SCOTTISH SCHOOLS SCIENCE

EQUIPMENT RESEARCH

CENTRE

Bulletin No. 79. April, 1975.

Contents

Introduction

Some years ago we suggested in this bulletin that perhaps some safety manual ought to be provided for the guidance of technicians and teachers in the storage, handling and disposal of hazardous chemicals, as well as the more common handbooks which only detail the hazard and give advice on first aid. We thought that a book which put the emphasis on prevention rather than cure of accidents and their consequences would have value in the teaching situation. The suggestion was taken up by the Scottish Education Department's Standing Committee on Safety and has since progressed with consummate slowness - we first suggested the manual six years ago - to the stage where it is almost complete. Decisions regarding layout and format, what chemicals should be included etc. were all the subject of discussion with various organisations, including the Department of Education and Science, which had expressed interest in the manual. A small group of chemists, mainly teachers, were commissioned to prepare the entries for individual chemicals. The material has been edited to ensure uniformity, and officials of the Scottish Home and Health Department have been consulted regarding the first aid advice, and have prepared an introduction on general first aid.

Such was the state of play when the Health and Safety at Work Act passed through Parliament. This Act applies to schools, and is now in force. It is likely that the Health and Safety Executive will appoint inspectors who will have responsibility for safety in schools, and that any code of practice such as the manual we have discussed will require to be approved by them. Hence there must be a further period of delay so that the manual and its implications may be considered by the Health and Safety Executive. We could close six years of work with no manual at all. On the other hand, we may emerge with a document with more bite to it than was originally intended. If the manual even in a modified form were incorporated into a code of practice approved by the Health and Safety Executive, it could acquire a legal standing which would raise it above the advice provided by other handbooks on the subject.

Biology Notes

One has to go back to Bulletin 10 (December 1966) to find our first reference to Albustix test papers as an alternative to Millon's reagent as a test for proteins. Since the pupils are not expected to know the reactions involved in the test - how many teachers do? - this has always seemed to us a piece of cookery book chemistry wherein any method which produced a satisfactory result was valid. Hence we have always sought to discourage the use of Millon's reagent because of its toxicity, and have recommended Albustix or Biuret instead.

In the 'O' Grade Biology paper for 1973, a question appeared which specifically mentioned Millon's reagent. We felt that this had the effect of destroying at a stroke any of the propaganda against Millon's reagent which we had been able to apply during the previous six years. The extent to which the terminal examination controls the methods of teaching, particularly at a time when there is a shortage of science teachers cannot be overlooked. We believe that the 1973 examination had the effect of confirming in many teachers' minds the necessity for retaining Millon's reagent as a protein test and we accordingly wrote to the S.C.E.E.B. concerning this particular examination question.

The reply we received from an examination officer of the Board stated "The view (of the Biology Panel) was that the Principal Examiner has been asked formally to pay particular attention to the point regarding the inclusion of very specific tests especially when other equally suitable tests are available. Regarding the use of substances which may in certain circumstances involve some risk, I understand that the feeling was that many compounds are potentially dangerous if the concentration is sufficiently high or the exposure sufficiently large and that therefore the pupils must learn how to use substances safely. This of course does not imply that a potentially dangerous compound should be used when there are equally suitable safer alternatives available."

We had hoped at that stage (December, 1973) to make some pronouncement in a bulletin regarding the use of Millon's reagent. Indeed we had hoped for a categorical assurance that Millon's would not be specifically mentioned in future examinations, but we felt that the Biology Panel's reply was too equivocal for us to give any worthwhile assurance to those teachers who wished to abandon the use of the reagent. The Principal Examiner had been left the loophole of 'equally suitable alternatives' - is Albustix equally suitable?

We had published (Bulletin 54) a short note on the use of Albustix, and had followed this up with a longer article (Bulletin 64) showing how Albustix could be used to determine relative amounts of protein in foodstuffs, something which Millon's reagent does not do. Albustix is specific to albumen, which although common is not a constituent of every proteinaceous food. (The same criticism applies to Millon's reagent; it will react with any phenolic compound in which the 3 and 5 positions are unsubstituted. Proteins give a red coloration with Millon's reagent because an unsubstituted phenolic ring occurs in the amino acid tyrosine - Experimental Biology Manual, Brown and Creedy, Heinemann, 1970). Because of its method of use, Albustix cannot be used, as Millon's reagent can, to show the localisation of protein in certain tissues of storage organs or seeds. If the Principal Examiner in Biology prefers tyrosine to albumen or localisation to quantification of protein, he may well consider that Albustix is not an equally suitable alternative. Hence we said nothing in the bulletin.

