does to bone marrow. Benzene, chromates, tetrachloromethane and some other halogenated hydrocarbons are all examples of such toxic chemicals that may have long term carcinogenic effects and if they are handled with the precautions that their toxicities warrant, they should present little danger of carcinogenic effects.

It is important, also, to realise that some carcinogenic chemicals may be treated with insufficient care because they are not unduly toxic. It is hoped that any such chemicals that might be met with in schools are covered in the following paragraphs. There are also some chemicals which are very potent carcinogens and these require very careful handling, whether or not they are toxic as well, but such chemicals are not necessary in school science.

2.0 PARTICULAR CHEMICALS

2.1 AROMATIC HYDROCARBONS

The only pure chemicals of this group likely to be found in schools are benzene, naphthalene and possibly anthracene. Benzene is highly toxic and carcinogenic and should be treated as such.

Indeed teachers should give serious consideration as to whether it is necessary to use benzene at all, and its use as a solvent for which there are good substitutes, is quite unnecessary.

However, while naphthalene and anthracene are both quite toxic, neither appears to be appreciably carcinogenic.

There is no evidence that derivatives of these compounds (including benzene), WITH THE EXCEPTION OF AMINO, NITRO AND AZO COMPOUNDS, are carcinogenic, (3) but they may still be toxic.

Carcinogenic polycyclic aromatic hydrocarbons may well be present in crude oil or 'tarry messes' left after some distillations. The only likely danger of significant exposure would arise when apparatus was washed up and the wearing of gloves for this operation would be advisable. The danger of fire during the distillation is much more serious.

2.2 AROMATIC AMINES

Some chemicals in this group are the only ones for which carcinogenesis is believed to have occurred in laboratory workers but these chemicals are all banned for use in schools. (See the summary).

Phenylamine (aniline) has been suspected as a carcinogen but in all cases the culprit has been found to be an intermediate in industrial processes involving phenylamine. It is, however, a highly toxic substance and should be handled with care.

Carcinogenic compounds identified so far in this group almost all have an amino group at a position on an aromatic ring equivalent to the 2-position in naphthalene (figure 1) or para to a biphenyl link

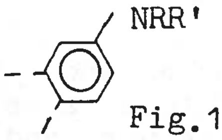


Fig.1.

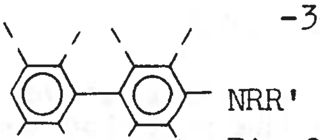


Fig.2.

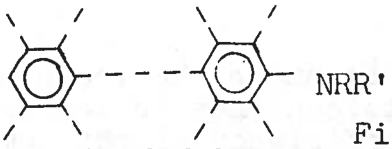


Fig.3.

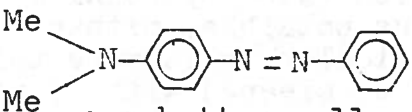
(figure 2). The biphenyl link may also be extended by inclusion of other structures (figure 3). Compounds corresponding to these structural types should not be prepared in schools.

The dye magenta (basic fuchsine) has not itself been proven carcinogenic although intermediates in its manufacture have posed hazards to workers in the dye industry.

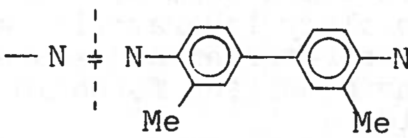
Some aromatic amines, although not carcinogenic themselves, may contain impurities that are. For instance, diphenylamine should not be hazardous if pure, but impure samples may contain the potent carcinogen 4-biphenylamine (4).

2.3 AZO COMPOUNDS

Some azo compounds are carcinogenic but the generalization that all are is unfounded. Most of those that are proven carcinogens would fall under the structural classification given for carcinogenic aromatic amines or would break down easily in the body to give such amines.



