SCOTTISH SCHOOLS SCIENCE

EQUIPMENT RESEARCH

CENTRE

Bulletin No. 75. November, 1974.

Contents

Introduction

We mentioned in Bulletin 73 the debt we owed to teachers and technicians for supplying the majority of ideas which made up our exhibition at Didacta. What is true for a special occasion like the Brussels exhibition remains true throughout the year. We are indeed very dependent upon, and very grateful for, a flow of ideas for science apparatus from these sources. Perhaps the most important function performed by the bulletin is the dissemination of such ideas. We want to appeal therefore to teachers - not just principal teachers, but assistant and student teachers - and to technicians, and not only senior technicians, to send us any suggestion or design which helps them in their work. They need not be sophisticated, with precise engineering drawings. Some of the best ideas are simple; some may have been used for many years by a teacher, who may not be aware that his idea is not generally known.

We test every idea suggested to us, and only when it has been properly validated will we publish it, with acknowledgment as to the source. Occasionally an idea does not get published, if we feel we have already published a better one. It sometimes happens, and we believe on too few occasions, that the publication of an idea leads to a suggestion for improving it. We wish that more people who on seeing something in a bulletin say to themselves 'I've got a better idea than that', would write and tell us what it is. We are only too pleased to publish such improvements, one of our reasons being that we want to dispel any idea there may be that SSSERC are the experts, whose word on anything must be final. SSSERC is a service to science teaching in Scotland; it can be made a better service through the contributions of the teachers themselves.

One aspect of such information flow needs to be stressed. Over four years ago, in Bulletin 40, we asked to be given an account of any accident occurring in a science department, solely so that we could publish as much factual information as possible in hope of preventing a similar occurrence. Since that time a generation of science teachers has entered the profession and perhaps been promoted out of it, so that we need no excuse for repeating the plea. As we said in the earlier bulletin, the school where the accident took place need not be named, and all information on location etc., will be confidential. We do need a name and address to which we can refer for further information if necessary.

One final word to overseas readers. If you believe that all the above is directed only to Scottish teachers, this is not so. There must be as many good ideas, and perhaps as many accidents in schools furth of Scotland as there are inside it. If you derive any benefit from the bulletins, perhaps you should consider whether you owe us this small return.

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The Centre will be closed on 25th and 26th December, and on January 1st and 2nd, 1975.

Opinion

What are flameproof cabinets made of?
Concrete or brick,
Three inches thick,
That's what flameproof cupboards are made of.

What are flameproof cabinets made of?
Iron and steel,
Cold to the feel,
That's what flameproof cupboards are made of.

What are flameproof cabinets made of?
Asbestos and wood,
Are both very good,
That's what flameproof cupboards are made of.

With apologies to all who think that safety in science departments is not a subject for levity, we believe that perhaps the above jingle puts quite succinctly the controversy surrounding the storage of flammable chemicals. One has to distinguish two situations, the laboratory and the store. It is not convenient, nor realistic, to ban all flammable chemicals from being kept in the laboratory. It is doubtful even whether it is safer to insist that they be carried to and from the store for every lesson. It increases the risk that the technician may be mown down by the rush of the Fourth Remove in the corridor, while carrying the bottles, and that a surreptitious 'drag' sets the whole alight. It is still possible to take sensible precautions for storing flammables in the laboratory. Only small quantities - 250 ml reagent bottles or less - should be kept, when not actually in use, in a wooden or glass fronted cupboard, not on the open shelves. Also the cupboard should be sited away from the exit doors.

The next best proposition, and obviously more expensive, for storage in the laboratory is a properly constructed cabinet having gauze-covered ventilation slats, and a spillage tray with capacity greater than that of all the bottles to be stored. Again, it will be safer if these ventilators do not open into the laboratory itself, but into a corridor, or through an outside wall. We are now approaching a counsel of perfection applicable only to new schools and laboratories about to be built. For existing schools, it may be an adequate fire prevention compromise to store small quantities in a lockfast cupboard away from any exits. Careful consideration still needs to be given to the materials used in constructing the cupboard. Laboratories - and store-rooms - with underfloor heating are a special hazard, and cabinets must be raised off the floor or otherwise heat-insulated.

Central storage is a more difficult problem. The quantities to be stored are greater, probably 2½ litre Winchester bottles. A brick or concrete cabinet entirely outside the school, which could be a lean-to on an outside wall, is probably safest, although a high vandal risk. Ventilator gauzes should be as inaccessible as can be, lest the vandals burn matches or stuff lighted paper against them.

