SCOTTISH SCHOOLS SCIENCE

EQUIPMENT RESEARCH

CENTRE

Bulletin No. 69. February, 1974.

Contents

Introduction

We asked in Bulletin 64 for information from any teacher who had used electronic calculators in school, in view of our commitment to test and report on these. We had a few letters and verbal comment, including an amusing account of one machine which could not acclimatise and had to be warmed up each day in the kitchen oven. Nevertheless it survived an accidental baking with the week-end roast, although the plastic case surrounding the works melted. As a result of these comments, and of causing a variety of calculators to be used in a school science laboratory, we have been able to make some recommendations which may be helpful to teachers. The comments we offer apply only to science laboratories; we think the requirements of the mathematics teacher who wishes his class to use calculators are quite different, and our observations have little relevance in that situation.

While preparing the report, and summary which we will give in the next bulletin, the "Which" report on desk calculators came out (December, 1973), and we revised and where possible re-tested the models in the light of their suggestions. We would recommend anyone purchasing a calculator either for school or their own use to study the Which report. The report, although it deals only with portable calculators, is more comprehensive than ours; for instance, it indicates the operating time obtainable from a full charge on the battery. We apologise for not printing the calculator summary in this bulletin; promises to print the gas chromatography apparatus, and an urgent need to find space in our bargain basement have taken up the available space in this bulletin. However, anyone who requires to purchase a calculator before our next bulletin appears, will get advice based on the summary by writing or telephoning the Centre.

Opinion

It was as far back as Bulletin 4 that I suggested the need for some device on battery operated equipment which would give a visible or audible indication that the apparatus had been left switched on, with resultant waste of battery energy. In the case of transistorised equipment I indicated that one of the problems was to procure an indicator which would not consume an appreciable amount of the battery power when the device was being legitimately used.

Since then the light emitting diode (LED) and liquid crystal have both made their appearance, but I have still to see an attempt being made to use either of these devices as a warning light. In the desk calculators we are examining, neither consumes an inordinate amount of power, and it would seem not impossible to fabricate either in a shape which would intensify the warning effect. In fairness it should be said that our experience with calculators does not encourage the view that LEDs are any help in warning us when one has been left on.

Mains driven equipment does not have this difficulty; it does however have an equally tangled one, which is what to do with the mains cable when the box is being stored. Most firms are content to let it fly, and their plug appendages to get shattered. Some will provide a cable harness at the rear or side wherein to wrap up the unruly cord; this still leaves the plug as a projection which can foul on storage trays or baskets. One Edinburgh school with a central storage system has reduced if not eliminated the problem by giving all their equipment a short back and sides, and fitting one half of an in-line connector to the remaining stump of mains lead. Each laboratory then has 10-12 lengths of mains flex, terminated at one end in a fused plug and at the other in the matching half of the in-line connector. At the expense of technician time, this does produce considerable saving on 13A square pin plugs, and more importantly it allows any mains operated apparatus to be stored without its getting entangled with its neighbours.

There should be a moral here for the manufacturer. It is now some years since they have come to accept as standard the 4mm output terminal. Is it not time that they similarly considered a standard mains input terminal, which is often fitted on industrial equipment, and which would take the form of a recessed socket fitted to rear or side of the apparatus? Outputs are, after all, very varied, from R.F. to D.C. to E.H.T.; the mains input presents no such problem. For everyone it is 240V, 50Hz; for all school science apparatus it is less than 1kW; it has already been standardised in the form in which our wall sockets make it available to us. What then stops the manufacturer from providing a standard socket on his equipment? Is it simply that there is no organisation whereby manufacturers of school equipment can be brought together to discuss such questions on which agreement would be to everyone's advantage? The Scientific Instrument Manufacturers Association, to which some firms belong, has its major interests in the much wider industrial field, and at the same time it is too specialised - makers of audio visual aids, for example, are not well represented. Perhaps there is a need for a Trade Association whose primary interest would be that of the school market.