e.g.butter yellow

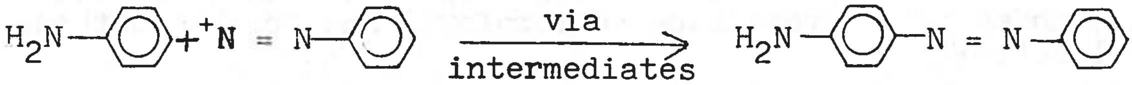


trypan blue

Substitution by a sulphonyl group often renders a dye non-carcinogenic (trypan blue (see above) is one exception: this large molecule DOES have sulphonyl groups and is soluble). Thus most water-soluble dyes and indicators are not carcinogens. In view of this it is suggested that sixth form preparations of azo dyes be restricted as follows:

a) Do not prepare dyes conforming to the structural types given for carcinogenic aromatic amines (see section 2.2) or containing such components within their overall structure. Examples include trypan blue and congo red. There is also the risk with these dyes that commercial samples may contain carcinogenic starting material as impurities.

b) Avoid the possibility of the diazonium salt coupling with undiazotized amine



by checking that diazotization is complete before proceeding to the next stage.

c) Prepare water-soluble dyes where possible: e.g. methyl orange.

2.4 NITROSO-COMPOUNDS

Many of these compounds are potent carcinogens but they are not used in schools and indeed legislation currently under preparation by the Health and Safety Executive may well prohibit use of carcinogenic nitroso-compounds except in certain exempted establishments.

N-nitroso-compounds might be prepared in schools in the reaction of nitrous (Nitric (III)) acid on secondary OR TERTIARY amines (5).

These experiments should probably be discontinued and indeed may have to be under the legislation mentioned above. A teacher who wishes to continue to demonstrate the reaction would have to be sure of the efficiency of the fume cupboard in which he does the work and provide adequately for the destruction of the N-nitrosamine after the experiment.

2.5 DIRECT ALKYLATING AGENTS

Again these compounds, some of which are very potent carcinogens, are not and should not normally be used in schools. However one potent carcinogen of this type may be met in schools as a product of a chance reaction. Methanal (formaldehyde) and hydrochloric acid vapours react to give trace amounts of chloromethoxychloromethane (bis-chloromethylether or BCME) which is highly carcinogenic and is not allowed to attain a concentration of greater than 1 part per thousand million in air and industry. Depending on the humidity and temperature as little as 10 ppm each of methanal and hydrogen chloride could give rise to this order of concentration of BCME (6). Methanal vapour should not therefore be allowed to interact with hydrogen chloride from hydrochloric acid.

As methanal is most commonly used in biology laboratories (as formalin) it would seem wise to exclude concentrated hydrochloric acid from biology laboratories and, as far as possible, methanal from chemistry laboratories and stores. In particular, glassware that has contained methanal (or formalin) should not be cleaned with hydro-chloric acid.

2.6 RADIOACTIVE SUBSTANCES

There is negligible danger from the sealed radio-active sources permitted in schools. Teachers should avoid any possibility of the escape of dust from uranium or thorium salts particularly when thorium oxide is used to generate radon. The risk from uranium ingestion seems to be due to its chemical toxicity rather than its radioactivity.

2.7 MISCELLANEOUS ORGANIC COMPOUNDS

Various other organic compounds have been reported to be car-cinogenic and are discussed below.

2.71 Tetrachloromethane and other halogenated hydrocarbons.

Many of these are severely toxic to the liver and in addition some are carcinogenic. These simple halogenated compounds vary greatly in their physiological activities and, while tetrachloro-methane (carbon tetrachloride), 1,2-dibromoethane, 1,2-dichloroethane and iodomethane do appear to have significant carcinogenic activity, others such as trichloromethane (chloroform) and trichloroethene are of doubtful activity.

In view of the severe toxicity of these compounds, they should be handled with care anyway, and preferably in a fume cupboard: if this is done potential carcinogenicity should not be a worry. For degreasing and general solvent applications it is now generally accepted that the less toxic 1,1,1-trichloroethane should be used.

2.72 Thiourea and phenylthiourea. Thiourea has produced cancers in rats but only at dose levels regarded as too high for it to be con-sidered an occupational carcinogen of any practical significance (7).

The Department of Cancer Studies at Birmingham University have carried out a literature search on phenylthiourea and concluded that:

> "it should be acceptable for limited taste-testing experiments with necessary precautions to limit possible intake".
>
> (See "Safety in Science Laboratories" DES Safety Series No. 2 (3rd edition) para. 129).