The preceding paragraph highlights another aspect of central storage, that of fire protection. If a fire establishes itself in the area outside a cabinet, how long will staff and pupils have to get clear before the contents ignite, perhaps with explosive force? In this respect, wood alone, asbestos-lined wood, or a wood-plasterboard sandwich all have a greater fire resistance than metal alone, because of its thermal conductivity. A crude order-of-magnitude calculation will show what can be expected of a metal cabinet.

We have examined one such, intended to store up to 60 litres of flammable liquids. It weighs about 90 kg, and its thermal capacity can be calculated at 41 kJ per degree. The auto-ignition point of diethyl ether is 180 °C. If the inside temperature is 20 °C, it means that the cabinet must absorb 6560 kJ before any ether inside will reach ignition temperature.

A bunsen burner heating a beaker of water over wire gauze requires about 10 minutes to bring 800 ml of cold water to the boil. The same rate of heat absorption applied to the cabinet would need four hours to ignite the ether. But few fires remain at single burner intensity as they develop. In the case of the beaker, if we assume all the heat absorption is over the base area of the beaker, and apply that rate of absorption to all four vertical sides of the cabinet, then the time to reach the auto-ignition point of ether would be ten seconds. If the cabinet contained carbon disulphide, these times would be halved. Obviously in the real situation the actual fire resistance time would be somewhere between these two extremes. But we would think it likely to be nearer the 10 s, than the 4 hours. Wood, by comparison has a fire resistance greater than metal.

A test on a wooden cupboard was carried out by the <u>Fire Research</u> Station in 1971. The cupboard was constructed from 17 mm block-board, and measured approximately 40 × 40 × 70 cm. Amongst other substances in the cupboard for the test were a 250 ml bottle containing petrol and a similar one of diethyl ether. Thermo-couples were used to record temperatures at various places. The cupboard was placed in a tray 130 cm diameter into which 10 gallons of paraffin and a little petrol for ignition was poured. The fire reached its full intensity in 2-3 minutes and a water spray was used after 10 minutes to extinguish it.

Depending on the position inside the cupboard, air temperatures reached a peak of between 200 and 400 °C seven minutes after ignition, although a Winchester on the bottom gave a maximum temperature of about 45 °C. 20% of the petrol and 50% ether had vaporised, but this did not result in fire or explosion inside the cupboard, although the quantity evaporated was sufficient to form an explosive atmosphere. Possible reasons for this are that the release of vapour was at such a rate that an explosive concentration did not occur, or that the oxygen content of the cupboard had been sufficiently depleted. So, if you do succeed in quelling a fire around your store cupboard, do not be in too much of a hurry to examine its interior. It would be a pity to be blasted into hospital through opening the door before everything had sufficiently cooled. We are awaiting the results of a similar test on a steel cupboard.

Biology Notes

Estimates of the rate of human breathing before and after exercise can be made very simply using a stopwatch and direct observation. However many teachers would probably agree that at 'H' grade and SYS level a more sophisticated and reliably quantitative method is required. Two different types of commercially available apparatus can be used which both require a kymograph type of recorder for their operation. They are the 'water-bath' spirometer and the mechanical stethograph and tambour. Kymographs can be very useful and for some purposes, e.g. nerve-muscle preparation work, there is as yet, no substitute for them. However, unless one envisages their use for such work, it is difficult to justify their purchase. Often the recorder part of the apparatus cannot be obtained unless one also buys the stimulator. In our view, a kymograph is a fairly specialised piece of apparatus. In contrast a pen recorder can be put to a very great number of uses in more than one branch of science. It can be used wherever the parameter one wishes to measure and record can be translated into an electrical form. There are several pen recorders now on the market whose cost compares favourably with that of a kymograph.

The piece of apparatus described below is a modification of the traditional stethograph and tambour in which the mechanical lever and pen method of producing a record has been replaced by an electrical arrangement. The stethograph can be a commercial one which tends to be of the 'hose and chain' type or the home-made version shown below using an almost complete circle of corrugated breathing hose. This hose, 22mm o.d., catalogue No. 825-08 is available in 28" lengths from Sub Aqua Products at 60p per pair. The stethograph is completed by a 10cm length of brass or copper tube, 25mm o.d., to which both ends of the breathing hose are attached and can be wired on if this be thought necessary to make it airtight. The outlet from the ring is a 30mm length of copper tube, 7mm dia., soldered to the middle of the wide tube. The ring so formed is worn round the subject's chest, and chest movements during breathing are translated into pressure changes in the ring. The tambour is made from any suitable metal can about 30mm dia.; its length is immaterial. We used an aluminium one which had contained a dosimeter; these can be supplied from the centre for 5p which includes postage. However a large cigar tube, or one of the type used to contain medical tablets would be just as effective, provided it is of metal or rigid plastic. A 20mm hole is drilled centrally out of the base, and the top is fitted with a one-hole rubber stopper carrying a short length of glass tube for connection. A piece of balloon rubber is stretched over the hole in the base and taped all round the sides of the can, using plastic insulating tape. It is essential that the joins are everywhere airtight, as it is the movement of the rubber diaphragm due to pressure changes in the breathing hose which make the device effective.

