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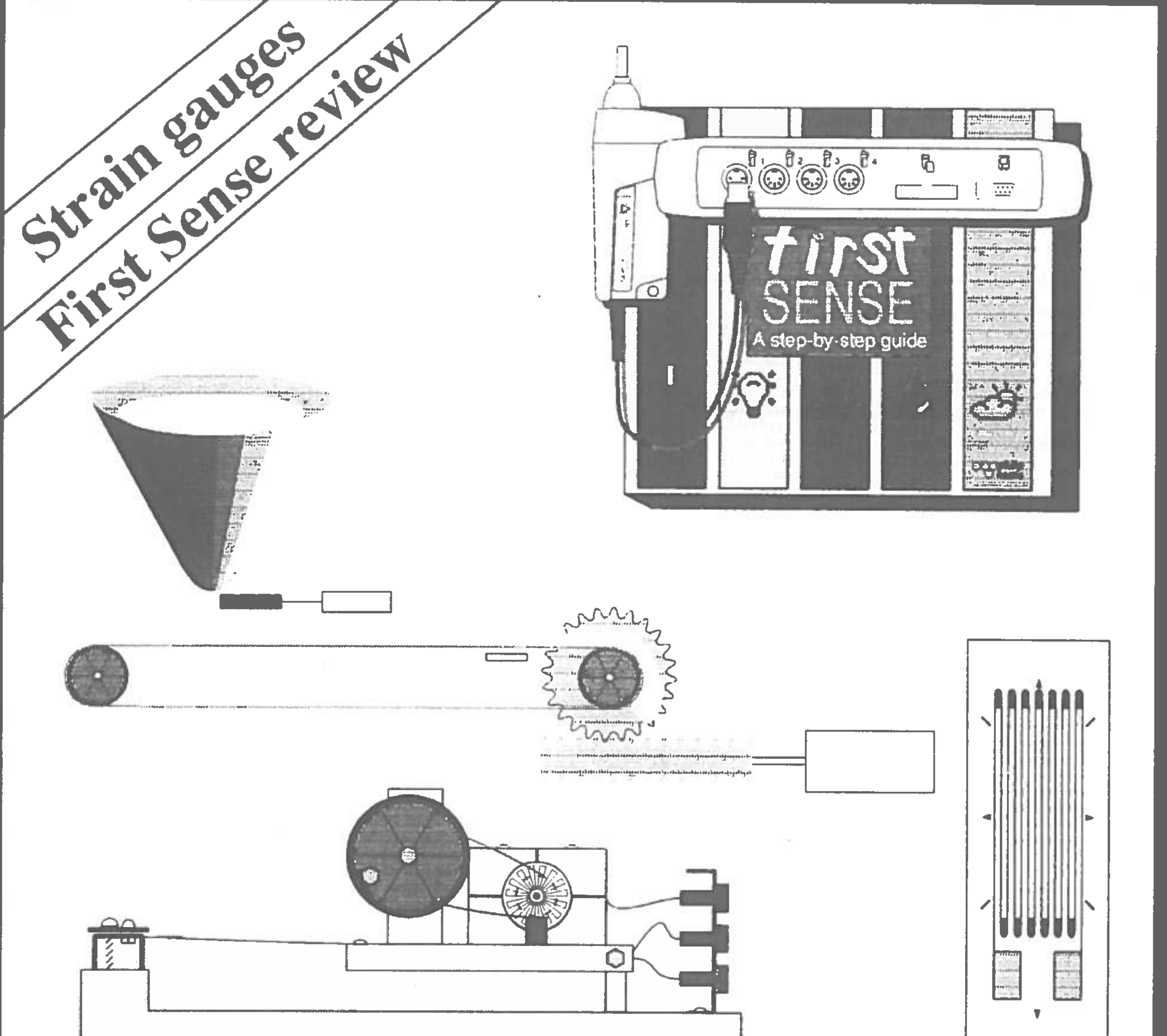

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Opinion

Ravings Again

The electric car is a very seductive idea. Electricity is so much cheaper than petrol, and there's no filthy exhaust. For the moment, electric cars don't have much *performance* - but some of us don't want it, and apart from fire engines and ambulances, none of us need it; so from an individual's point of view, they're probably quite a good idea.