2.73 8-hydroxyquinoline. There is some evidence from animal experiments that this substance may be of low carcinogenic potency. It may be used where necessary but should be handled with care.

2.74 "Ninhydrin". No tests for carcinogenicity on this substance have been reported; it is however, a strong irritant and should be handled carefully. It should be sprayed only in a fume cupboard.

2.75 Thioethanamide (thioacetamide) hydrazine, dioxan. These compounds which are unlikely to be found in schools anyway, have all shown evidence of low carcinogenic potency in animal experiments and should be treated with care. There is no reason to suppose that all hydrazine derivatives, as for example 2,4-dinitro phenylhydrazine, are carcinogenic.

2.8 INORGANIC COMPOUNDS AND MINERALS

Chromium and nickel compounds are now commonly reported to be carcinogenic. However, this needs to be put in perspective. It is noteworthy that an expert in the field has recently said that:

> "inorganic compounds are not regarded as significant carcinogenic hazards on the small scale" (8).

In both cases evidence of carcinogenicity comes from industry, particularly mining, where workers are exposed to high levels of dust or fumes.

2.81 Chromium compounds. Chromium compounds in mining operations have been reliably associated with nasal and lung cancers and the use of chromate baths in the plating industry has given rise to non-malignant skin ulcers. Most experimental evidence points to the Cr(VI) oxidation state alone being carcinogenic and then the highest potency is shown in the less soluble compounds such as lead or calcium chromates.

Hexavalent chromium compounds are certainly a danger to the skin and should be handled carefully, preferably with gloves. This is, however, largely a toxic effect. Inhalation of chromate dust or mist should be avoided. The only significant possibility of this happening would appear to arise from the 'volcano' experiment which should, for preference, be done in a fume cupboard.

2.82 Nickel compounds. Insoluble nickel compounds such as nickel(II) oxide and the sulphide Ni_3S_2 have been shown to be carcinogenic if breathed as a dust. However, soluble nickel compounds have not shown carcinogenic activity in experiments. Even the insoluble compound most likely to be prepared in schools, nickel(II) sulphide, does not appear to be carcinogenic.

There would appear to be no cause for concern about nickel compounds as carcinogens when they are used in schools.

2.83 Asbestos. One form of asbestos, crocidolite or "blue asbestos" is highly carcinogenic but is never found in the asbestos used in laboratory apparatus. Chrysotile ("white asbestos") does carry some carcinogenic risk and is restricted to less than 2 fibres per cm^3 in the air in industry where it is used. It is extremely unlikely that even this low airborne concentration would be reached through the use of asbestos products in school laboratories but as good substitutes are now available for asbestos centred gauzes, asbestos mats and other asbestos laboratory products there is no need to use them.

<u>SUMMARY</u> Carcinogenic and potentially carcinogenic chemicals: guidelines for handling in schools.

...pounds that should definitely NOT be kept or used in schools (2).

(a) Naphthalen-1-amine or naphthalen-2-amine (alpha- or beta-naphthylamine)

(b) Biphenyl substituted by:
(i) at least one nitro or primary amino group, or by at least one nitro and primary amino group;
(ii) in addition to substitution as in (b) (i) above, further substitution by halogeno, methyl or methoxy groups: but not by other groups.

NOTE: The most frequently used substituted biphenyls used in laboratories are the following, or their salts:
biphenyl-4,4'-diamine (benzidine)
4-aminodiphenyl (xenylamine)
3,3'-dimethyl biphenyl-4,4'-diamine (o-tolidine)
3,3'-dimethoxy biphenyl-4,4'diamine (o-dianisidine)

(c) The nitrosamines. (Note that school pupils should not under any circumstances prepare N-nitroso compounds from amines).

(d) The nitrosophenols (para-nitrosophenol is safe and may be used in schools).

(e) The nitronaphthalenes

(f) Chloroethene (vinyl chloride monomer).

B. Highly toxic compounds which should be used very carefully in schools, if at all.

(a) which are also carcinogenic
Benzene, tetrachloromethane (carbon tetrachloride), 1,2-dibromoethane, iodomethane (methyl-iodide), and

(b) which may also be carcinogenic
Trichloromethane (chloroform), trichloroethene (trichloroethylene), hydrazine, dioxan.

