SCOTTISH SCHOOLS SCIENCE

EQUIPMENT RESEARCH

CENTRE

Bulletin No. 34. November, 1969.

Contents

Introduction

At the last meeting of the Governing Body, Councillor Melville Dinwiddie, who has been Chairman since SSSERC began four years ago, announced his resignation owing to his forthcoming retirement. Councillor Dinwiddie has taken more than a layman's interest in the activities of SSSERC, visiting us often, suggesting persons or organisations who could assist us to solve specific difficulties and recommending visits to this or that institution. We know from his comments that he is one the most assiduous readers of this Bulletin. We shall miss his influence and his shrewd but kindly comments. The staff at the Centre, the Development Committee and I am sure his colleagues on the Governing Body desire now to thank him for past services, always generously given, and to wish him a long and happy retirement.

Opinion

In the past, the balance has been looked upon as a piece of science furniture, stationary and immobile. In some quarters even, it was the lares et penates of the science room, to touch which without permission meant instant expulsion. When balances emerged from their glass cases, some of this worshipful attitude disappeared but too many teachers still look on their balance as something which must never be moved, far less lifted for dusting under each day.

With the introduction of the top pan balance, there is a need for teachers to re-examine their attitude to balance use. Top pan balances are more expensive than their equivalent constant-load balance, but they are faster in operation and an advantage which is rarely considered is their mobility. Top-pans are locked by a single clamping screw which admittedly in some models such as Oertling and Mettler (A. Gallenkamp) need a fair amount of turning. The Sartorious 2250 series (Philip Harris) is locked by a quarter turn clamp, and a single click position of the weight knob, requiring no more than a second to immobilise the balance. On all models, however, it should require no more than five seconds to immobilise the balance to the point where it can be uplifted and carried - or wheeled on a trolley - from one room to another. On arrival at the new position, it will require slightly longer to set the balance up, due to the need to re-level.

Seen in this light, the top-pan balance becomes highly competitive as regards price with its constant-load sister. A top-pan costing £160, but serving the needs of two laboratories, is better value than a fixed installation single pan balance costing £100. It is better economics too, since it gives the balance a chance to wear out, rather than fade out through obsolescence. I still hear of new schools being built and supplied with 10 double pan beam balances per science room. The first new broom to enter these schools will sweep away perfectly good but obsolete balances of value only as scrap brass since manufacturers will not accept them on an exchange basis.

With central store facilities, and technical help, a school of five laboratories might work on three top pan balances. Not all would be the same model, since in general physics and biology/

biology require a higher capacity balance than does chemistry. Finally there is a psychological advantage. The technician can rejoice in the responsibility which the care and maintenance of a complex piece of apparatus brings to him, and it makes a nice change from writing bottle labels.

Chemistry Notes

Many teachers in the West of Scotland will have known that they could obtain copies of infra-red spectrographs for use with Section 4 of the Certificate of Sixth Year Studies in Chemistry from Strathclyde University. As long as this knowledge remained regional there was no reason to suppose that the University would be prepared to supply spectrographs on a national scale, but with the publication of a recent article in Education in Chemistry (1), the picture has changed somewhat as this obviously gave a wide publicity to the service. On enquiry we learned that the University were prepared to produce sufficient copies to meet the probable demand, provided SSSERC undertook their distribution. This we have agreed to do under the same conditions as the University, viz. at a cost of 2s. per copy.

The material comprises an 11 page explanatory booklet, and 14 spectrographs as follows:

1. Water
2. Heavy water
3. Potassium cyanide dispensed as a powder in nujol
4. Potassium ferrocyanide " " " " " "
5. Potassium ferricyanide " " " " " "
6. Cyclohexane
7. Cyclohexanol
8. Cyclohexanone
9. Benzene in cyclohexane
10. Phenol in cyclohexane
11. Phenol in hydrochloric acid
12. Phenol in sodium hydroxide
13. Phenol phthalein in acid and basic solutions
14. Cobalt (II) chloride in water and acetone

In addition, there are microdensitometer traces taken from X-ray powder diffraction photographs of sodium chloride, sodium bromide, metallic tin and mixed phase grey tin - white tin. It should be noted that there are no spectrographs of carbon dioxide, or of "paraffin and olefin for fingerprint difference" (2). Other sources of infra-red spectrographs are given in the references below (3, 4).