But what about the benefits to the community as a whole? On sober analysis, they're not quite so clear after all. Why is electricity so much cheaper than petrol? Surely because of the economy of scale, converting chemical energy in large quantities all in one place? Green alarms should be ringing already - *small* is beautiful, isn't it?

Certainly there are real economies in large scale conversion: a carefully designed power station can have an efficiency four times that of a car engine. If you consider losses between the power station and the domestic three-pin socket, it doesn't look quite so good; but actually the losses are genuinely quite small. Even the initial energy cost of building the distribution system is fairly reasonable. But most of the difference in price comes from the purchasing power of electricity companies, and taxation on motor fuel.

Where the energy losses start to mount up is between the three-pin socket and the car wheels: in battery chargers, in the charge-discharge cycle inefficiencies of batteries, in high-current cables, motors, and motor control circuitry on the car. Worst of all, in the energy costs of replacing hefty batteries fairly often.

From the overall community point of view, electric cars are not without a filthy exhaust - it's just that it's at the power station, not at the car. At least it doesn't have lead in it - but even that comes out at the battery factory.

They (some of *them*, somewhere) are working on improving the electric car. Mainly, what they're trying to do is improve the performance, by which they mean acceleration, top speed, and range. Such energy saving advantages as the electric car has mostly arise from the limitation on its acceleration and top speed.

I'm not trying to say the electric car is necessarily a bad idea - just that there is more to it than meets the eye.

Let us hope they can reduce the inefficiency of the charge-discharge cycle, and improve the life expectancy of batteries. Another way to save a tremendous lot of energy would be to *reduce* the performance of conventional cars. One very worthwhile by-product would be the saving of a great many lives and limbs. Best of all, we could reduce the amount we use cars, and use trains or buses instead.

Another idea which I find seductive is Combined Heat and Power. A nice, well established idea - a pity it isn't a nice, well established practice. But I'm not thinking of miles of pipework connecting everyone's central heating up to the waste heat of the local power station - I'm thinking of replacing my central heating boiler with an old car engine.

I'll just plumb in the water cooling system of the engine in place of the boiler, and run a wee generator off the engine. I'll convert the engine to run off mains gas, so I'm not paying too much of a premium for my fuel. My electricity will still come out a little expensive, but my heating will be free - or vice-versa. Overall I should be well in pocket.

Or will I? Less than half the heat from an engine comes out in the cooling system; most of it comes out in the exhaust. Unless I can retrieve a good proportion of the heat from the exhaust, I may well *not* end up gaining. So now I'm involved in heat exchanger design - perhaps my old central heating boiler will come in handy?

At least my exhaust will be relatively clean, since I'm using gas as fuel (all that warm carbon-dioxide: would the plants in my greenhouse like it?) - pretty much the same as the flue gas from the old heating system, plus a bit of old engine oil.

Now I'll just plug in my electric car . . .

What has all this to do with school Science and Technology?

Discuss; investigate; compare and contrast . . . oh, you think of lots of nice buzz words and TLAs[1] to put all that rubbish into a curricular context.

Just one other thought, while I'm here:

Not tested on cute little fluffy rabbits? So you're going to test it on *me?* Or is it simply that you're selling nothing but water, which has been fairly thoroughly tested on quite a lot of people, not to mention rabbits; or soap, likewise; or other long-established ingredients. Not that being long-established is any guarantee of benignity.

Thanks, I'll stay dirty.

Green consumerism? There's a contradiction in terms!

[1] Three Letter Acronyms

INTRODUCTION

Saturday Opening

Saturday morning opening will begin again on the 7th and 14th of September and will continue thereafter on the first two Saturdays of each month, excepting the first Saturday of January 1992 (the 4th) until further notice.

Christmas closure

Given our staffing situation at the time of writing, we are not at all sanguine that we will meet our deadlines for this issue which normally allow for a publication date in September. Distribution to schools in October looks more likely. That explains the somewhat early announcement of our closure dates.

The Centre will close for business on the 24th of December 1991 and will not re-open until the morning of Monday the 6th of January 1992.

New status for SSERC

Contractual problems

Over the years the Centre has occasionally met with problems because legally SSERC, and before it SSSERC, never existed. Both organisations were mere clubs the members of which were all the Scottish Regional and Islands Councils as Education Authorities and a number of individual subscribers such as firms, independent schools and overseas readers. Any contracts, whether for employment of staff, projects or property leases, had to be signed by and through Lothian Regional Council as host Authority.