Physics Notes

Shortage of space precludes the repetition here of items of surplus equipment still in stock, but many listed in Bulletin 67 are still available and enquiries are invited. The following new items are offered.

Item 405. Bromide paper, Kodak WSG1S, 2S and 3S, $5\frac{1}{2}$" x $5\frac{1}{2}$", box of 100 sheets, 50p. Specify grade when ordering.

Item 406. Bromide paper, Kodak WSG2S, 12 x 16.5cm, box of 100 sheets, 50p.

Item 407. Bromide paper, Kodak WSG4S, 16.5 x 21.6cm, box of 100 sheets, 60p.

Item 408. Bromide paper, Kodak WSG1S, 8" x 10", box of 100 sheets, 70p.

Item 409. Bromide paper, Kodak WSG1S, 10" x 10", box of 100 sheets, 75p.

Item 410. 50μA moving coil meters, uncalibrated scale of 15 divisions, £1.

Item 411. Asbestos sheet, 380 x 380 x 1mm, 5p.

Item 412. Asbestos sheet, 1m x 1m x 3mm, 40p.

Item 413. Nickel cadmium battery, 12V, totally enclosed in box 20 x 13 x 5cm high, capacity unknown, £1.

Item 414. Perspex sheet, 3mm, various areas between 0.8 and 1.0m^2, uncovered and therefore scratched, £1.

Item 415. U.S. army field telephone set, powered by 2 U2 type cells, with hand generator, 75p.

Item 416. 1/3 HP 240V AC motor, £3.

Item 417. Various fan units, mostly for 230V mains but some 12-24V DC, price £1-£5, depending on size.

Item 418. Nasal spray; glass 30ml container and valve controlled blowball producing a fine spray, 30p.

Item 419. Binocular loupe; a pair of glass prisms with adjustable separation on an extended spectacle frame, to give stereoscopic magnification of 2-3x which could be used for dissection or printed circuit work, 30p.

Item 420. Stainless steel petri dish, 95 x 15mm, no lid, 20p.

Item 421. 25mm dia rubber balls; these do not bounce, but can be drilled to make ball and spoke models (we use beheaded wire nails) or they will stack in pyramidal or tetrahedral shape, 40p per 100.

The following items are from data processing machines used to transmit and receive information on punched tape through the telephone system. Excepting the first three, which are in working order, they are offered for their components.

Item 422. Stabilised power supply 24V, 200mA, stabilised for load and mains input variation, together with other DC supplies up to 40V at low current, £5.

Item 423. Stabilised power supply 24V, 5A, really heavy smoothing of 36,000µF. £5.

Item 424. Power Unit, unstabilised 30V, probably about 1A, 20p.

Item 425. Logic unit, contains 100+ transistors, 500+ signal diodes, £5.

Item 426. Logic unit, contains 50+ transistors, 200 diodes, £3.

Item 427. Receiver drive unit, 230V, 1/20 HP AC motor and two sets of nylon differential gears, £3.

Item 428. Transmitter drive unit, similar to Item 427, £3.

Item 429. Logic unit, 6 OC20, 3 OC36 and low power transistors, £2.

Item 430. Data receiver, about 30 transistors, £1.

Item 431. Data transmitter, about 20 transistors, OC84 and OC42, 50p.

Item 432. Control unit, contains relays, electric bell, push button switches etc, 20p.

Item 433. DPST heavy duty switch, operated by Yale key (like car ignition switch), 10p.

Chemistry Notes

Gas chromatography is a part of the 'O' grade syllabus which has suffered in the change-over from town to natural gas. This may be one reason why a recent report by Gunning and Johnstone, 'An Evaluation of Practical Work in School Chemistry Courses at 'O' Grade', University of Glasgow, lists the separation of hydrocarbons by gas chromatography as one of the experiments seldom done. In the SCEEB syllabus for 'O' grade chemistry, the separation of lighter fuel is suggested. Gas chromatography may not be considered thereafter, except as a CSYS project. There would therefore seem to be a need for an apparatus which will be comprehensible to the 'O' grade pupil, which will illustrate the principle of column separation, and which preferably will separate the constituents of lighter fuel. Because of the varied provision throughout Scotland, it should be capable of operating off town gas, natural gas, L.P.G. etc.