Late in 1974 we learned of an accident involving Millon's reagent. A teacher had warned the class of the dangers of skin contact with the reagent, a warning which one pupil chose to ignore. A boy spread it on the backs of both hands, and then showed his class-mates that it had no effect, inviting them to do likewise. Fortunately none did. Next day his hands were swollen, then he was off school, and finally he had to remain in hospital for a week, during which it was conclusively established that mercury was the cause of his illness. In view of these circumstances, which neither we nor the Biology Panel could have foreseen, how does one apply their dictum that pupils must learn how to use substances safely? How other in fact than by giving the details of this accident the maximum publicity and hoping that every teacher who continues to use the reagent relates these details to the class, and that no pupil will then be foolish enough to ignore such reinforced warnings? But there are many weak links in this chain of communication and it would be better if the use of Millon's reagent in schools could be stopped altogether.

After learning of the accident we wrote again to the S.C.E.E.B. asking for an assurance that the test would not specifically be required in future examinations. The reply said no more than had already been said, that the Principal Examiner had been asked to pay particular attention to the point regarding the sole inclusion of a specific test such as that involving Millon's reagent where a choice is available, and, concerning the use of dangerous substances, that the Biology Panel would hope that where equally suitable techniques/reagents are possible the teacher would use those involving the least risk.

There the matter rests. How likely it is that a future examination will mention Millon's reagent must be left for the teacher to judge for himself. If the S.C.E.E.B. believe as we do that the examination acts as a strong conditioner on what is taught and how it is taught they should feel a strong obligation not to mention it and to phrase a question in a manner which allows alternatives. We agree entirely with the Panel's view that pupils should learn how to use dangerous substances in safety, but equally we believe that we have a duty to safeguard the foolish ones from the results of their own actions if they choose to ignore the warnings given them. This we can do only by keeping them away from unnecessary risks, and amongst these we include Millon's reagent. We should like to see its use by pupils banned entirely. This would require a circular to be issued from the S.E.D. but the Biology Panel of the Board and the Central Committee on Biology would be required to acquiesce that the syllabus would not be adversely affected.

As the result of our researches we believe that we can now marshal powerful arguments for restricting Millon's reagent to demonstration, if not to suggest the abandonment of its use in schools. There are two basic recipes for Millon's reagent. The traditional Millon's uses mercury dissolved in concentrated nitric acid with subsequent dilution in distilled water. A typical solution made up in this way would contain up to 340 g/l of mercury in 7.5 M nitric acid. The action of traditional Millon's relies on the presence of small amounts of mercury(II) nitrite formed from traces of nitrous acid present when the reagent is made up.

The reagent was modified by Cole in such a way that less mercury is required in a weaker acid. Cole's recipe involves dissolving mercury(II) sulphate in sulphuric acid. The nitrite is provided by adding 1% sodium nitrite solution just before or during use. Millon's made to Cole's modified recipe would contain 100 g/l of mercury(II) sulphate in approximately 2 M sulphuric acid, which is about 80 g/l mercury in acid twice the strength of bench acid. This reagent is sold by supply houses as Millon's solution A.

Systemic poisoning by mercury through skin absorption is usually the result of repeated or extended exposure over a period of time. However, with Millon's the presence of strong acid may modify this and ease the penetration and absorption of the mercury compound. Certainly with traditional Millon's the 7.5 M nitric acid is a hazard in itself and is bound to increase the already serious local irritant effects of mercury compounds. These are not long-term, but are classed as 'acute' in the medical sense, i.e. as the result of short exposure or a single dose. It is our opinion that these effects are still being under-estimated in some quarters.