All the above are highly toxic. Use substitutes wherever possible and avoid breathing their vapours if they are used. Wear gloves and eye protection and avoid any possibility of spilling them on the skin. Benzene should never be used as a solvent: 1,1,1-trichloroethane is a safer substitute for tetrachloromethane and trichloromethane in solvent applications.

C. Less toxic compounds of possible carcinogenic potential.
8-hydroxyquinoline, "ninhydrin", thioethanamide (thioacetamide), thiourea.

As with other toxic substances, wear gloves and eye protection when handling these compounds and take care to avoid spilling them on the skin. Sprays containing any of these compounds should be used only in a fume cupboard.

D. Crude oil
There should be little danger from a properly conducted distillation experiment. Gloves and eye protection should be worn especially when cleaning apparatus after the experiment.

E. Azo dyes
Use water-soluble indicators where possible. Avoid staining the skin with indicator solutions. In preparation of azo dyes check that diazotization is complete in the first stage by testing for excess nitrous (nitric(III)) acid. Prepare water-soluble dyes such as methyl orange if possible. (A preparation is given in Vogel, Practical Organic Chemistry).

F. Methanal (formaldehyde, formalin)
The vapour of this substance can form a very potent carcinogen if allowed to mix with hydrochloric acid vapour.

Do not store concentrated hydrochloric acid in biology laboratories or prep. rooms and do not store methanal in chemistry laboratories or prep. rooms. As far as possible avoid their use in these rooms as well. Only sealed bottles should be kept together in the same store. Where concentrated hydrochloric acid is specified in preparations of condensation polymers involving methanal use 50% sulphuric acid instead.

G. Thorium and uranium compounds

Avoid any possibility of creating a dust of these compounds in the air. 'Thorium cows' used for the generation of radon should always be fitted with a dust filter.

H. Chromates

Chromates should always be handled wearing gloves and eye protection and the generation of dust or spray (as in electrolysis) should be avoided.

I. Purity of compounds

Some compounds, particularly aromatic amines, although themselves relatively safe may contain carcinogenic impurities. A case in point is diphenylamine which should always be purchased as pure as possible. In general any compound that is likely to contain as an impurity any of the substances listed in section A should be avoided or at least obtained in as pure a form as possible and handled carefully.

REFERENCES

(1) Howe, Laboratory Practice, July 1975, pp 457-467.

(2) DES Safety Series No. 2 "Safety in Science Laboratories". Paragraph 94A (1978).

SED Circular No. 825 "The Use of Carcinogenic Substances in Educational establishments".

(3) Hueper, W. C. and Conway, W. D., "Chemical Carcinogens and Cancer", C. C. Thomas, Springfield, Illinois (1964).

(4) George W. H. S. and Searle C. E., A.C.S. Monograph Series No. 173, Chapter 10 (1976).

(5) Walters C. L., Chem. Brit. 13, (4). p 140 (1977).

(6) Environ, Sci. Technology 8, (4), pp 356-359 (1974).

(7) Guidance Note EH 15/77. Health and Safety Executive (1977).

(8) Searle C. E., Chemistry and Industry (3) p 111, (1972).

Cleapse Reports

A number of new and revised reports and repair notes have been received from our sister organisation C.L.E.A.P.S.E. A list is given below. These documents are available on loan for one month and may be obtained by writing to the Director of SSSERC.

Reports:	L24a	Advice on microscopes and magnifiers for Junior Schools.
	L24b	Advice on microscopes and magnifiers for middle schools.
	L85d	Electronics construction methods.

	L107a	Newtonmeters
	L127b	Photography, darkroom work.
	L133	Replacement for asbestos products.
	L135	Eye protection
	L144a	Mercury, how to handle it and clear up spillages.
	L145	Beakers, measuring cylinders, funnels - glass or plastics?
	L150	Equipment List 1.
	L151	Ammeters etc.
	L152	Spirometers.
Addenda:	L135b	Eye protection for science laboratories.
	L142b	Environmental Equipment for schools.
Repair Notes	PUM 79	Air pumps for aquaria - d.i.y. maintenance.
	VAC 79	Maintenance of electrically powered rotary vacuum pumps.
	WAT 79	The repair of mechanical stopwatches and stop clocks.
	MET 79	D.i.y. repairs of ammeters etc.