While the construction details of the apparatus we have produced are given in the Workshop section of this bulletin, the principles and practice of its operation will be given here. Air is used as the carrier gas, driven through the system by an aquarium pump. A flow rate of 5-10 ml/min should be aimed at. When the apparatus has been built, this flow rate should be checked e.g. by using a MeTeRaTe flowmeter, DR1A, from Glass Precision Engineering but once the correct rate has been achieved by choice of a suitable pump and/or screw clips on the tubing, the flowmeter should be removed for the sake of simplicity. For guidance, the aquarium pump, which can be bought from pet shops etc., or borrowed from the biology department, should produce a pressure of about 1.5×10^4 N/m^2 or more familiarly, 160cm of water.

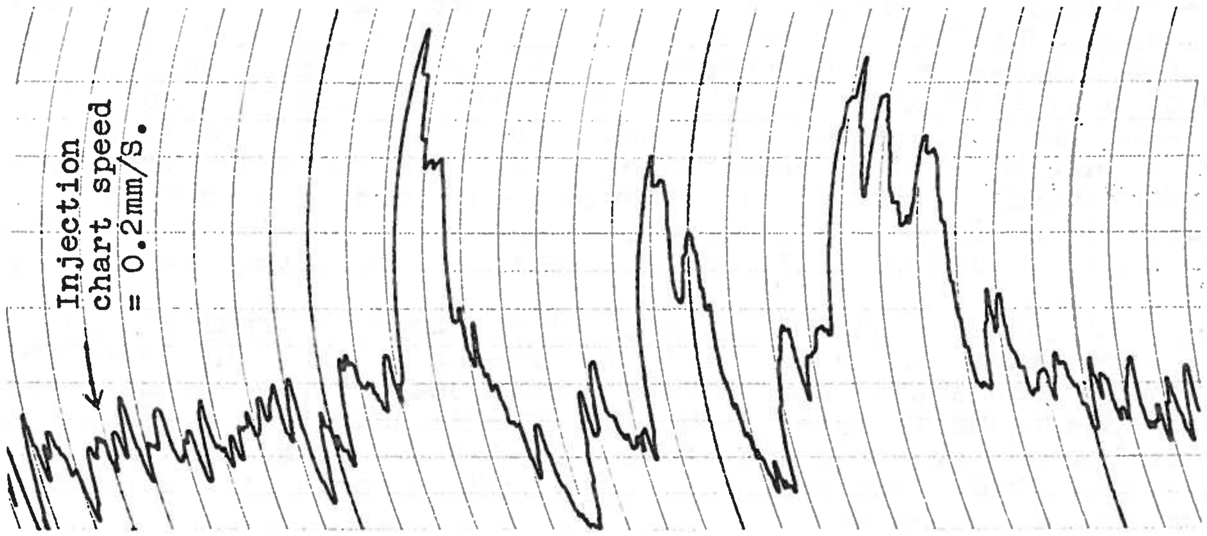
The air is dried by passing over silica gel and then passes into the column, which consists of 20% by weight of squalane deposited on 30-80 mesh celite. The squalane is dissolved in 50ml of dichloromethane and the solution added to 20g celite in a beaker. The mixture is stirred to form a slurry and stirring is continued occasionally while the beaker is heated in a water bath. When the celite is quite dry it is finally heated in an oven at 100°C for 2 hours or more. The celite then flows freely and the complete column can be filled through a filter funnel at one end, the other end being plugged by a 25mm length of lightly packed glass wool. During filling the tube should be tapped gently to ensure uniform packing of the column. The filling end is then similarly plugged with glass wool.