References:

1. Introducing Spectroscopy to Schools, Dr. R.H. Nuttall, Vol. 6, No. 5.

2./

2. Certificate of Sixth Year Studies, 1969, S.C.E.E.B.
3. The Physics of Chemical Structure, Unilever.
4. Workshop Introduction to Chemical Spectroscopy, Sharp and Johnstone, Heinemann.

* * * * * *

A glance through a supplier's catalogue will show that the cheapest and therefore smallest desiccator costs about £1. To hold one sample from each pair of pupils in a class requires probably three or four desiccators, if not more. Hence an individual and cheap desiccator may be an advantage in a laboratory, if only for the reason that if one lid is not properly closed, only one experiment is spoiled.

We bought two plastic lunch boxes, 500ml size, at 2s. each from local ironmongers, of the type which has a sealed lid which is pressed down all round the rim. In both we put a 15mm deep layer of silica gel and left one with the lid off, the other being closed. They were weighed daily. In nine days, the gel in the desiccator had increased in mass by 0.15% and that in the control by 19%. The actual gain in mass in the desiccator was 130mg. These boxes are therefore an efficient means of preventing the movement of air between inside and outside.

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In the supplement to our last Bulletin, No. 33, we gave details of the running speeds of the centrifuges we had tested. Due to a clerical error, the speeds for lid open and lid closed were transposed; in all cases the greater speed is that obtained when the lid is closed.

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In Bulletin 33 we omitted to give in the list of SSSERC reports on balances the Oertling Model R10, which has also been tested by us.

Display Laboratory

The following items have been added to the display laboratory since this item was last included in Bulletin 31.

Item	Manufacturer
Constant Current Source	SSSERC
Brownian Motion Model	SSSERC
Ring Main Model	SSSERC
Centre of Gravity Model	SSSERC
Free Fall Apparatus	SSSERC
Orbital Models Cutting Jig	SSSERC
Pipette Filler	SSSERC
Nim Playing Machine	SSSERC
A.S.A. Microscope	Leech
Double Beam Oscilloscope	Advance
Digital-3 Balance	Griffin and George

Colorimeter/

Colorimeter	Griffin and George
Spectrophotometer	Griffin and George
Direct Vision Spectroscope	Griffin and George
Laboratory Safety Apparatus	Griffin and George
Gas Chromatograph	Aimer
pH Meter, Model 700A	Analytical Measurements
pH Meter, Model 100	Analytical Measurements
Absorptiometer/Nephelometer	Morris
Disc Molecular Models	W.A. Benjamin
B.D.H. Compressed Gas Bottles	Macfarlane Robson
MeTeRaTe Flowmeter Tubes	Glass Precision Engineering
Overhead Projector, 3G	Ofrex

Trade News

We wrote in Bulletin 32 of the present difficulty in obtaining Japanese Mabuchi motors. The latest Proops Brothers catalogue lists two types only, viz. 15R at 3 for 12s.6d., and 55 at 6s. These prices include postage. Characteristics of these types were given in Bulletin 20. Also in the catalogue is a Mohs hardness scale kit, required for Brunton topic Earth Science, at 10s.

The temporary connecting of equipment to the mains supply has too often been done with the aid of matches pushed into mains sockets, a practice which pupils should not see, let alone copy. A low-priced connector which will accept bared wire ends and couple them safely to the supply, called the Keynector, is now on the market. From Electronic Brokers, it costs £1.19s.6d.