The sensor is a strain gauge, type W16/100/G/C/3 from Tinsley Telcon which costs £1.25. Essentially this is a zig-zag of fine wire, attached to thin backing material and covered for protection so that it resembles thin foil. The gauge is stuck with Evostik on to the stretched balloon rubber. It should be left overnight and preferably longer to allow the adhesive to dry thoroughly. When the rubber distorts, bulging either convex or concave, the gauge is similarly stretched or compressed, and the resistance of the wire changes. It is this change which constitutes the active principle of the tambour.

The electrical side of the apparatus is shown in Fig. 3. The gauge, which has a nominal resistance of 100Ω, is in one arm of a Wheatstone bridge circuit, the other bridge resistances being standard resistors from R.S. Components. Originally we had a second strain gauge in the bridge for temperature compensation, but we found it to be unnecessary. The 10Ω potentiometer, shunted by 1Ω which can either be bought from R.S. Components or made up as described on page 10 of this bulletin, is used to set zero on the bridge.

The amount of p.d. variation produced by the potentiometer is less than 1mV, as it has to be if one is to achieve fine control of the bridge balance to set the position of the ammeter and/or pen recorder. This means that it is highly unlikely that when first wired up the bridge will be in balance or within the limits achievable by the potentiometer, because of variation in individual resistance values. To get balance, we suggest the following method of trial and error. Connect up the circuit of Fig. 3 with the d.c. amplifier connected to a 10mA meter and the gain set to maximum. Verify that when the amplifier input is short circuited, the meter is at or near zero; if not, make this adjustment on the amplifier control. Connect the bridge circuit to the amplifier, with the bridge components accessible. Because of imbalance the meter pointer will be against its stop either at zero or full scale. Take a 1kΩ resistor and hold it so that it is in parallel with the 100Ω resistor. If the meter does not show any change, repeat with the 1kΩ shunting the strain gauge. In one of these two positions the meter will deflect to the other end of the scale because the imbalance has swung the other way. Now proceed to try resistance values greater than 1kΩ, shunting across the component which has shown the imbalance swing, until one reaches a value which allows the bridge to be balanced, using the 10Ω control. This resistor should then be soldered permanently into position. The assembly of the bridge components should not present any difficulty. Ours were soldered to a piece of tagboard mounted inside a plastic box to which the potentiometer and two pairs of terminals, colour-coded red and black, are fitted. The terminals are marked 'Battery' and 'Output'. The tambour was fixed to the top of the plastic box using two Terry clips, although if a small can were used for the tambour one clip would be sufficient. Leads to the strain gauge pass through two holes in the box top. The balloon rubber may perish in time, but with care the gauge can be removed and fixed to a new membrane.

The reason for colour coding terminals is to get a consistent deflection sense. We chose to correlate a positive meter deflection with inhalation, which also corresponds to reduced pressure in the stethograph and consequently a concave membrane. A popular way of checking the operation of the apparatus when the stethograph is not being worn is to squeeze the breathing hose, which should give a negative deflection of the meter.

Preliminary adjustments of the apparatus are as follows. A 1mA demonstration meter, or the pen recorder, is set to centre zero. The d.c. amplifier with its input shorted, and gain set at or near maximum, is similarly set to zero. The subject puts on the stethograph, and the tap is turned through all three positions once or twice to equalise pressures within the apparatus. Then the tambour is isolated from the rest of the apparatus by the tap, the battery to the bridge circuit is connected in, and the bridge potentiometer set to zero. The stethograph and tambour are now connected and the subject is asked to inhale fully and hold his breath. The amplifier gain is adjusted to give a deflection at or near maximum, and the apparatus is now ready for use. The adjustments are aided by asking the subject to inhale and exhale fully several times, which will give the operator an idea of the range of movement of meter and/or recorder pen to be expected, and these adjustments should be confined to the bridge potentiometer and the amplifier gain controls. There will be some drift in the circuit as the gauge warms up due to the current in it, and the makers allow for this by recommending that the circuit be switched on for 30 minutes before use. We found that after the first ten minutes drift was negligible.