The other argument against the use of Millon's is that of pollution control. The Pharmacology Sub-Committee of the Ministry of Agriculture, Fisheries and Food has recommended (1971) that every effort should be made to reduce further contamination of the environment including the seas, with mercury in any form. It is ironic that biology teachers who may teach pupils about pollution and conservation are themselves responsible for contamination of the environment. We have calculated that in a secondary school with four integrated science sections and two biology groups, using traditional Millon's in food-testing practicals, as much as 120 g of mercury would go down the drain each year. To meet the recommended dilution for disposal of 10 p.p.m. by weight would require 12,000 litres (2,700 gallons) of water. If every secondary school uses Millon's, and we assume an average consumption half that quoted above, the national use of the reagent would mean that 40 kg of mercury, requiring dilution with four million litres (870,000 gallons) is being put down the drain annually. Cole's recipe instead of traditional Millon's would divide these figures by four. Restricting Millon's to demonstration only would reduce them by a factor of 20 - 25.

As a postscript, and in case Albustix is not deemed equally suitable, we suggest the test described below. We did not know of the test until we carried out some library research following the accident. We would like teachers to try it as an alternative to Millon's reagent and to report to us cases where they find it more or less satisfactory than Millon's. Only when we have collected a sufficient body of evidence will we all be in a better position to judge whether Millon's should be discarded. It is interesting to reflect on the furore which would have ensued if the 1973 'O' Grade paper had mentioned 'Sakaguchi test' instead of Millon's reagent, and that this outcry would have resulted not from any difference in merit between the two, but only on the relative familiarity for the teachers concerned. Perhaps if the proportion of foreign nationals in our schools, and universities, increases, we shall not be so hide-bound by Western tradition.

Sakaguchi test. The following is reproduced from Laboratory Techniques in Botany, 2nd ed., Purvis, Collier and Walls; Butterworths, 1966, and we acknowledge our indebtedness to Butterworths for permission to reprint it here.

"(A) 5% sodium hydroxide (prepared as for Biuret reaction).

(B) 1% α-naphthol; take 1 g α-naphthol and dissolve in a little commercial alcohol. Make up to 100 ml with alcohol.

(C) 10% sodium hypochlorite.

Method - to 3 ml of solution under test, 1 ml of A and two drops of B are added. These are well mixed and one drop of C is added and mixed. A red coloration indicates the presence of arginine. This test is a good general test for protein as arginine is a basic amino acid found in all proteins."

α-naphthol is now correctly named naphthalen-1-ol. In (B), propan-2-ol may be used in place of alcohol, and in (C), neat 'Domestos' may be used in place of 10% sodium hypochlorite.

The main advantages of the Sakaguchi test are;

a) Like Millon's it can be used to test solids to show the actual location of proteins.
b) No heating is required so that there is no risk of 'bumping' or spurting.
c) The reagents are relatively non-polluting.
d) The scale can be reduced to drops without adversely affecting the test.

The disadvantages include;

a) The test is more complicated than Millon's, three reagents having to be added to the sample in the correct order. Traditional Millon's needs one reagent only, and Cole's method two.
b) Naphthalen-1-ol is affected by light, is effectively short-lived and should be stored in a dark glass bottle.
c) Naphthalen-1-ol is toxic by skin absorption over an extended period or with repeated doses in the same way as mercury. However, the effects of short exposure or single doses are likely to be less serious. Naphthalen-1-ol has less irritant effect than mercury and is less poisonous by inhalation. After repeated or extended doses the local irritant effects are as serious as those of mercury but unlike mercury there is little risk of local allergenic effects. In addition, high levels of mercury are present in Millon's reagent whereas the Sakaguchi test uses only 1% naphthalen-1-ol. But the presence of alcohol may increase the risks of skin absorption and the 5% sodium hydroxide and 10% sodium hypochlorite will be corrosive and irritant.

In summary, Millon's and Sakaguchi are necessary only if one wishes to show the location of protein; for anything else, Albustix or the Biuret test are satisfactory. Both tests are potentially hazardous but of the two we think Sakaguchi is the safer alternative. How much safer it is will remain a matter of opinion.

Chemistry Notes

We give below a brief account of laboratory accidents which have been brought to our notice recently. The first of these concerns the heating of lithium metal. This experiment occurs in Nuffield chemistry but not in our syllabus, where the only suggestion is for a demonstration of the action of lithium on water (Chemistry Takes Shape, Book I, p. 42). When the accident occurred the lithium was being heated on porcelain, and it exploded. Those interested will find a discussion on this hazard in the School Science Review No. 196, p. 632. One suggestion (not given in the above reference) is that high atmospheric humidity may be conducive to an explosion.