MeTeRaTe flowmeter tubes in standard glass tubing are an inexpensive method of keeping check on the constancy of flow in gas chromatographs. They are available from Glass Precision Engineering, type DR1 in a variety of ranges from a minimum flow rate of 2 ml/min, at £2 each.

The Omal Group have introduced an overhead projector selling at an educational price of £59. Features of the projector are the N - S (or up and down) movement of the scroll, and the use of a thermostatically controlled fan which continues to run after the machine has been switched off. The lamp is a 650W tungsten-halogen type.

A stencil cutter by Gestetner, the TH4, which sells at £140, will reproduce on a stencil, from which duplicated copies may be made on any Gestetner duplicator, any printed material which has a carbon base. Thus it will copy newsprint and book material, although in the latter case single pages would have to be detached from the book. Stencils cost about 2s.3d. with reduction for quantity and are available from Block and Anderson. The TH4, which uses a thermal process, will also reproduce on transparent film for use with overhead projectors.

Advance Electronics have discontinued production of their PP15 low voltage power unit. Some teachers have asked us whether the SG65A signal generator from the firm differs in any way from the SG65 which we have included in our equipment lists. The answer is that while the circuit of the SG65A contains some small modifications, the specification of both types is the same.

In/

In Bulletin 31 we wrongly attributed the production of disposable 1 ml serological pipettes, type DP1010 and costing 6d each, to Exelo. In fact these are made by E-Mil to whom we now apologise for this error.

Edwards High Vacuum have increased the prices in their vacuum equipment. The EQ4C system comprising rotary pump, oil difussion pump with baseplate and bell jar now costs £145. The accessories kit for 20 vacuum physics experiments is now £51.10s.

Bimetallic strip for the construction of fire alarms etc. is no longer available from the International Nickel Co. which was one of the sources mentioned in item 47 of our Integrated Science Course list. We have obtained samples of several types of strip from another firm and are currently testing these. It is likely that we shall purchase a bulk quantity of a suitable strip and make it available to schools at cost plus postage.

Four new catalogues on biology, biological equipment, osteology and laboratory glassware respectively have been issued by T. Gerrard and Co. Prices are integral on three of these; the biology equipment catalogue has a separate price list.

We mentioned in Bulletin 29 the existence of an aerosol type fire extinguisher, the Sargom Baby Fireman. As a result of enquiries by some teachers, we have established that this extinguisher has not received the approval of the Fire Offices Committee which represents insurance company interests. The Fire Protection Association which is apparently a different body from the Fire Offices Committee, although they share the same address, has written to us as follows: "Our chief recommendation to anyone considering the purchase of an extinguisher is to ensure that it conforms to the appropriate British Standard Specification or is approved by the Fire Offices Committee for insurance purposes. There is at present no B.S. specification for aerosol-type extinguishers. We are not qualified to give detailed information on insurance matters and we think that the question of using these appliances is one which would have to be raised by each school with its insurance company. We think, however, that there will be no objection if these appliances are installed in addition to the recommended scale laid down by the insurance company."

Following representation by a teacher, we wrote to Teltron on the question of part exchange of any of their electron tubes which had failed either mechanically or electrically. Part of their reply is worth printing here as information to their customers. "Where such complaints arise we prefer to treat each one on its own merits, because sometimes the failure can be attributed to a manufacturing fault, in which case we usually accept full liability. On the other hand, where the failure is obviously caused by customer misuse or mishandling then we have to look into the situation a little more closely to see what kind of mutually satisfactory arrangement can be made, and to do this we require the tube to be returned, properly packed, to the works. From an analysis of the failure and other features we can decide, with a fair degree of certainty, the cause, and then we can make an offer accordingly. It is unfortunate that the cost of salvage of re-usable parts just about equals their value. More often than not where the teacher reports that he has had an accident we immediately offer a special discount off the price of a replacement tube, but we have no set rebate arrangement. We mark the tubes at the/

the time of manufacture so we know their age. We "operate" a warranty period, i.e. failures before three months are replaced free of charge, but since tubes sit in stock in supply houses often longer than this we do not adhere to this rigidly. Our aim is to be fair and we believe we succeed in this, but we have to beware of the occasional customer who is not prepared to admit his part in a failure and "tries it on."