The subject is asked to sit quietly with his/her back to the apparatus and given sufficient time to relax. He can be given a book to read as an aid to relaxation. When the movement of the pen has settled down to a reasonable rhythm the chart can be started and a record of the relaxed breathing obtained. The effect of breathing re-breathed air can then be investigated by asking the subject to breathe in and out of a plastic bag for several breaths. The stethograph can be disconnected using the tap, or the chart recorder switched off during this time. The subject is then told to 'breathe away' and record of the new rate and depth of breathing obtained. That the differences seen are due to an effect on the body of an increased carbon-dioxide content and not a reduced oxygen content can be simply demonstrated. The subject is asked to breathe air for several breaths from a plastic bag which has had a <u>small trace</u> of carbon dioxide added to it from a cylinder. This produces a similar effect to rebreathing ordinary air but with a greater magnitude. The effects of exercise can be measured by disconnecting the stethograph by switching the 3-way tap and asking the subject to do step-ups on to a stool-bar or low bench. If the subject is disconnected completely by removing the rubber tube from the stethograph, he can run up and down stairs etc., with the stethograph on and be 'plugged in' and a record obtained immediately on his return.

The records shown below were obtained on the CR500 chart recorder by <u>Educational Measurements</u>, chart speed 2mm/s and range 100mV. While checking the tambour for airtightness, we discovered by accident that the air speed indicator, which we described in Bulletin 59, and of which we still have a few left, is sufficiently sensitive to respond to normal breathing. If the school has a number of these, and we know that they have been bought in quantity by physics departments, then the experiments described can be done on a pupil scale. All that is required is a stethograph ring as constructed above, an indicator, rubber tubing to connect the two and perhaps a stopwatch to measure breathing rate. If a three-way tap is also used, the pressure in the system can be raised slightly, as this brings the indicator pointer on to the scale and allows quantitative indications of depth of breathing which are almost as good as those shown by the electrical system with demonstration meter, as described above.