A recent report from The Guardian describes how a pupil squirted liquid from an unlabelled beaker, using a syringe. Both beaker and syringe were on the laboratory bench, and at the time of occurrence the teacher was absent from the room. The liquid, thought by the pupil to be water, was sulphuric acid, and the boy into whose face it was squirted required plastic surgery, and was awarded £1,800 damages.

The next accident concerns the heating of a liquid in a closed flask fitted with a Bunsen valve. The latter is a length of rubber tube with a slit in it, the far end of the tube being sealed with glass rod. The intention is that if pressure increases in the flask the slit is forced open. On this occasion the valve stuck, and the stopper with valve attached blew off and hit the ceiling, together with the contents of the flask.

Butyric acid was the cause of the next accident. A pupil took from the wall shelves a small bottle containing the acid, and after sniffing it proceeded to surprise other members of the class by suddenly holding it under their noses. One girl reacted sharply and hit the hand holding the bottle so that a third pupil nearby was splashed in the face by the acid. Prompt remedial treatment lessened the effects of the accident although the boy's face showed areas where the epidermis had been stripped off by the action of the acid. Fortunately there were no permanent scars.

Finally, for another example where a pupil's misbehaviour resulted in hospital treatment, readers are referred to the article preceding this, p. 2, where an accident involving Millon's reagent is described.

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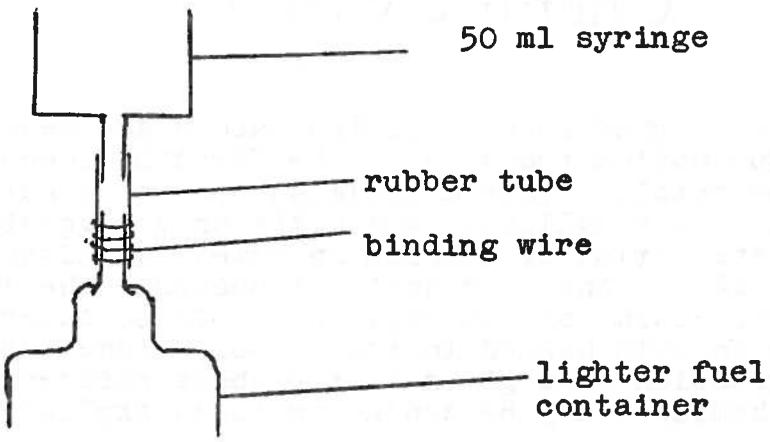
In Bulletin 46 we described how an empty Ronsonal multi-fill lighter fuel container was used to determine the molecular weight of gases. The container available at that time had a plastic nozzle fitted with a silicone rubber disc and the lighter was filled when an injection needle in the filler penetrated the disc. The containers now in use have a narrow nozzle which when pressed causes a valve to open. This makes possible the simple arrangement shown below without modification of the container for determination of the molecular weight of a gas.



The container is first emptied to atmospheric pressure by pressing down the nozzle to open the valve. The syringe is filled with 50 ml of the gas and attached to the rubber tube so that nozzles of syringe and container are in contact. Pressing down the syringe piston causes the valve to open. The container is weighed before and after addition of 50 ml of gas on a 1 mg sensitivity balance. The container should be checked occasionally to ensure that the valve is satisfactory.

It is still possible to modify the container as suggested in Bulletin 46. A suitable size of hole can be drilled in the metal top; this will cause the valve to drop inside the can where its presence does not affect the experiment. The rubber plug is then inserted and the top sealed with epoxy adhesive.

Physics Notes

An article in the School Science Review No. 191, p. 365 on the use of street lamps in schools may have prompted some teachers to acquire discarded sodium lamps from their local Lighting Department. The 35 W size of lamp makes a very intense and convenient sodium spectrum source for experimental work. The power requirements of the lamp are for mains a.c. at 450 V as a striking voltage, and this must drop to about 70 V at 0.5 A once ionisation has taken place. Hence the transformer is required to have high impedance; this is fulfilled by the 'auto-leak' type supplied for running the Phillips spectrum tubes, e.g. <u>Griffin and George</u> L59-310/006 or <u>Philip Harris</u> P8871.