Nim

Nim is a mathematical game for two players, well within the compass of school children and giving practice in the use of binary counting. We describe the theory here to provide a background for the Nim-playing machine which is described in the 'Workshop' section of this Bulletin. At the same time we give the Boolean algebra associated with Nim as a method of illustrating how a series of basic logic gates can be assembled to play the game.

In the game of Nim, a number of matches, counters etc. are set out in piles. There is in theory no limitation on the number of counters or piles, although here we shall confine the discussion to three piles with not more than seven counters in each. In turn, each player draws as many counters as he chooses but from one pile only. For each player, the object of the game is to draw the last counter. To analyse the game, take the simplest case where the number of counters in three piles are 1, 1 and 0 respectively. This is a winning combination for the player who set it up since the opponent can pick only one counter leaving the player to take the last one. Similarly, piles with 3, 3, 0 are a winning combination for the player. Consider the following possibilities.

(1) The opponent takes all 3 of one pile, when the player follows suit;

(2) The opponent takes 2 from one pile and the player again follows suit leaving 1, 1, 0 which was shown above to be a winning combination.

(3) The opponent takes 1 from a pile, when the player follows suit. This leaves 2, 2, 0; if the opponent then takes 2, we are back to case (1), while if the opponent takes 1, we are back to case (2).

Similarly it can be shown that 3, 2, 1 is a winning combination for the player for these reasons:

Player sets	3	2	1	3	2	1	3	2	1	3	2	1
Opp. sets	3	2	0	3	1	1	1	2	1	2	2	1
Player sets	2	2	0	0	1	1	1	0	1	2	2	0
	(case 3)			(case 2)			(case 2)			(case 3)		

<u>Binary Coding</u> On the binary scale, quantities (numbers) are represented by two digits only, 1 and 0. It will save time and explanations if we give here the binary code equivalent of the first seven natural numbers, viz:

Denary/

Denary	1	2	3	4	5	6	7
Binary	1	10	11	100	101	110	111

Because binary code uses only two digits, 1 and 0, electric circuits, the simplest of which is a switch, can be easily made to register two states, off and on, corresponding to binary 0 and 1. When the circuit is on, it can be made to light a lamp, punch a hole in a tape or print a character on a typewriter. When it is off, registering binary 0, it will do none of these things. If we take all the winning combinations for Nim given above, and write the numbers of counters in each pile in binary code, we get:

D	B	D	B	D	B	D	B	D	B
1	1	2	10	3	11	3	11	5	101
1	1	2	10	3	11	2	10	4	100
0	0	0	0	0	0	1	1	1	1

The last example has been included although not discussed above, because it is not difficult to check that whatever draw the opponent makes, the player can always reduce the combination to one of the others given alongside.

Notice now that the number of 1s in each vertical column of the binary coded quantities is even. It is this rule which makes a winning combination for the game of Nim. Thus if two piles contain 6 and 5 counters respectively, then

D	B
6	110
5	101

this can only be made even in every column by having binary 11 = 3 counters in the third pile.

It follows then that when a winning combination has been set by the player, his opponent must upset this because he is limited to drawing from one pile only. He thus disturbs the 1s and 0s in one row only of the binary table, making the numbers of 1s in some of the columns uneven. The player can then always reset a winning combination by arranging to remove counters from a pile so that the 1s in every column are again even. Suppose we start with four piles containing 7, 5, 3 and 1 counters respectively. The table below shows how a game might go, with the numbers represented in binary code, and their denary equivalent in brackets. It will be noticed that 7, 5, 3, 1 is a winning combination.