These instructions are suitable for preparing a column for the separation of lighter fuel or other mixtures of hydrocarbons, or halogen substituted hydrocarbons. For general purpose use, e.g. the separation of an acetone/ether mixture, which we have carried out, silicone fluid MS550 on celite is used in place of squalane. The procedure is the same except that benzene is the solvent instead of dichloromethane. Both these solvents are toxic, and inhalation or skin contact should be avoided; the work should be carried out in a fume cupboard. Benzene is very flammable and no naked flame should be used, but an electrically heated water bath.

The proportion of liquid phase may seem abnormally high to those experienced in the subject; the reason is that our detector is relatively insensitive and therefore requires a large volume of the test sample to be injected. This has the disadvantage of producing long retention times, so that 15-20 minutes are necessary for a separation. Tide detergent has not proved suitable as a separating medium in this apparatus.

The principle of the detector will be seen in Fig. 1 below. The carrier gas emerges from the left through a hypodermic syringe needle. There it impinges on the flame produced by any combustible gas at a second needle. The flame performs the function of a pilot light. On the far side of this is a simple thermocouple, hopefully recallable from section 3 of Integrated Science, made by twisting copper and eureka wires together. When the fractions emerge with the carrier gas they are ignited by the pilot light and the flame is driven towards the thermocouple. These fractions are large enough to show that burning is occurring at the needle, but only by close inspection and certainly not large enough for demonstration to a class. The emf generated by the thermocouple depends on its temperature, which in turn depends on its position relative to the pilot light. Details are given in the constructional article, but we found it convenient to adjust the thermocouple until it produced a 'rest' current of about 5µA in a 50µA MR65 type DC meter, which would increase three fold when a fraction was being burnt. These values correspond to an emf of 8-25mV generated by the thermocouple. Obviously these low values of current or emf must be amplified before showing to a class on a demonstration meter, and this can be done either through the meter amplifier described in Bulletin 55, or with the commercial amplifier sold by Weir Electrical Instruments, which has a 50µA range.

We have said earlier that any combustible gas may be used for the pilot light; the only criterion to be met is that the flame height should be in the range 3-5mm. Indeed we have used a methylated spirit burner with some success; its construction, from glass tube and cotton wool, is shown in Fig. 2. It is stuck to the baseboard in the appropriate position with plasticene. One method of regulating flame height with this burner is to have the cotton wool initially too far out of the jet, so that the flame is too high, and then to push it back into the tube with a syringe needle, with the flame lit, until it is the correct size. During operation this burner can be topped up with more fuel injected into the open end with a syringe.



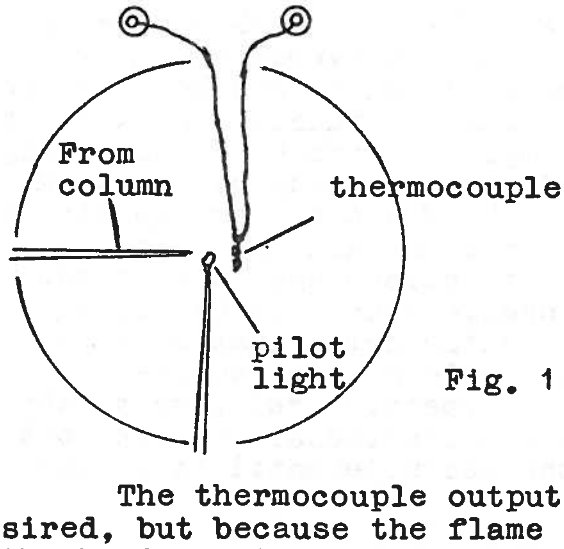


Fig. 1.

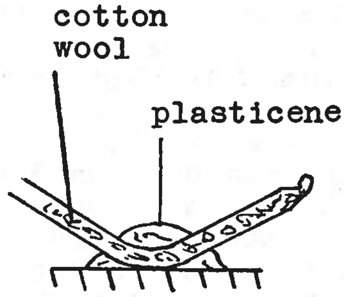


Fig. 2.