Biology Notes

At the request of a school biology department which was experiencing difficulty with a WPA oxygen meter, we have investigated the behaviour of their electrode. The difficulty experienced by the school was in setting the reference points, 21% oxygen in air and 100% saturation in an air saturated sample of water. The 'calibrate' potentiometer had insufficient range to allow these values to be set at normal room temperatures.

The electrode was tested using our own home-made polarising and amplifying circuitry and was compared with two other electrodes which we knew were functioning properly with the WPA circuits. We found that the 'suspect' probe gave consistently higher output signals, approximately three times greater than the other two probes at the same amplifier gain settings.

We discussed these results with WPA and they concluded that over a period of time the electrolyte had probably 'crept' through the seals in the electrode body. Some electrolyte was in contact with the leads, effectively lowering the resistance of the electrode. WPA emphasised that this was not normally a problem in new electrodes. Usually it only occurs in older electrodes and is aggravated by storing the electrodes full of the saturated KCl electrolyte. WPA have been working on this problem for some time and the latest generation of electrodes has been improved in this respect. However there are still difficulties caused by the inflexibility of the epoxy adhesives they need to use to fulfil other requirements, and the remarkable propensity for the KCl to 'creep' through any tiny crack.

WPA have told us that they now advise that oxygen electrodes be emptied and washed out after use and be stored dry. Previously it was thought that electrodes could be left filled without any ill effects. However it now looks as though the lifetime may be greatly extended if these simple precautions are taken.

Trade News

A number of years ago we spent much time on a fruitless search for electron micrographs for inclusion in our biology equipment list. Now this gap has been filled by two sets of prints from Philip Harris Biological. Each contains 12 micrographs and costs £2.40. The sets are EMP1 - 'the cell', cat. No. M80100/4 and EMP2 - 'the Tissues', M80115/6. Set EMP1 is also available as overhead projector transparencies cat. No. A60100/7 at £8.

In Bulletin 114 we mentioned a new metal heat of combustion apparatus, from Philip Harris, C42805/2, and we mistakenly reported that various accessories like burners, thermometers were included. Unfortunately the price we quoted does not include these, and to make the experiment complete would require a separate purchase of two thermometers, nickel crucible, spirit lamp, filter tube and tube holder. The crucible, C42842/3, £2.12 and a spirit lamp, C42900/7 at £4.63 are probably the only essential parts which the school might not already have.

In Bulletin 114 we mentioned that three-way taps, which we have used in a number of experiments, were available from Griffin and George. Philip Harris also provide them, cat. No. C75380/7 at £2.62 for a pack of five.

The day after the printers got Bulletin 116, in which we lamented that cheap Japanese single range meters had disappeared from the market we got the Proops Bros. catalogue from an electronic journal. The firm offers what are fantastic bargains at prices which will never be repeated, so that anyone who wants to stock up on pupil meters for junior classes would be well advised to take advantage of the offer. Some examples (d.c. range unless stated to be a.c.) are:

MR38P 42 x 42mm, 1-0-1mA, 2mA, 200mA, 3V. 15V, 15V a.c., £1.50 each.
MR45P 50 x 50mm, 100-0-100μA, 10mA, 100mA, 1A, 1A a.c., 15V a.c., £1.50 each.
MR65P 78 x 86mm 1-0-1mA, 50mA, 500mA, 50mA a.c., 200mA a.c., 10V, 50V a.c., £3 each.

Too late for inclusion in Bulletin 116 where the bulk of our surplus equipment was publicised, we got a load of perspex offcuts. Hopefully there will be enough for all, so that we are not balloting it, but simply selling it as orders are received. The thicknesses vary from 2-6mm; state the approximate thickness required. Sheet size is approx. 46 x 123cm. Clear sheet, £2.25: patterned (frosted) sheet, £1.00; coloured (opaque) sheet, £1.50. This can also be bought in 25kg pallets of the same size of sheet averaging 10-14 sheets, 80% or more in clear sheet, at £16.50 per pallet.