	Player	Opponent	P	O	P
A	1 1 1 (7)	1 1 0 (6)	1 1 0 (6)	1 1 (3)	1 1 (3)
B	1 0 1 (5)	1 0 1 (5)	1 0 1 (5)	1 0 1 (5)	0
C	1 1 (3)	1 1 (3)	1 0 (2)	1 0 (2)	1 0 (2)
D	1	1	1	1	1

The 3, 2, 1 state has already been shown to be a winning combination.

Boolean/

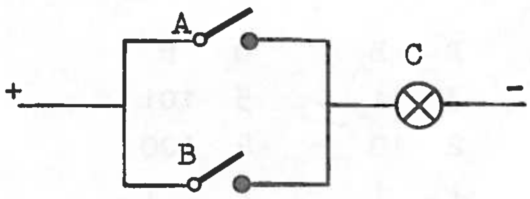
<u>Boolean Algebra</u> This deals with the two binary states, 1 and 0. The following nomenclature is used:

+ denotes an OR function

x (abbreviated as in standard algebra) denotes an AND function;

A bar thus ‾ over the top of a symbol denotes a NOT function.

For example, if we have two binary quantities, A and B, A + B = 1 is read as A or B = 1, and is true if either A = 1 or B = 1 or both = 1.



A	0	1	0	1
B	0	0	1	1
C	0	1	1	1

Truth table for Fig. 1.

Fig. 1. Circuit for A + B = C.

The electrical circuit for generating this OR function is shown in Fig. 1. Connected to a suitable supply, lamp C will light up (indicating 1) if either switches A or B or both are closed. If we accept the convention that when a switch is closed it indicates a 1, and when open indicates 0, then this circuit represents A + B = C. Alongside is the "Truth Table" for the circuit. Here we list all possible combinations of A and B settings in the first two rows, and in the C row are the resulting states of the lamp. In logic terminology the above circuit, excluding the lamp, is called a two input OR gate. Three switches in parallel would be a three input OR gate etc. The output of the circuit, i.e. before the lamp, can be used as an input to other gates and in this way binary computers are built up. If the switches are mechanical e.g. relays, their operating time is of the order of 0.1s, and the computer is slow, large and power consuming. With integrated circuit gates the switching time is of the order of 10^{-9}s, hence their advantage.

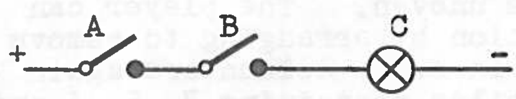
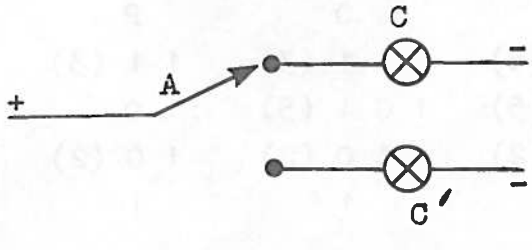


Fig. 2. AB = C

A	0	1	0	1
B	0	0	1	1
C	0	0	0	1

Truth table for Fig. 2.



A	0	1
$\bar{A}$	1	0
C	0	1
C	1	0

Fig. 3. C = A and C′ = $\bar{A}$

Truth table for Fig. 3.

In/

In a similar fashion Fig. 2 shows the circuit for an AND gate. Obviously the lamp C will light up only if switches A and B are both closed. This state is shown in the last column of the truth table. In Fig. 3 we show how a change-over switch can be used to indicate a NOT function. The NOT function is defined as the inverse of the original state, i.e. if $A = 1$, then $A = 0$ and if $A = 0$, $\bar{A} = 1$. Since a change-over switch cannot be in both positions at once and must always be in one or other position, one channel of the switch can be taken to represent the direct 'A' state, and the other will then give the inverse $\bar{A}$ state. It is a matter of convention when reading the switch to decide which position indicates $A = 1$, and which $A = 0$.