The thermocouple output can be fed to a chart recorder if desired, but because the flame is unaerated it is very wavery, even with the draught shield which we use, and this results in fluctuations in output of order 3-5μA, so that the chart record shows a great deal of background "noise". This is not so evident when the result is displayed on a demonstration meter, as the inertia tends to damp out rapid fluctuations.

The injection technique is simple; 10ml of sample are taken into a glass syringe and injected directly into the rubber tubing at the start of the separating column. The graph above shows a record we obtained from the apparatus, using our meter amplifier and the Russian H 320/1 recorder, the sample being 10ml of gas lighter fuel and the pilot driven from town gas. We have not attempted to run pure compounds through the apparatus in order to identify particular fractions in the mixture nor to arrange to heat the column to achieve faster operation, because we believe these refinements are more appropriate to a CSYS study where a more sophisticated apparatus with a reference detector at the head of the column is desirable. Throughout, our aim has been for simplicity and understanding, with all parts of the apparatus in full view.

Electronic Calculators

All calculators perform the four basic functions, but there are two methods by which information can be fed into the machine. Simply put, the instruction as to what to do with a number may be fed in either before or after the number itself. In the case of multiplication and division, the instruction always precedes the number, i,e, one punches x4 or ÷4 in order to multiply or divide what is already in the machine by that number. For addition and subtraction, both methods are found. For machines using what "Which" calls full flow arithmetic, and the salesman may call algebraic logic or algebraic mode, the + and - are also given before the number to which they refer. Thus 15 - 3 = would be punched as written, and the answer would appear only after the = key had been pressed. On others, using "flow arithmetic" or "add list mode", the same operation is punched as 15 + 3-, and the result appears as soon as the - key is pressed. For this reason, many calculators using flow arithmetic combine the = key with both the + and - keys. Full flow arithmetic models always have a separate = key, but not all models with a separate key have full flow arithmetic. Once the particular system of a machine had been learned, there appeared to be no difference between the two methods, although full flow is easier for pupils to learn.

Almost all the calculators have a 'clear last entry' function. This is used if a number is wrongly entered and you wish to replace it by the correct number. It cannot be used if an instruction key has been pressed after the wrong entry. On many models this key is marked CE, the clear key which clears the machine completely being marked C. Some models combine the two functions on one key, pressing once to clear the last entry, and twice to clear the machine. Again there would seem to be no difference between the two systems, although we suspect, without proof, that pupils may make wrong calculations through not clearing the machine completely in the combined key system, by pressing it once only at the start of a calculation. On some models with full flow it is also possible to correct a wrong instruction, i.e. to change from + to x, say, if the former has been wrongly punched. The advantage of this is debatable, because there is nothing to tell the operator that the wrong key has been punched, whereas a wrong number entry shows immediately on the display.

Most calculators have floating decimal point, which means that the number of digits after the point depends on the result of the calculation. Some have provision for fixed as well as floating point, and fixed point can be preset to a number of different positions. There is some teacher opinion that a fixed point set to one or two decimal places has the advantage that results are rounded off for the pupil, and he is less liable to give an over significant result. On the subject of significant figures, most calculators employ zero suppression, which means that zeros after the point are dropped, even though these may be significant. Thus on floating point, 2.0 x 3.5 will give the result 7. On fixed point operation the zeros after the point will be given, whether or not they are significant.

Two other facilities often found on calculators are %age, and constant keys, the latter usually marked K. %age allows you to answer questions such as 'What is 19% of 250?' and 'What %age of 250 is 136?'. We cannot see great need for this calculation in science subjects. The constant key allows x and ÷ (and in some cases + and -) of a constant quantity by a range of other numbers without entering the constant each time. Thus if you had a number of distances, measured in yards, to be converted to meters, it would be necessary to enter the conversion factor, 0.9144 x, once only. This would have application, e.g. in reducing to STP a number of gas volume readings, although we believe the occasions would be limited, and the usefulness of the facility has to be set against the opinion of at least one teacher that the constant key is a nuisance because it can be left on inadvertently.