Available from Mackay and Lynn is a holder for hot beakers or dry ice. Shaped like a small oven cloth for use with one hand, and made of silicone rubber it retails at £6.50. The same firm also sells latex gloves in small, medium and large sizes at £2.70 per 100.

Technical and Optical Equipment have moved to the address given in page 12.

In The Workshop

We have recently received, via a science adviser, a report of an accident involving a microscope sub-stage illuminator. The illuminator in question was a type SL-4 supplied some years ago with a Technical and Optical Equipment's Russian MBR microscope. This illuminator has a poor cable clamping arrangement with little to prevent the cable turning. On the apparatus in question continual twisting of the wires had frayed them. The body of the illuminator became live and a pupil touching it received a live to earth shock.

Schools possessing MBR or Zenith Biolam microscopes fitted with SL-4 type lamps, should inspect them carefully for frayed cables and wires. An inexpensive modification can be made to the lampholder in order to improve the clamping of the cable. Alternatively the lampholder of the newer style SL-5 or OI32 illuminators can be purchased as a separate item and used to improve the SL-4 illuminators. Obviously this is the more costly option, SL-5 lampholders costing approximately £3.50 each at the time of writing. SL-5 illuminators have been supplied to anyone ordering within the last eighteen months. Technical and Optical Equipment have informed us that these new illuminators meet the relevant British Standard.

Of course, lack of adequate cable clamping and fraying wires are not confined to one model of illuminator. It is a sensible precaution to check periodically the cables on all portable apparatus. However sub-stage illuminators and bench lamps are used and abused very frequently and deserve more attention and maintenance than they perhaps receive in schools.

(a) Cut side clip off a 'Bic' pen top - (b).

(c) File a groove 5mm deep and 2mm wide across the base.

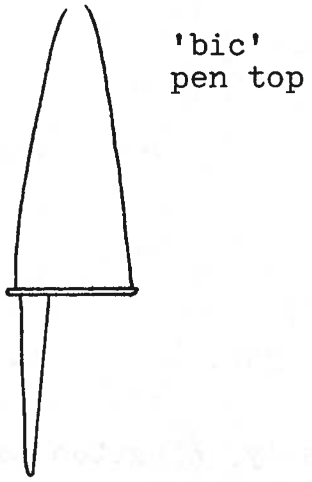
(d) Cut 9mm section from the base of the pen top.

(e) Cut a 4mm section of 5mm i.d. 8mm o.d. rubber tubing.

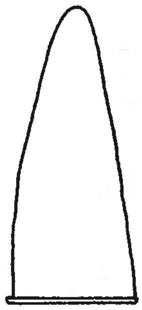
(f) The plastic collar and rubber tubing are threaded onto the cable as shown. The earth wire is brought out through the collar and tubing sleeve as shown and soldered to an earth tag.

The next step is to drill a hole in the brass housing of the actual lampholder to take an 8BA screw to hold the earth tag (see (g)). A pair of holes will also be required in the lamp-housing and lampholder so that a screw can be inserted to prevent the lampholder being accidentally pulled out or being rotated in the housing.

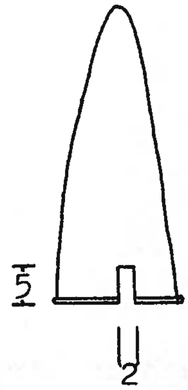
The lampholder can now be assembled. Discard the thin brass ring previously used as the earthing point. Fit the bakelite bayonet holder into the brass collar before screwing down the cover. This should be screwed on carefully so that the slot in the plastic collar is pushed down onto the raised section of the holder. The rubber tubing will distort and help hold the collar down onto the live and neutral and the central raised section. This will prevent the cable turning and the live and neutral wires from fraying. The earth is taken out through the central hole in the cap and the tag attached to the holder. The bulb can then be refitted, the holder replaced in the lamp-housing and the screw tightened up.