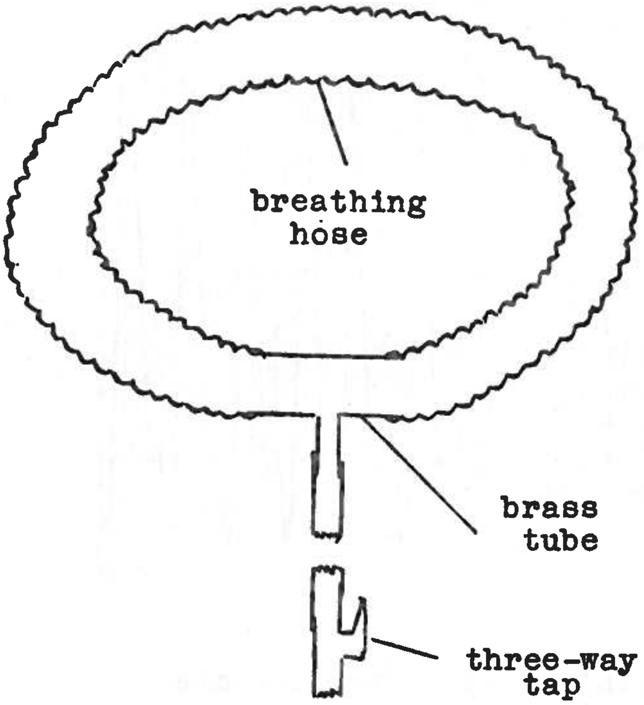


Fig. 1. Stethograph

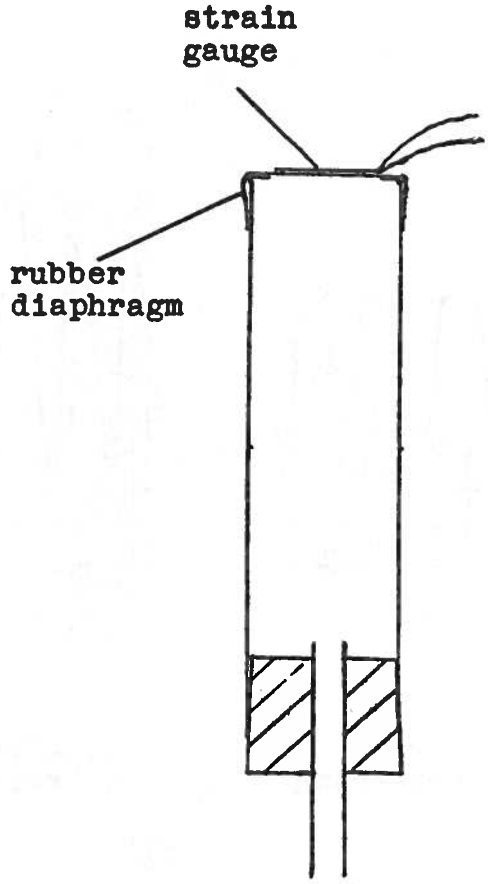


Fig. 2. Tambour

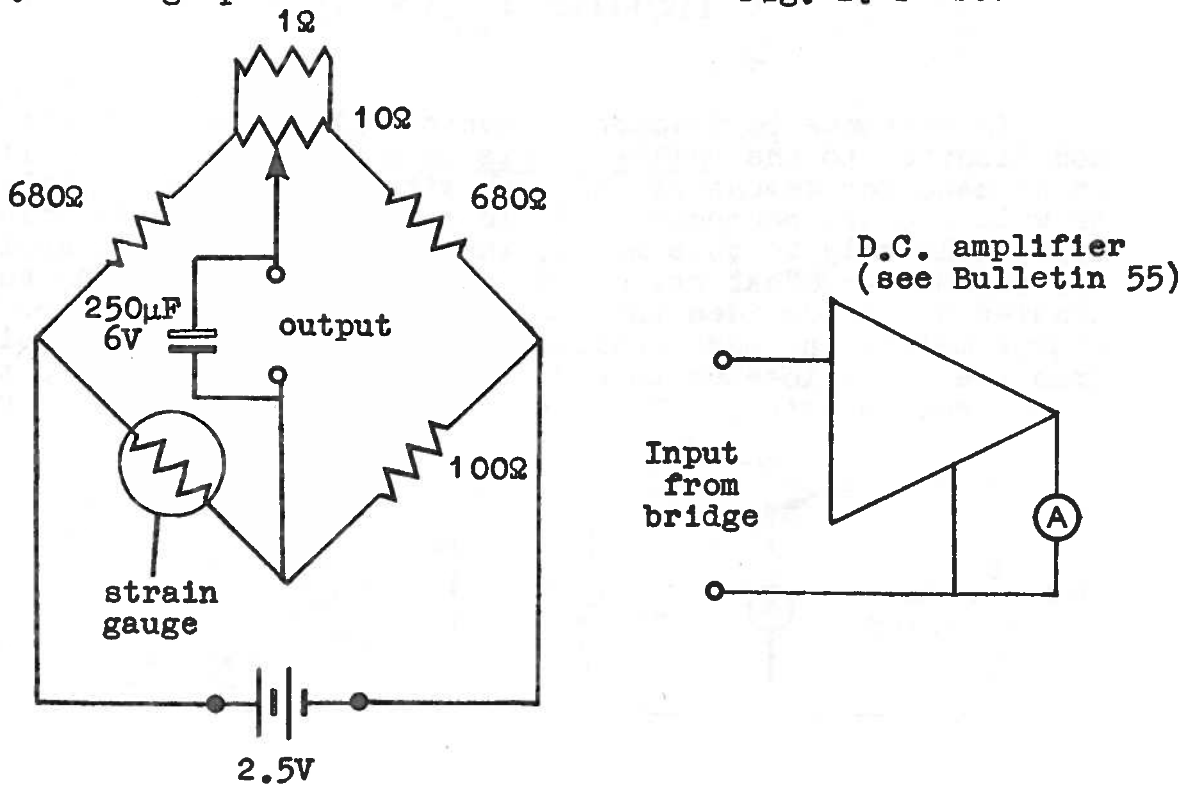
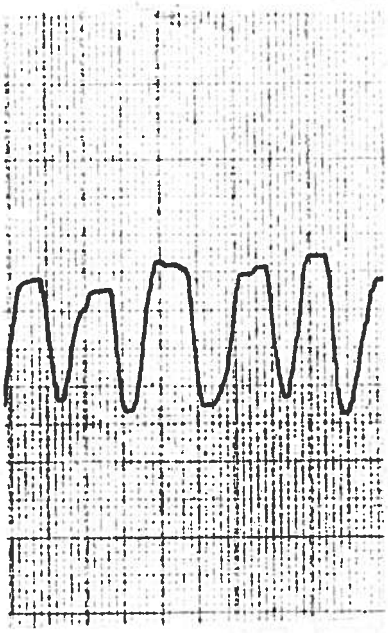
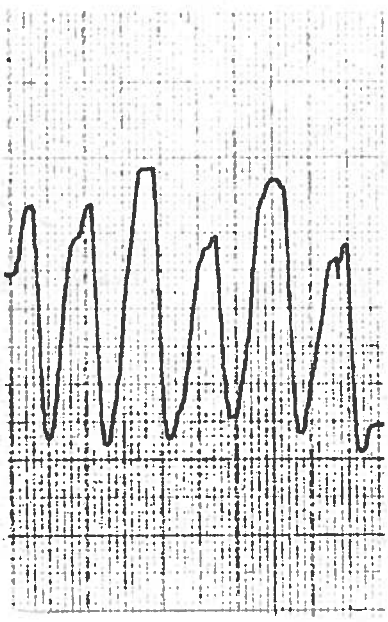