Underflow and overflow. These are two pieces of calculator jargon with which the salesman may attempt to bewilder you. The second means simply having too many digits for the capacity of the machine, which can occur either by entering too many digits, or as a result of a calculation (usually multiplication) producing too great a whole number for the machine. In the first case the machine simply holds the most significant digits of the number and allows you to carry out calculations with those. A calculation overflow can produce one of several effects. The calculator may show a single, or a row of zeros, which means that your answer is lost and you have perforce to begin again. It may retain the most significant digits of the calculation and seize up, no further calculation being possible, in which case you have probably lost the decimal point position, and have to write down or remember the digits while you clear the machine and re-enter the number, divided by such power of 10 as you think will enable you to complete the calculation.

If it has underflow, then the calculator will retain the most significant digits and will also indicate how many have been lost by the position of the decimal point. An example, borrowed from Which, will make things clearer. On a machine with 8 digit calculating capacity, which is most common, the calculation 88888888 x 2 = 177777776 will have one digit too many for the machine. With underflow, the display would show 1.7777777 where the decimal point, moved one digit in from the left, shows that one digit has been lost from the right hand side of the calculation. Had the same string of 8s been multiplied by 20, the result would have been 17.777777, showing two digits dropped. Normally the calculator will now be locked, so that the number has to be remembered or written before clearing the machine and re-entering. On some machines however, the paralysis may be removed by using the 'clear last entry' function, which allows further calculation to proceed on the digits retained. Clearly this is the most useful of all the types, although one wonders how frequently an 8 digit capacity will be exceeded in pupil calculations and therefore whether the different ways of treating overflow are of significance in choosing a calculator.

Two other features of calculators may be worth mentioning. Every calculator will square a number if, after entering the number, the x and = keys are punched. Repetition of the x= sequence produces 4th, 8th, etc., powers of the original number. If you do the same thing with ÷ = the calculator will first give you a 1, and then stop, which is not very helpful. Secondly, some models, described as having an "omni-constant" will repeatedly perform a function if that function key is pressed more than once, sometimes on all four functions, sometimes only on x and ÷ . With such a facility, punching 6+++ results in 18; 6--- in -18; 6xxx in 216; and 6÷÷÷ in 0.16, i.e. the reciprocal of 6. While this may be a useful way of finding reciprocals, although no faster than 1 ÷ 6 =, we are not sure if this is not outweighed by the mistakes which can and do occur from pupils inadvertently double punching the keys.

Tests in a school showed that the portable battery operated instrument was virtually useless because of the frequency with which the batteries discharged. Opinions of teachers also were that these machines were far from thief proof. Amongst the mains operated machines, there is a choice between straight forward mains driven, or rechargeable battery models. The latter can readily be portable and come in a range of sizes from the pocketable to the desk top machine. Direct mains driven machines all tend to be desk top size, and tend also to greater sophistication and cost, because they provide more than the basic four arithmetic functions of +, -, x, and ÷ .

We believe that only these four functions are necessary in school science. The argument against anything more complex is that the pupil, who at most will use the calculator twice a week, and may spend many science periods not using it at all, has to learn from scratch any more complex operation - say taking a square root - every time he does it because he forgets from one time to the next. This may easily take longer than more conventional methods by slide rule or logarithms. In fact in the instance quoted, it is as quick to guess at the square root, multiply up with the calculator and so arrive at the result by successive approximation, as to use the $\frac{1}{2}(A/n + n)$ formula where n is an approximation to $\sqrt{A}$, which is the usual method suggested for this calculation.

Our evidence tends to show that not more than 8-10 pupils can be accommodated by a single machine. This would suggest that a minimum of two, but preferably three calculators will be required per laboratory. It was found that once pupils had been 'feather-bedded' to the use of calculators they would queue for its use rather than perform relatively simple calculations, thus wasting time. This phenomenon is not confined to students; the writer has seen a salesman use his machine to divide 100 by 4!