The S.S.R. article states that any faulty tube must be broken under water, as it is illegal to put sodium into the litter bin, and we want to sound a mild warning about this procedure. We acquired a batch of lamps from Edinburgh Corporation and found three defective tubes. To dispose of them, the outer glass envelope was broken off by nicking with a file and using a hot glass rod to run the crack right round. With a little manipulation and twisting the central glass U containing the sodium was extracted and the metal parts removed. The U contains neon gas under slight positive pressure so that if the glass pinch is broken off, gas escapes. The sodium it contains can usually be seen as a shiny deposit in the bend of the U, although some lamps have dimples in the legs of the U in which the sodium is supposed to collect.

We broke off both legs of the U, using the hot glass rod technique, near the middle, and put all the parts in shallow water in a sink. With the first tube all went well; the sodium formed a molten ball which was nearer hazel-nut than pea size, floated into open water and dissolved normally. With the second tube the sodium remained in the U-bend and then exploded, throwing pieces of broken glass and burning sodium over a distance of 1 - 2 m. Therefore we would not recommend this technique, but that after breaking both legs of the U, ethanol or propan-2-ol (iso-propyl alcohol) be put into the parts to dissolve the sodium, after which the material may be washed down the drain. If necessary the addition of propan-2-ol should be repeated at 24-hourly intervals until all the sodium has reacted.

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In the family of logic gates, an inverter is a device which gives an output which is the inverse of its input. Moreover as the input level changes, the output switches very rapidly from low to high, and vice versa. Hence the device behaves very similarly to a triode valve or transistor in a multi-vibrator circuit, and two inverters, cross coupled as for a multi-vibrator will give something approximating to square wave oscillation.

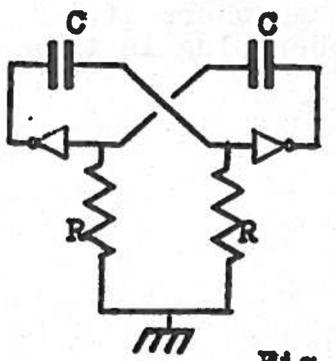


Fig. 1.

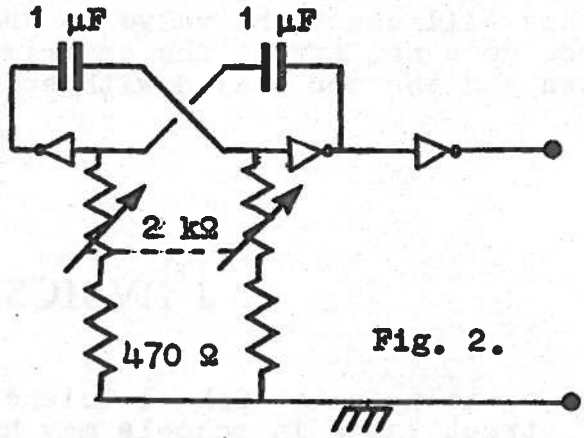


Fig. 2.

The SN7404 integrated circuit chip may be bought for 18p from <u>G. F. Milward</u>, or much cheaper in quantity (<u>Bi-Pak</u>, 12 for 54p) and this contains six inverter gates. For these, the limiting values of R which will sustain oscillation are approx. 100 Ω and 3.5 kΩ, which give frequencies of 3.5 kHz and 160 Hz respectively, when used with 1 µF capacitors. The output can be made square by passing it through a third inverter gate. If variable frequency square waves are required both CR time constants must vary in step, which will require a ganged potentiometer. Fig. 2 shows a practical circuit giving square waves in the frequency range 170 Hz - 1 kHz.

If in Fig. 1, R = 2.2 kΩ and C = 47 pF, an oscillation of frequency around 3 MHz and which will be far from square, will result. As the circuit of Fig. 2 uses only half of the inverter gates on a SN7404, it is possible to build both high and low frequency versions of the circuit on the same chip. However, there is cross-modulation between the two and it is desirable to arrange to switch one off when the other is being examined. Like all SN74 integrated circuits, the chip requires a nominal V_{cc} = +5 volt supply; if this is obtained from a 9 V dry battery, the circuit of Fig. 3 can be used. Current consumption is about 18 mA.