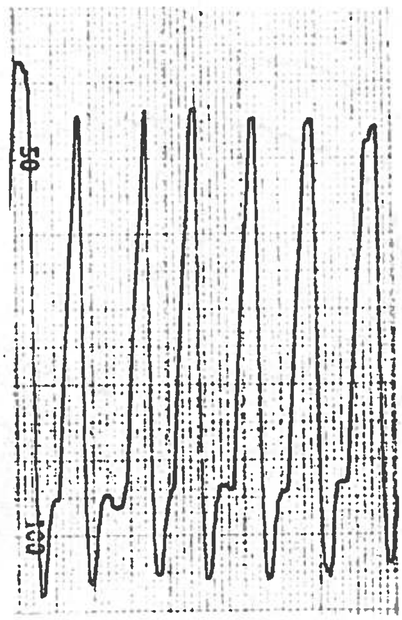
Fig. 3. Bridge circuit



1. Normal breathing



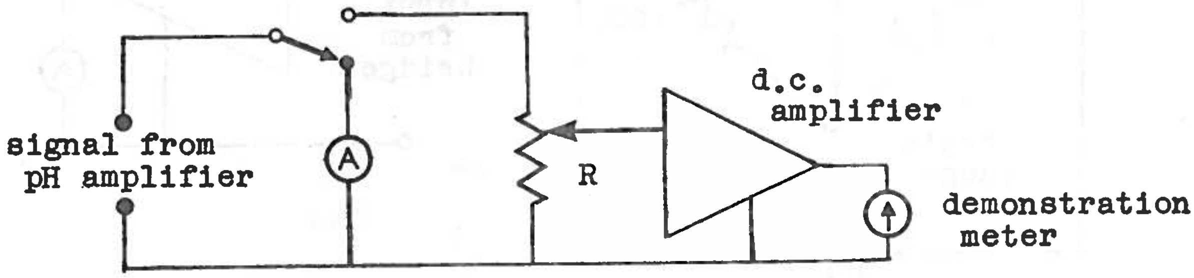
2. After breathing rebreathed air



3. After exercise.

Chemistry Notes

In response to teacher requests we have made a small modification to the Philip Harris pH meter B5160/1, to allow it to be used for demonstration work with a large-scale milliammeter, or with a chart recorder. While the method to be described is applicable only to this model, the principle could be applied to any pH meter. That principle is to replace the moving coil ammeter which provides the read-out, with a potentiometer having approximately the same resistance and to apply the variable p.d. from the potentiometer to a d.c. amplifier and thence to the demonstration meter. The basic arrangement is shown in Fig.1.