(a)

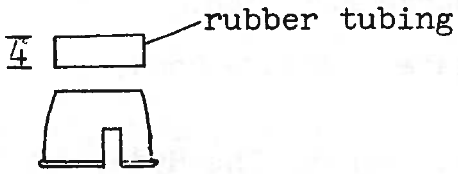


(b)

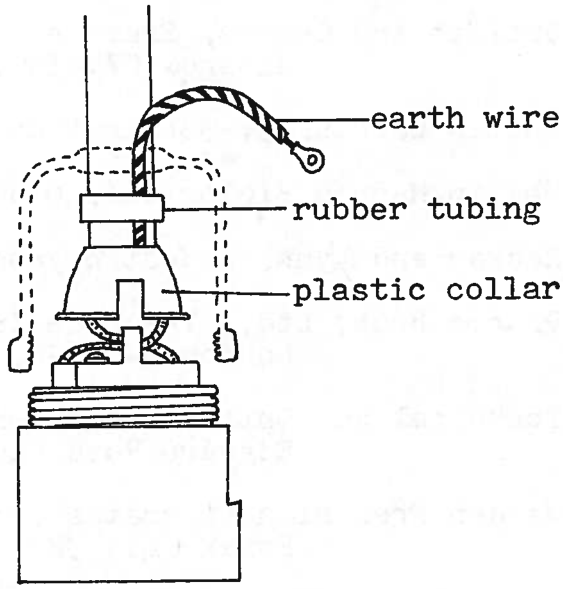


(c)

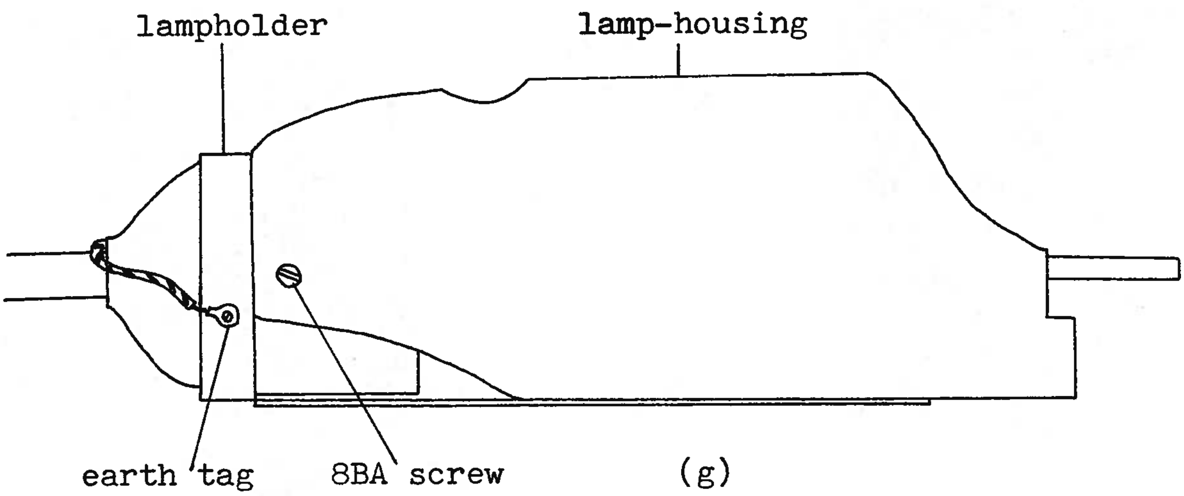
(d)



(e)



(f)



(g)

All dimensions in mm. Scale approx. 1:1

S.S.S.E.R.C., 103 Broughton Street, Edinburgh EH1 3RZ.
Tel. No. 031 556 2184.

C.L.E.A.P.S.E., Development Group, Brunel University, Kingston Lane
Uxbridge, Middlesex.

Griffin and George, Braeview Place, Nerston, East Kilbride,
Glasgow G74 3XJ.

Philip Harris, 34-36 Strathmore House, Town Centre, East Kilbride.

Philip Harris Biological, Oldmixon, Weston-Super-Mare, Avon.

Mackay and Lynn, 2 West Bryson Road, Edinburgh EH11 1EH.

Proops Bros. Ltd., The Hyde Industrial Estate, Edgware Road,
London NW9 6JS.

Technical and Optical Equipment Ltd., Zenith House, The Hyde,
Edgware Road, London NW9 6EE.

Walden Precision Apparatus Ltd., Shire Hill, Saffron Walden,
Essex CB11 3BD.