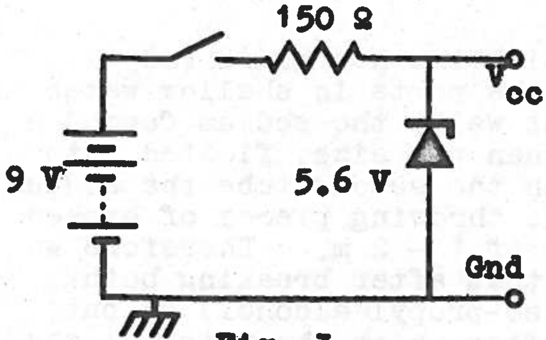


Fig. 3.

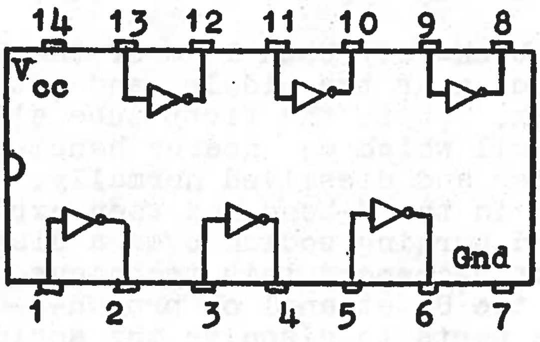


Fig. 4. Connections to SN7404 as viewed on top.

Trade News

A transistor tester from Adlab, the TT1, must be one of the simplest for giving a quick check on the state of a transistor. The correct type, pnp or npn is selected, the transistor is plugged in and a gain control is turned until an indicator lights up. The current gain is then read directly from the control setting. The TT1 costs £7.50.

Unilab have produced a joulemeter, Cat. No. 082.601 with a range of 0.1 - 100,000 J and three digit read-out. Although still in prototype form, it is expected to sell for under £28. The unit is equally usable on a.c. and d.c., so that as well as counting energy input to low voltage immersion heaters, it can measure the energy stored in a capacitor. A pair of terminals when connected to a 1 mA d.c. meter will register the power in the circuit in watts.

Baird and Tatlock have introduced an Educhem range of chemicals designed to meet the requirement of most school chemistry for something better than technical grade, without going to the expense of Analar reagent. Each bottle label will carry the purity specification, as well as hazard warnings etc. where advisable. The range is marketed in Scotland by Asschem, who are sole agents and stockists. Asschem deliver using their own transport to the main centres of population and will send by road or rail freight to outlying areas. As time goes on Asschem hope to build up their stocks of apparatus for school chemistry.

Another Baird and Tatlock item is their Educhem periodic table. Measuring 30 × 21 cm, it is specifically for pupil use. The name, symbol, atomic mass and number are given, and the list of elements goes as far as Lawrencium, number 103. The tables are sold in packs of 50 at 1p each.

A plastic syringe valve, in the shape of a T, is sold by Gordon Keeble at £1.50, and is basically two non-return valves in a single housing. If a syringe is connected to one limb and repeatedly pumped, gas or liquid is drawn in through a second limb and expelled through the third, in the manner of a force pump. The valves are claimed to be gas and liquid tight up to 80 lb/in^2 pressure. Many applications come to mind, e.g. inflating balloons with any given gas. Another application will be found in our dissolved oxygen measuring apparatus in Bulletin 78.

Philip Harris are marketing a plastic linear air track, Cat. No. P10041, which with accessories and 2 light and one heavy vehicle costs £27.

Fears have been expressed recently (Bull. of Brit. Myc. Soc., 1974, 8, 2, pp. 79-80) that certain makes of immersion oil constitute a health hazard in that they contain polychlorinated biphenyls (p.c.b.) which are poisonous by skin absorption. The Projectina Co. are agents for a new immersion oil from Nikon which is p.c.b. free and meets all the usual optical requirements. The oil costs £4.20 for 50 ml.

'Aquafeed moisture matting' available from Amberol and costing £3.50 for a roll 3 yd × 18 in wide, or £2.60 at 12 in wide, can be used to make low cost automatic capillary watering systems for the greenhouse or laboratory. (See School Science Review, No. 196, pp. 537-8).

It would seem that some schools are having difficulty in arranging to have their microscopes serviced. Although the firm of Watson no longer manufacture microscopes, they have engineers in Scotland who will service a wide range of microscopes either on a contract or one-off basis. Those in east central Scotland should contact Mr. Scrimgeour; those in Glasgow and the west should get in touch with Mr. Easson. Those uncertain of their geographical category should contact Mr. Scrimgeour in the first instance.