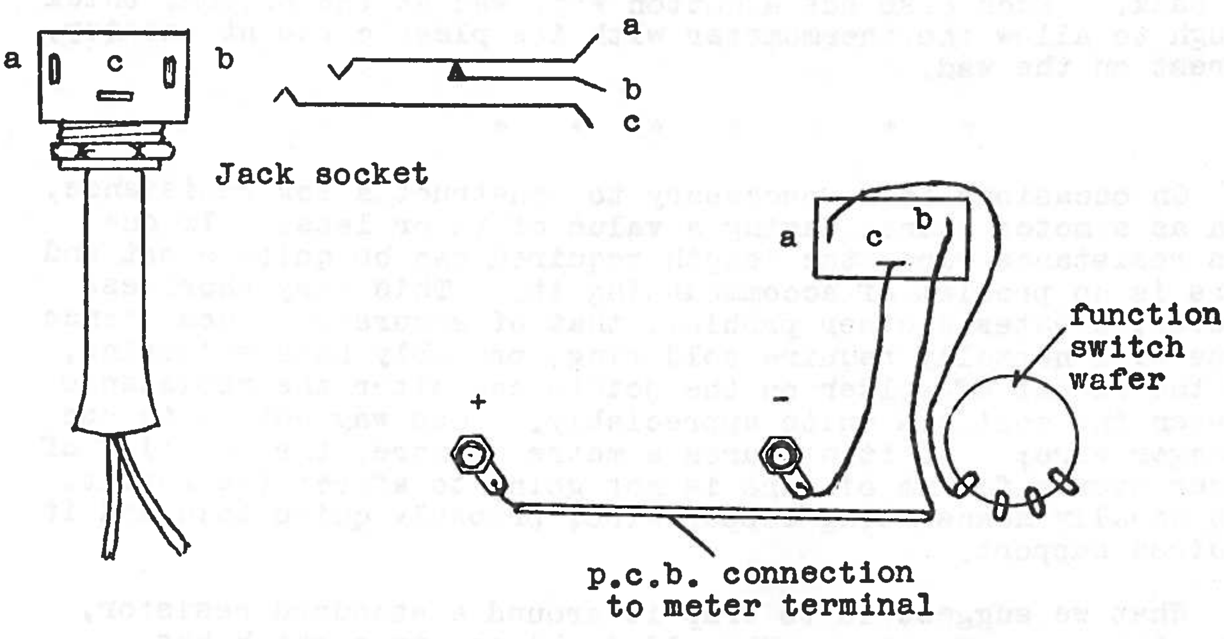


A is the read-out ammeter in the instrument; the switch and all components to the right have to be applied externally.

For the Harris meter, a hole to fit a R.S. Components sub-miniature jack socket is made in the front panel in any position where there is room, and it does not interfere with the labelling; in our case, near the input millivolt terminals. The sub-miniature jack has a pair of normally closed contacts which are separated on insertion of the jack plug, and this provides the necessary switch action. One of these contacts is connected to the centre pin of the jack plug when this is inserted. A separate third socket connects to the other terminal of the jack plug.

The meter resistance was 960Ω, so we used a 1kΩ potentiometer. The printed circuit board on which most of the components are mounted is bolted to the meter terminals. The positive terminal of the meter is connected through a strip of p.c.b. laminate and a short length of wire to one terminal of the function switch wafer. The circuit is broken at this length of wire, and both parts connected with plastic covered wire to pins a and b of the jack socket. The third pin c of the socket is similarly wired to the negative meter terminal. The circuit diagram of the socket in Fig. 2 shows that when the plug is inserted a is parted from b, isolating the instrument meter, and applying the signal to terminal a. The leads from the jack plug go to a 1kΩ linear wirewound potentiometer and thence as in Fig. 1 to a d.c. amplifier, which can be the Harris "black box", P8067/25, or the SSSERC amplifier as described in Bulletin 55, a version of which is obtainable from <u>Fortronic</u>. The output from the amplifier can be applied to either a 1mA or 10mA demonstration meter.

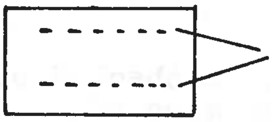
To operate, the pH meter should first be checked by itself, using buffering solutions differing by 2 or more pH. The meter amplifier is then switched on and the zero set, the 1kΩ potentiometer is set to approximately half-way position and the jack plug inserted. Using the same buffer solutions, the potentiometer and amplifier gain controls can then be set to get the required pH range on the meter. By using these controls and the amplifier zero set control we found it possible to have the meter read 2 - 10 pH or to expand the scale so that from zero to f.s.d. corresponded to 1 pH change. For the expanded range the control settings are more critical, particularly if a 10mA demonstration meter is being used and they may be difficult to set accurately.

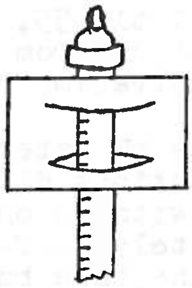


Physics Notes

After several teachers had complained to us about thermometer breakages, principally due to their rolling off benches, we wrote to Philip Harris and Griffin and George asking if anything could be done. Both replies said much the same, that thermometers were mass produced, and that there was little hope of persuading the manufacturers to modify a design which was intended for insertion into a round hole, so that it would not roll off the bench.

One of the complainants, in Liberton High School, has solved the problem by making small plastic tabs which fit over the thermometer. The tabs are cut from plastic detergent bottles, 15 x 30mm, and two knife cuts 20mm long are made lengthwise (see sketch). The thermometer fits into the tab, which does not interfere with the use of the thermometer and in fact can be an aid to younger pupils in reading it. To stop the tabs being pulled off the top and lost, we have fitted a band of rubber tubing at the top of the thermometer.





An associated idea from the Berwickshire High School prevents that other source of breakage, dropping through the thermometer case. It is to drill holes halfway into a wood block, 20mm thick, to act as a stand for the cases, in the same way that pencils are sometimes stored upright. The rack can be either free-standing on the bench, or fixed to the wall with a piece of hardboard at the back. Each case has a cotton wool wad at the bottom, thick enough to allow the thermometer with its plastic tab at the top, to rest on the wad.