Pupils can make mistakes in calculation by entering the wrong numbers, by punching the wrong instruction keys, and by wrongly reading the result in the display. Displays can be in red, green, orange or white, and of almost any size from 3mm high upwards. After test in a school where we analysed the results of over 200 calculations performed on a machine we found no evidence to prove that the smallest display was more difficult to read. The %age of mistakes in reading varied from 1.5 to 7. %age errors in entry varied from 5 to 23, and on those machines which would give a wrong result if the instruction keys were double punched, mistakes from this source were as common as wrong number entry.

In The Workshop

The gas chromatograph described in the Chemistry Notes section of this bulletin is located on a plywood baseboard measuring 120 x 25cm. Halfway along this a second piece of plywood, 120 x 15cm is fixed using softwood supports so that it slopes backwards at an angle of 45°. The detector and separating column are mounted on this rear panel, while the air pump and silica gel tube are on the front part of the base board.

The separating column is made up of two lengths of 5mm soda glass tubing, 100 and 105cm respectively, joined by a short length of PVC tubing so that they may be bent into a U and mounted 5cm apart on the back panel. Three pairs of Terry clips are used to hold the column on the panel. A 40mm wide strip of aluminium sheet is bent up to form a bracket for holding the aquarium pump to the baseboard; the size of this must be adjusted to fit the pump being used. Two pairs of 6BA bolts are used to secure this to the baseboard. The silica gel drying agent is contained in a 25 x 300mm length of glass tube, with a short plug of glass wool and a single hole stopper at each end. This is held to the baseboard by two Terry clips, No T80/3. Standard rubber tubing is used to connect pump to drying tube, and tube to column.

The detector is assembled around a block of 12mm thick chip-board, measuring 110 x 90mm, from the centre of which is cut a 75mm diameter hole using either fret saw or trepanning tool. This size of hole is selected only because inside it will fit one of the popular sizes of tin can used by the canning industry and which acts as a draught shield. Three slots are cut half-way down in the chipboard block, to take the syringe needles and thermocouple. The needle from the separating column, to which it is connected by a short length of rubber tubing is size 17.25G, 24mm long. The needle for the pilot light is size 1.17G, 38mm long and is also connected to rubber tubing which fastens into two Terry clips on the baseboard and which must be long enough to reach the gas supply being used. The thermocouple is made by twisting with pliers a 25mm end of 22 SWG copper and 30 SWG eureka wires, the free ends being connected to 4mm sockets. Fig. 2 shows the layout of the various parts of the detector and their approximate positions, although the final settings are best obtained by trial and error.

The tin can referred to above has top and bottom removed, and three slots cut in it to coincide with those on the chipboard block. The inside of the can, and the base of the panel under the detector are painted matt black to make the flame more visible.