Legal identity

Recent contracts such as that for the Joint Support Activity Project[1] have been on a significantly larger scale than hitherto. Scottish EAs became understandingly anxious to regularise the position of SSERC so that the organisation had its own separate legal status and corporate identity. This was in order to allow SSERC itself to enter into contracts and other agreements in legal form.

CoSLA Working Group

The deliberations of a Working Group, appointed through the Convention of Scottish Local Authorities (CoSLA), have led to SSERC registering as a Company without issued share capital - a Company Limited by Guarantee. A certificate of incorporation was granted to *SSERC Limited* with effect as from 29th April 1991.

The Company was subsequently recognised by the Inland Revenue as a charity for the purposes of Corporation and Income Tax. Charitable status is retrospectively effective back to the date of incorporation.

1 Funding for our JSA Project STERAC (Science and Technology Equipment Research and Advisory Centre) officially ceased at the of July. We have however decided to try if at all possible to continue a basic service to technology education departments.

SSERC Staff

Currently staff remain *de-facto* employees of Lothian Regional Council and are permanently seconded to SSERC. It remains to be seen whether the new Board will draw up revised contracts of employment and offer these to the staff (just as it remains to be seen whether existing *core* staff will accept such new contracts).

Board of Directors

Control of SSERC now passes from a Governing Body appointed through CoSLA to a Board of Directors. These changes are however not as far reaching as they might on the surface appear. In the past most of the Governors have been nominated by EAs and appointed through CoSLA. The majority of members of the new company and of its Board of Directors will be from those same Authorities. We won't even be using the title "SSERC Ltd." save on our stationery to show our limited liability and charitable status.

No material change?

On the face of it then, SSERC's changed status to that of a Company Limited by Guarantee is nothing more than a tidying up of a legal anomaly. Control will remain vested in much the same quarters. Financing of the core information, advisory, and consultancy services hopefully will continue on much the same basis as before - that of a mixed economy. This should allow continuation of our open access enquiry system *free at the point of use* (shades of the NHS?).

But, will all Authorities pay?

A few EAs are making significant noises about moving over to a totally fee-charging basis even for the funding of the core advisory services. One Region has already broken ranks and has unilaterally reduced its contribution - read on!

Strathclyde orders - delays

We apologise to customers in schools and other establishments in Strathclyde who may have experienced delays in our meeting orders for components and materials or SSERC publications and software.

Strathclyde shortfall

On the 20th of July 1991 we received formal notice from Strathclyde Regional Council Education Department that, because of financial constraints, they would be not be meeting their full share of the CoSLA recommended subvention[2].

In 1990-91 all EA contributed funding for SSERC was frozen at 1989-90 cash levels. Regional and Islands Councils' share of funding for all Centre activity fell to

2 Our Strathclyde correspondent called it a "Grant" which it most emphatically is not. The subvention is the cost of being a member of the SSERC consortium and is a COSLA Category A recommended levy which has been approved by CoSLA committees on which Strathclyde is represented.

less than 60%. For 1991-92 CoSLA's recommendation had been for a cash increase, below inflation, of 4.75% over the 1989-90 figure.

Strathclyde have not heeded that CoSLA recommendation. They have actually cut their contribution by 20% of the 1989-90 figure (and by 24% of their share of SSERC costs as recommended by CoSLA for 1991-92).

Referral to SSERC Board

In the circumstances, the Management Team of the Centre had no choice other than to refer the matter to the SSERC Board for a decision on whether Strathclyde establishments could continue to enjoy the same terms and conditions as other Scottish EAs and SSERC subscribers who have paid at the recommended 1991-92 levels. In the interim all deliveries of goods and publications to Strathclyde schools and colleges were frozen.

Direct charging

It is doubly ironic that Strathclyde is one of the EAs leading a movement to put SSERC on a completely direct, fee-charging basis. Even before this latest cut pressure from Strathclyde, as the largest single Scottish EA, had obtained for them a funding formula based on a sliding scale of pupil numbers. This resulted in a payment of about 30% of all EA contributions. In this latest move, Strathclyde's direct contribution to SSERC has fallen to less than a quarter of all such payments.