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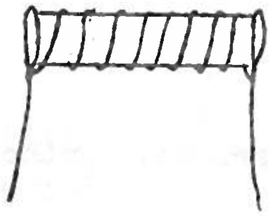
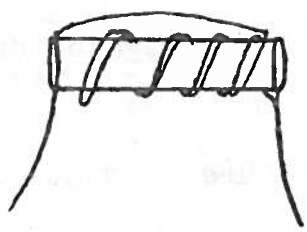
On occasions it is necessary to construct a low resistance, such as a meter shunt, having a value of 1Ω or less. If one uses resistance wire, the length required can be quite short and there is no problem of accommodating it. This very shortness however, creates another problem, that of accuracy. Resistance wires will normally require soldering, probably hard soldering, and the amount of solder on the joints can alter the resistance between the contacts quite appreciably. One way out is to use a longer wire; if it measures a metre or more, the position of solder over a few mm of wire is not going to affect the result. This usually means using copper wire, probably quite thin and it requires support.

What we suggest is to wrap it around a standard resistor, using this as a former. The old fashioned type which has 'shoulders' of connecting wire at each end (see sketch) is ideal for this purpose. The shoulders prevent the wire from peeling off the ends, with no need to secure the turns with adhesive. The ends of the wire are soldered to the resistor leads; if the resistor has a value of 100Ω or greater it will not appreciably shunt the low resistance.





non-inductive winding

It is true that as constructed the 'resistor' will have some inductance, although there will be few instances in a school situation where this will introduce a significant error. If it is thought likely, the wire can always be wound non-inductively, by doubling it along its length, and then winding on the 'former'. In this case the end loop of wire would need to be secured.

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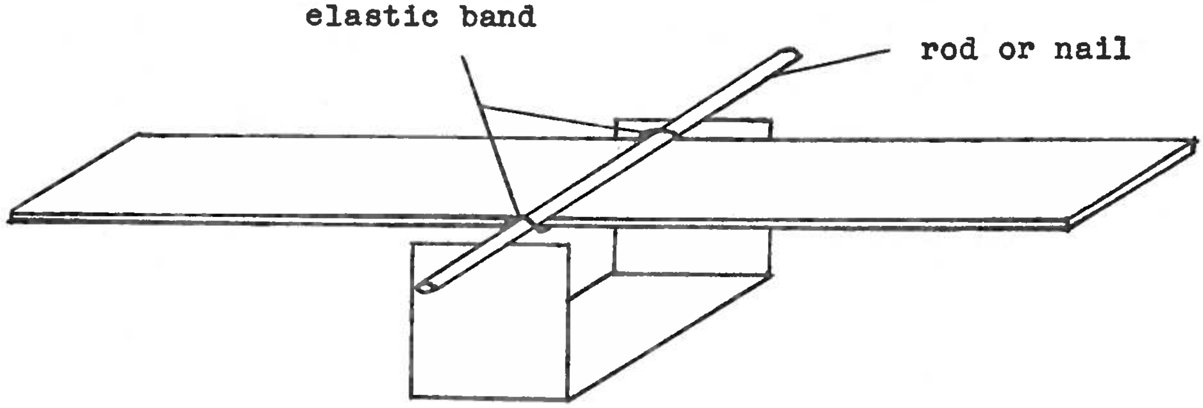
The apparatus for investigating the simple lever law, used in Nuffield and our own Integrated Science course suffers from one practical disadvantage which pupils find difficult, that of instability. The fulcrum is a wedge, on top of which is placed a straight lever, which in turn supports the 'weights'. The centre of gravity of this system is of necessity above the fulcrum, and one hopes that friction will allow the apparatus to balance. The idea sketched below reached us from Trinity College, Glenalmond, is stable, and can be made up from material already in school. The elastic band passes over the nail and under the lever at each side. The U support is obtained from the yoke of the Westminster electro-magnetic kit or can be bent up from sheet aluminium.



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

Educational Measurements Ltd., 1 Brook Avenue, Warsash, Southampton, SO3 6HP.

Fire Research Station, Borehamwood, Herts.

Fortronic Ltd., 13 Knowehead Road, Crossford, Fife.

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.

R.S. Components Ltd., P.O. Box 427, 13-17 Epworth Street, London, EC2P 2HA.

Sub-Aqua Products Ltd., 63-65 Twyford Road, Eastleigh, Hants, SO5 4ZG.

Tinsley Telcon Ltd., Werndee Hall, South Norwood, London SE25.