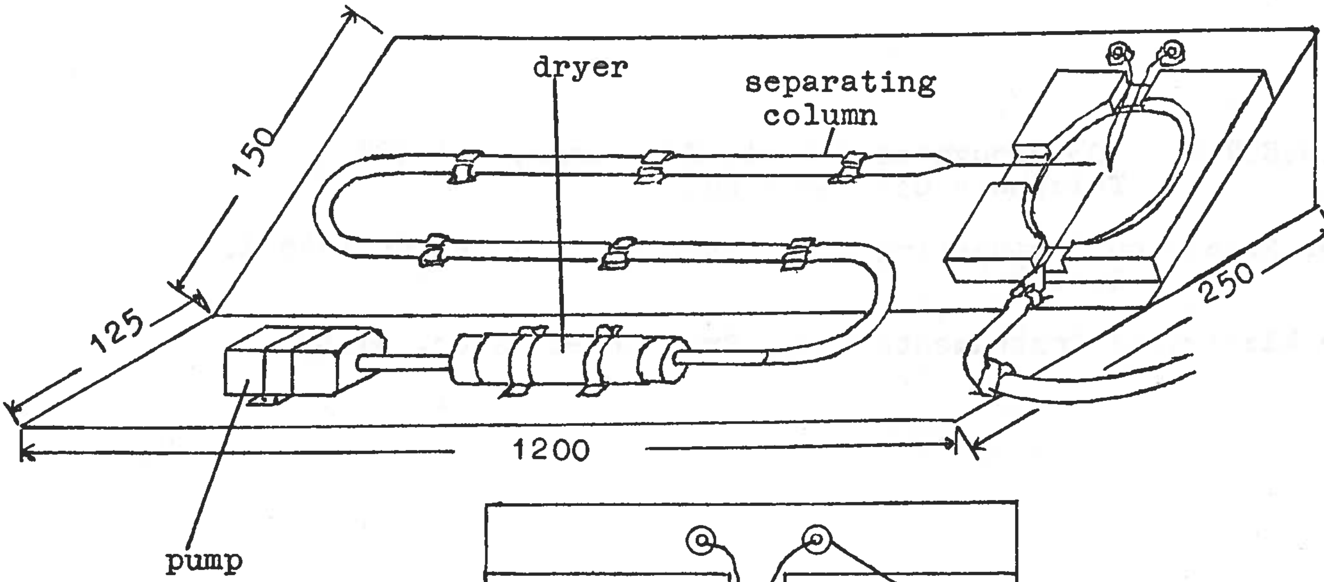


Fig. 1. General layout

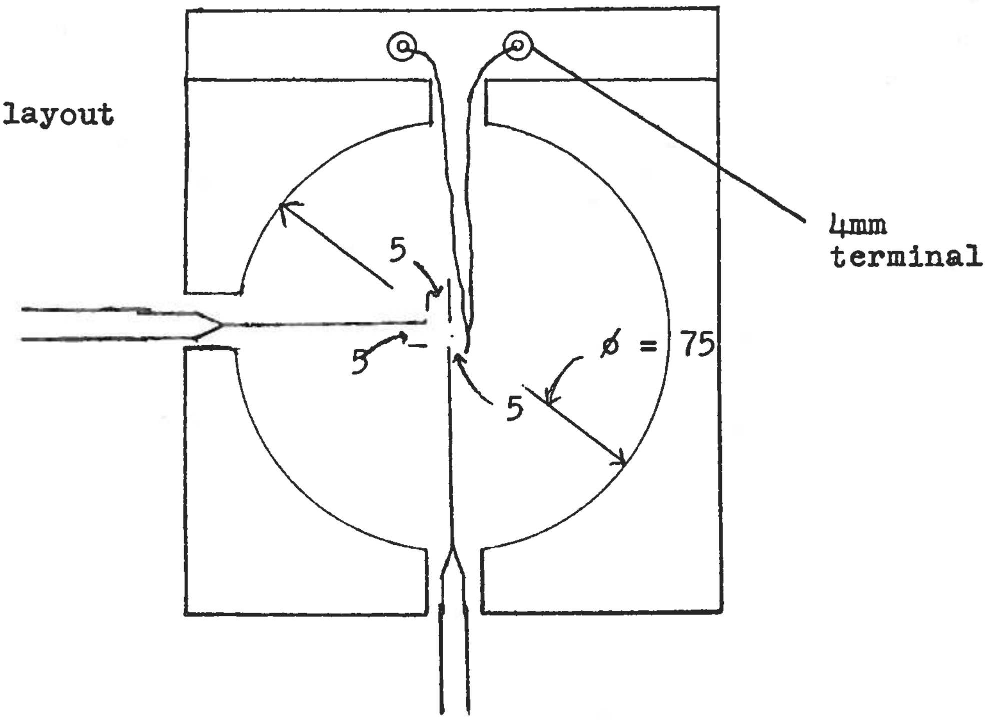


Fig. 2. Detector detail

Dimensions in mm. Not to scale

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

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

Weir Electrical Instruments Ltd., Bradford-on-Avon, Wilts.