If we return now to the Nim game, the condition for setting a winning combination was that the number of binary digits in each column should be even when the counters in each pile are written in binary code. We can therefore construct a truth table showing when we require a binary digit in pile C to "balance up" the unevenness in piles A and B.

A	0	1	0	1
B	0	0	1	1
C	0	1	1	0

Truth table for Nim

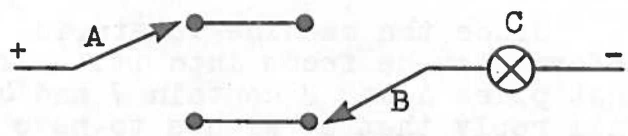


Fig. 4. Circuit for Nim, giving $C = A\bar{B} + \bar{A}B$.

The middle two columns of the truth table give the condition for pile C to contain a digit and can be read as "A, and not B" (column 2) or "not A, and B" (column 3). In Boolean algebra this is written $C = A\bar{B} + \bar{A}B$. Fig 4 shows how two change-over switches can generate this function. As drawn both switches A and B are taken to be in the OFF position, indicating 0; then if the circuit is examined, it will be seen that when either switch is thrown (i.e. $A = 1$ and $B = 0$ OR $A = 0$ and $B = 1$) the lamp C comes on but not otherwise. It is this circuit which forms the basis of the Nim machine, described elsewhere in this Bulletin.

If the reader wishes a more ambitious game than is described here, he can verify by means of a truth table that if Nim is played with counters in four piles, A, B, C and D the state of pile D for a winning combination is

$$D = A\bar{B}\bar{C} + \bar{A}B\bar{C} + \bar{A}\bar{B}C + ABC$$

which will factorize to

$$D = A\,(BC + \bar{B}\bar{C}) + \bar{A}\,(B\bar{C} + \bar{B}C)$$

and that this circuit can be constructed using a single pole change-over switch for A, and double pole change-over switches for B and C.

In The Workshop

The method of operating the Nim machine, the theory of which is given on page 6 of this Bulletin is as follows. The machine is "told" the number of counters in piles A and B, by throwing the appropriate switches. The switches are arranged in two columns of three, as shown in Fig. 1. The upper row denotes 4 (binary 100) the middle row 2 (binary 10) and the bottom row a 1. When all three switches are thrown, this indicates a 7 (=4 + 2 + 1), and this is the capacity of the machine. The machine replies by showing on the lamps in column C, the number of counters it wishes to have in the third pile. The person playing against the machine must then do his own subtracting in order to set the numbers in each pile as indicated by the machine. When the player has made his draw, the machine is informed of the new situation in two of the piles, and it again selects the number it requires to leave in the third pile.

Since the machine is stupid, the player must select the information he feeds into it. If for example the machine is told that piles A and B contain 7 and 4 counters respectively, then it will reply that it wishes to have 3 counters in pile C. If this is done and the player takes two counters from pile C giving 7, 4 and 1, the machine will again reply 3 if it is "told" 7 and 4. This is impossible; one cannot leave three counters in a pile containing only 1. Similarly if the machine is told 7 and 1, it will reply 6, which is again impossible since that pile contains only 4. But if it is told 4 and 1, it will reply 5, i.e. drawing two counters from the pile containing 7. Common sense suggests that the machine be first of all given the two smaller numbers, allowing it the greatest freedom to draw from the largest pile. This is not always the case, particularly if one constructs a "four pile" machine as was suggested on page 9. Consideration of the theory will also show that if two piles contain the same number of counters, the machine will always reduce the third pile to 0 irrespective of how many counters it originally contained.

Because the number of 1s must be even in each order of binary digits, the horizontal rows in Fig. 1 are entirely independent, there being no connection except that of a common power supply. The wiring diagram, which is given in Fig. 4 on page 9 is also the same for each row. Change-over switches can be constructed from S.P.D.T. switches sold by Radiospares. Referring to Fig. 2, an S.P.D.T. switch is such that in one position pins 1 and 2 are connected together, and when the switch is thrown this connection is broken, but pins 3 and 4 are now connected. Hence if pins 1 and 4 are wired together they form a change-over contact which moves from 2 to 3 when the switch is thrown.