The Prior 460 series of microscopes has undergone several modifications since the 'H' Grade summary was published in Bulletin 66. Some comments in the summary and the assessment given are no longer applicable. An updated report is available and can be obtained on loan for up to one month by writing to the Director of the Centre.

Pyser are marketing a new stereomicroscope, the M20E at £49.50 for 10× or 20×. Additional objectives cost £6 each. We have obtained samples and a report will be available in due course.

The stereomicroscopes from Vickers Instruments in the 'Sterimag' range are now replaced by the M69 series. We have tested these and a report will be available in the near future. The standard M69 is a short arm instrument and costs £98; the long arm version costs £112.

Polythene bags with re-sealable tops can be useful in storing materials in the laboratory or workshop; the following sizes, all in inches, are available from Mackinnon and Hay;

$2\frac{1}{4} \times 2\frac{1}{4}$	-	44p per 100,
$4 \times 5\frac{1}{2}$	-	63p per 100,
$5 \times 7\frac{1}{2}$	-	87p per 100,
6×9	-	£1.15 per 100.

In The Workshop

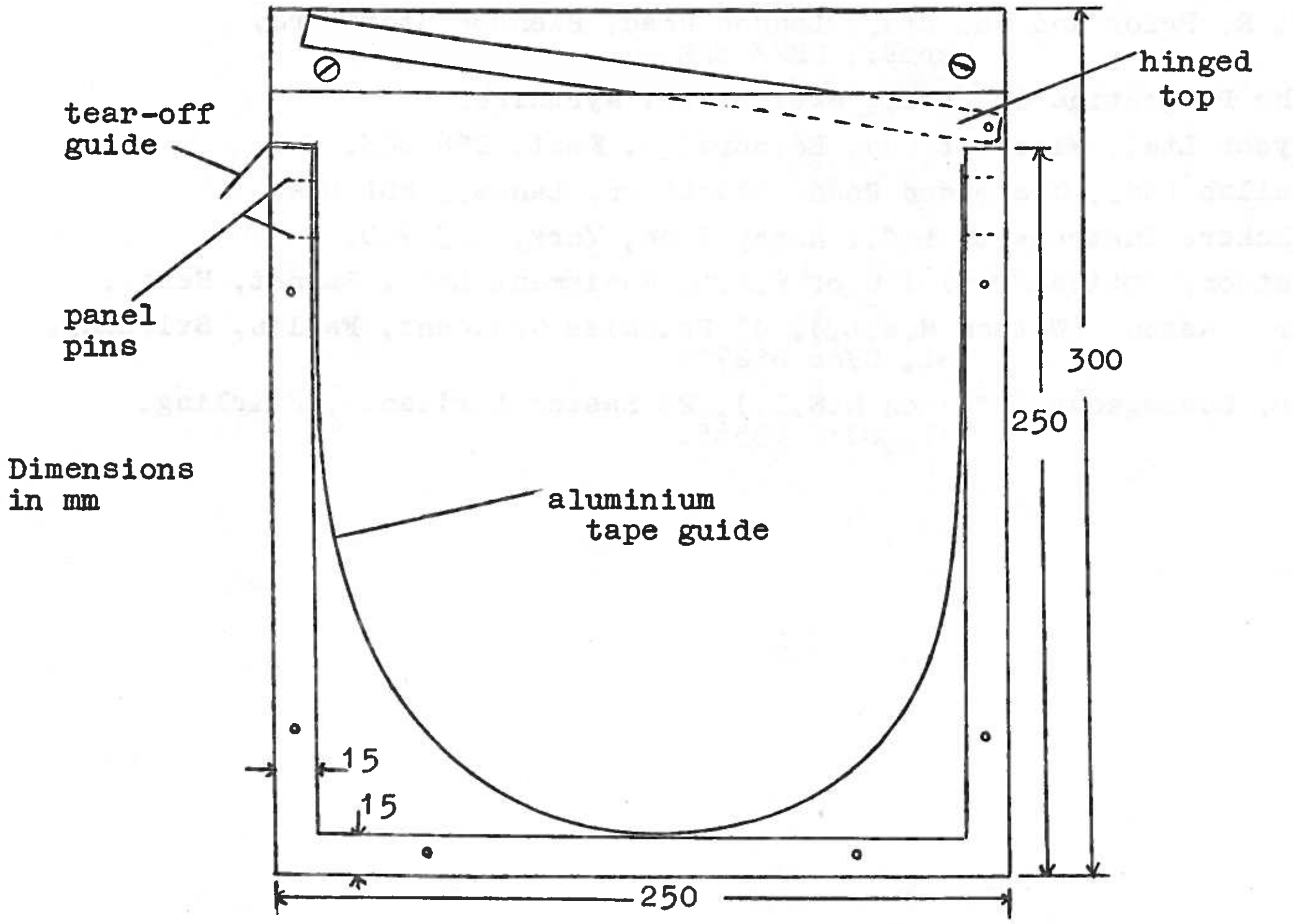
The idea for this apparatus originated in John Neilson High School, Paisley. It is useful in preventing tape from coming off the roll, and perhaps it also helps reduce wastage. The scale of provision must be decided by the individual teacher, but we think that two or more per physics laboratory, sited at different parts of the lab. will be necessary.