Several analyses of SSERC contact statistics[3] over the years have however shown that Strathclyde establishments take up just under 50% of available SSERC staff time. On a straight population basis this is exactly that share to which the Region is entitled.

Board decision

The SSERC Board met on the 29th of August. They agreed that Strathclyde orders placed before that date should be met at the original advertised prices. Schools and colleges in all Strathclyde Divisions should however note that a 25% surcharge is being applied to all Strathclyde orders received after 1st September 1991. Where contracts for training courses were agreed before that date then no additional charges are to be made. Any new arrangements may however be subject to surcharge.

We are genuinely sorry to have to take this action. We happen to believe that national educational support services should be co-operative and cohesive, not crudely competitive. We didn't invent the rules for these latest educational, market-orientated, games. We are just trying to play fair by them. To continue to supply and deal with Strathclyde establishments on the same basis as those of other EAs which have met their obligations in full was obviously unacceptable.

3 We have long had performance indicators - possibly since before some current EA officers were in teacher training!

No Comment

Classroom practice

"We showed how in certain areas, for example home-school links, the curriculum and whole-school management, clear policies can be appropriate and helpful; and how in other areas, notably classroom practice, advisory staff seemed eager to prescribe in some detail how teachers should organise their classrooms and manage their teaching, a focus for policy and action at that level which seemed rather less appropriate."[1]

"The focus, the report says, must switch to childrens' learning."[2]

"Learning is the end, organisation the means. Teaching strategies and classroom organisation should never be viewed as ends in themselves."[1]

References

1. Report "Primary Education in Leeds" by Professor R. Alexander (to be published shortly by Routledge as part of a book on educational policy and practice).

2. TES Review thereof 16th August 1991.

The nature of science education

"I think that science education in Britain is in a parlous state. Something must be done, but I hope that what does not get lost in the wash is that sense of awe. Science must not be seen simply as a way of making life better or increasing the GNP.

They are currently fashionable as reasons to do science and to some extent I do not demur from them. But I feel sorry for people who do not see science as romantic or cultural. It affects our lives in a profound way."

Sir David Attenborough in his Presidential Address to the British Association for the Advancement of Science. (Reported in TESS, 30th August 1991.

Comment

Vacancies and vacuity

Readers may recall that last year, in this section of Bulletin 168, we commented on the pattern of vacancies for higher education courses as revealed in press advertisements placed jointly by Scottish Universities through the Scottish Universities Council on Entrance (SUCE).

Well, the first of the 1991 SUCE adverts ran to half page spreads and the implications for the future development of science and engineering have apparently worsened. The only Scottish University not advertising any vacancies at all for this session was St.Andrews. Of the 224 courses, across the other seven institutions, for which vacancies were advertised in the press on 21st August, 167 (ca. 75%) were in science, engineering or *hard* technology related disciplines.

That average conceals some startling figures for some of the individual establishments. Edinburgh University had vacancies on 18 of its undergraduate courses. The sole example which wasn't in some science or engineering discipline was their BMus course. Glasgow similarly had ca. 95% of its unfilled courses in science and engineering departments - indeed if you recognise nursing as largely science based and throw in the Bachelor of Nursing (BN) degree course then 100% of the places lay within science and technology related courses.

Equally disturbing were the overall totals for courses with vacancies in our two supposedly more technological universities. Heriot Watt had vacancies on no fewer than 55 of its courses. Strathclyde was not far behind with 49 courses not then filled. In Heriot Watt's case 65% of those courses were undoubtedly science or engineering with the equivalent figure for Strathclyde standing at 78%. If the figures for mathematics and maths related disciplines are counted in then you could get really depressed.

By the following week (28th August) the picture in the press ads had indeed got gloomier. There was by then a smaller number of courses listed but - you guessed it - most of those which had gone from the lists weren't engineering or science related.

No doubt the other Higher and Further Education institutions will again suffer knock-on effects on their courses and entry requirements.

Given that we obviously can't fill the ones we have already - especially not with science or technology students - just who is it that wants or needs more Scottish Universities?[4]

4. Apart, that is, from a certain Minister and the, by now notorious, Napier Ninja Turmites.

SAFETY NOTES

Gas guidance

An overview is provided of current requirements for both the safe installation and the regular inspection and maintenance of gas supply systems in educational establishments.