Fig. 3 shows the complete wiring diagram for a horizontal row. Power supply and lamps are chosen to suit each other; the simplest arrangement is that of M.E.S. bulbs and a U2 cell. We used 2.5V pea-lamps available from Halfords or other cycle accessory dealers. The glass on the end of the bulb is thickened to give a converging lens effect which makes up for the fact that they are being under-run on 1.5V from a single cell. A wooden box is necessary to house the components; the cell is held by a Terry clip screwed into the base of the box, and a second clip, cut in two with the halves screwed at the correct spacing at each end of the cell is used to make connection to the cell terminals. An on/off switch was fixed in one side of the box, and all other components are mounted/

mounted on the box lid. The lamps are suspended by a bracket from the lid so that the bulb ends are flush with holes in the lid (see Fig. 4.).

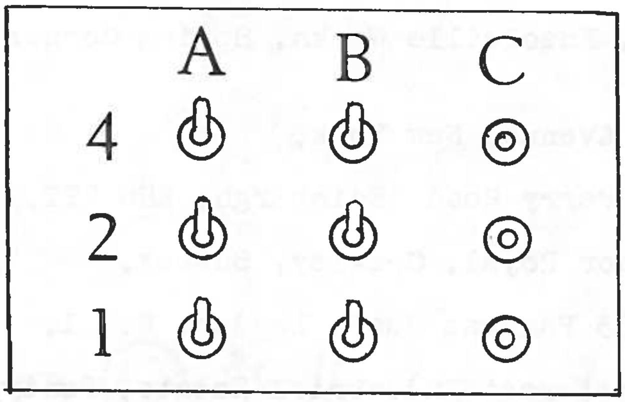


Fig. 1. Top panel layout

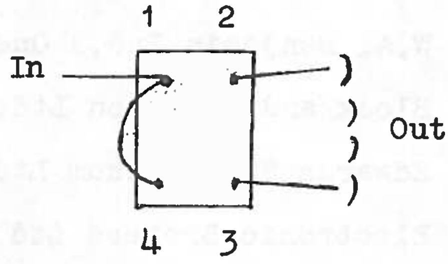


Fig. 2. S.P.D.T. switch connected for change-over operation.