The device is simply a wall-mounted flat box carrying a roll of ticker tape, with a hinged top to allow the reel to be dropped in, and a metal guide to assist in tearing off the required length of tape. The dimensions given are for 10 mm tape width; schools using ½ in tape should increase the depth of the box in proportion.

The base, or back of the box when it is mounted, is a 30 × 25 cm piece of 12 mm thick plywood or blockboard, and has two countersunk holes for wall fixing screws near the top. The sides and bottom are lengths of 12 × 15 mm hardwood, glued to the base. The top is a similar length of hardwood, hinged at one end by a single wood screw fixing it to the base. Sufficient clearance must be left between the top and the side of the box to allow the hinge to operate. The cover or front face of the box is a 25 × 27 cm piece of either perspex sheet or hardboard; six wood screws are used to secure it to bottom and sides of the box. Although more expensive, perspex allows the content to be seen at a glance, so that a fresh reel may be made ready to replace one nearly finished.

A tape guide is made from a 10 mm wide strip of 16 s.w.g. aluminium about 66 cm long. It is bent roughly into a U shape and pinned to both sides of the box with two small panel pins. At the side opposite the hinge, the tape guide is bent over and protrudes about 2 cm to give a tear-off edge for detaching the required length of tape.

It will be seen that the perspex top overlaps the hinge; this is done so that the friction between them will keep the hinge firmly in place when tape is being pulled off. Otherwise it is possible that the reel could force its way out of the box. Secondly if there is a wide gap where the tape exits there may be a tendency for the short length left after tear-off to drop back inside the box.



S.S.S.E.R.C., 103 Broughton Street, Edinburgh, EH1 3RZ.
Tel. 031 556 2184.

Adlab Ltd., P.O. Box 1, Farnworth, Bolton, Lancs., BL4 7SN.

Amberol Ltd., Railway Wharf, Derby Road, Belper, Derby, DE5 1UX.

Asschem, Redding Industrial Estate, Redding, Falkirk.

Baird and Tatlock Ltd., Freshwater Road, Chadwell Heath, Essex.

Bi-pak Semiconductors, The Maltings, 63a High Street, Ware, Herts., SG12 9AD.

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

Philip Harris Ltd., 30 Carron Place, Kelvin Industrial Estate, East Kilbride, Glasgow G75 OTL.

Gordon Keeble Laboratory Products Ltd., 8a Chapel Street, Duxford, Cambridge, CB2 4RJ.

Mackinnon and Hay, 3 Warriston Road, Edinburgh, EH3 5LQ.

G. F. Milward, 369 Alum Rock Road, Birmingham, B8 3DR.

W. R. Prior and Co. Ltd., London Road, Bishops Stortford, Herts., CM23 5NB.

The Projectina Co. Ltd., Skelmorlie, Ayrshire.

Pyser Ltd., Fircroft Way, Edenbridge, Kent, TN8 6HE.

Unilab Ltd., Clarendon Road, Blackburn, Lancs., BB1 9TA.

Vickers Instruments Ltd., Haxby Road, York, YO3 7SD.

Watson, Optical Division of M.E.L. Equipment Ltd., Barnet, Herts.

Mr. Easson, (Watson M.E.L.), 35 Polmaise Crescent, Fallin, Stirling.
Tel. 0786 812795.

Mr. Scrimgeour, (Watson M.E.L.), 25 Easter Livilands, Stirling.
Tel. 0786 63585.