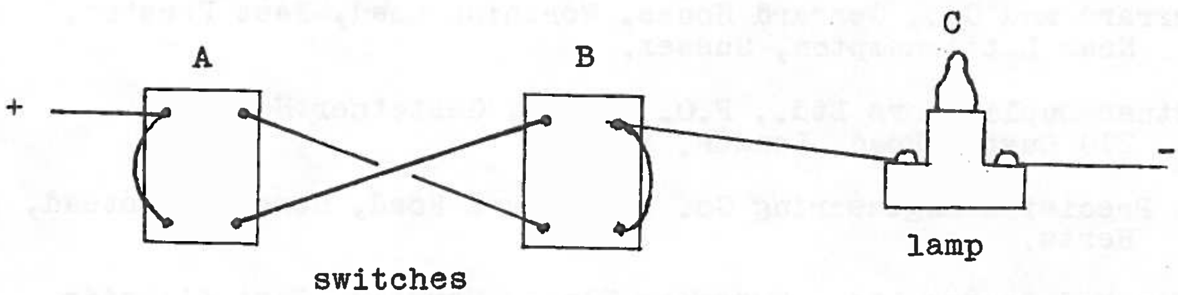


Fig. 3. Wiring diagram for a horizontal row

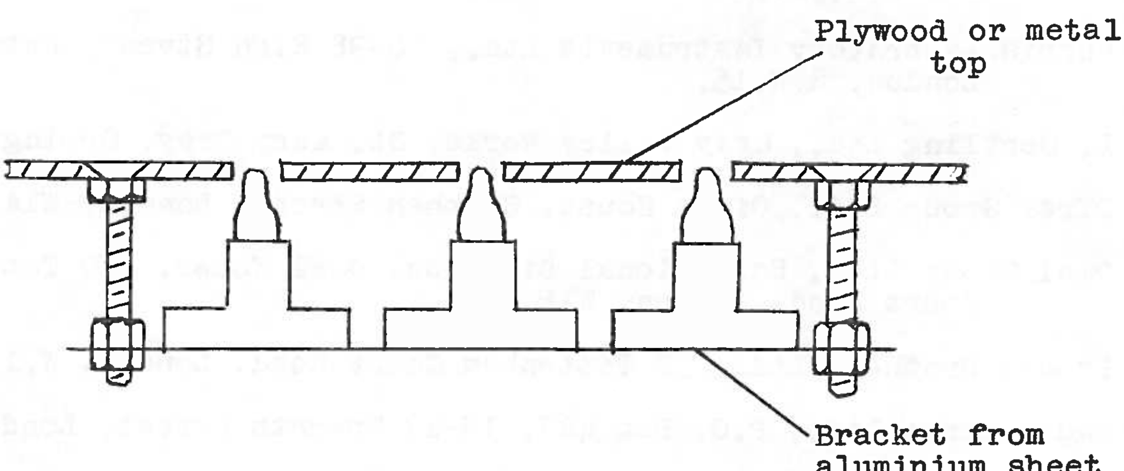


Fig. 4. Lamp mounting.

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

Advance Electronics Ltd., Roebuck Road, Hainault, Ilford, Essex.

Aimer Products Ltd., 56-58 Rochester Place, Camden Town, London, N.W.1.

Analytical Measurements Ltd., Ensoleille Works, Spring Corner, Feltham, Middlesex.

W.A. Benjamin Inc., One Park Avenue, New York.

Block and Anderson Ltd., 605 Ferry Road, Edinburgh, EH4 2TT.

Edwards High Vacuum Ltd., Manor Royal, Crawley, Sussex.

Electronic Brokers Ltd., 49-53 Pancras Road, London, N.W.1.

(E-Mil) H.J. Elliott Ltd., Treforest Industrial Estate, Pontypridd, Glamorgan.

Fire Protection Association, Aldermary House, Queen Street, London, E.C.4.

A. Gallenkamp and Co. Ltd., Portrack Lane, Stockton-on-Tees.

T. Gerrard and Co., Gerrard House, Worthing Road, East Preston, Near Littlehampton, Sussex.

Gestetner Duplicators Ltd., P.O. Box 23, Gestetner House, 210 Euston Road, London, N.W.1.

Glass Precision Engineering Co. Ltd., Mark Road, Hemel Hempstead, Herts.

Griffin and George Ltd., Braeview Place, Nerston, East Kilbride.

Philip Harris Ltd., St. Colme Drive, Dalgety Bay, Fife.

International Nickel Co. Ltd., Thames House, Millbank, London, S.W.1.

Leech (Rochester) Ltd., 227 High Street, Rochester, Kent.

Macfarlane Robson Ltd., Burnfield Avenue, Thornliebank, Glasgow, S.3.

Morris Laboratory Instruments Ltd., 96-98 High Street, Putney, London, S.W.15.

L. Oertling Ltd., Cray Valley Works, St. Mary Cray, Orpington, Kent.

Ofrex Group Ltd., Ofrex House, Stephen Street, London, W1A 1EA.

Omal Group Ltd., Educational Division, Omal House, 170 Tottenham Court Road, London, W1P 9LG.

Proops Brothers Ltd., 52 Tottenham Court Road, London, W.1.

Radiospares Ltd., P.O. Box 427, 13-17 Epworth Street, London, E.C.2.

Sargom (Northern) Ltd., 20 Alva Street, Edinburgh, EH2 4PY.

Teltron Ltd., 32/36 Telford Way, London, W.3.