Introduction

We have received a number of enquiries of late on up-to-date requirements for the installation and maintenance of gas supplies in educational laboratories. One or two major incidents in English schools in recent years have also led others to look again at this whole area. As a result of that, as well as of our own enquiry work for some individual Authorities, we can now offer initial general guidance on this whole topic.

A draft of this article has been commented upon by an expert in gas safety at British Gas plc. Amendments were duly made. Any remaining errors or lack of clarity are however the responsibility of SSERC. An amended draft was also submitted to relevant specialist sections of the HSE. We still await a response but have decided not to further delay publication. Any material additions or amendments which result from that consultation will however be notified to readers through these columns.

General duties

Employers have a duty to provide safe plant and systems. They are also to maintain these in a safe state. They must do so in order to safeguard the health both of their employees and of others, not employed by them but who might nevertheless be affected by their activities. Educational employers, that is EAs and governing bodies, are not excepted from this general requirement.

Safe plant includes gas pipes and other installations as well as any appliances which might be hooked on or into to the system.

This is the well known general duty laid on employers by and spelled out in, the Health and Safety etc. at Work Act, 1974 [1].

More specific requirements

The Gas Safety (Installation and Use) Regulations 1984 [2], together with a number of British Standards, give more detail as to good practice. Specific guidance for educational use is provided in a document drawn up jointly by British Gas and the DES.

These "Guidance Notes on Gas Safety in Educational Establishments" (IM/25)[3] specifically cover the safe design, installation and educational use of natural gas in schools and colleges. Boiler houses and canteens are dealt with in other standards ([4], [5]).

Clearly, IM/25 should be of interest both to those who build, design or modify laboratories, and those who have responsibilities for maintaining equipment in a safe state.

Installations

Pipework and valves

Major, published, requirements refer to the need for:

- gas pipework to be located in spaces and ducts which are ventilated to the outside air or to the air of the room. Pipework should not be placed in unventilated voids, ceiling spaces, or in ventilation ducts which are part of an air supply into or an extract system from, any room

- pipework of adequate strength, well supported and if exposed and not more than 2.4 m from the floor to be of mild steel, and in all cases with the number of joints kept to a minimum

- each lab or workshop to have a readily accessible manual gas isolation valve at the point where the pipe enters the area. A permanent notice beside this valve must state that all downstream valves and gas taps for individual Bunsen burners and other appliances are checked to be in the 'off' position before closing or opening the isolation valve. In some installations it may be desirable to be able to control this valve from near the exit or the teacher's *usual* or seated work position[1].

Bench supplies

Gas taps and other manually operated valves should be:

- sited on top of benches, never at the side where they may be too easily accidentally damaged and that damage go unnoticed

- so designed that it is easy to see they are on or off

- rigidly attached to the bench so that they cannot be rotated with respect to the supply pipework[2].

Portable or moveable equipment

Flexible hoses from overhead booms or for connecting service bollards to supplies from the floor shall be:

- connected to the fixed supply by means of a flexible hose with a self-sealing plug and socket-end fittings[3].

- kept as short as possible, not anywhere exceeding 1.4 m

- have plug and socket self-sealing connectors of a type which will not be confused with supply lines for other fluids. Each outlet socket should be clearly marked with the type of service supplied by it

- be adequately ventilated, i.e. each structure or unit for natural gas, such as a bollard, should have ventilation holes at a high level. For heavier than air gases the ventilation will have to be at the bottom. *Note particularly that IM/25 was not written with the use of LPG or 'bottled' gas in mind*

- in the case of work stations or mobile fume cupboards which are supplied from a high level, the entry connections should be at a minimum height of 1.8 m from the floor. Flexible hoses need ties to prevent them unnecessarily overhanging the teaching area. This requirement also applies to any wires or other arrangements designed to restrain overhead booms.

1 Systems are now available with remote shut down facilities and which use combinations of solenoids and diaphragm valves. In special situations and for some installations it may be desirable to provide external means of automatic shutting down and restoration of supply to each teaching area. Such controls may be installed at exit doorways.

2 See Bulletin 159 [6] for details of anti-rotation devices such as the Belfast or Liverpool plate.

3 The 1984 gas regulations [2] require that such flexible hoses be of metallic construction. The hosing should comply with BS 669 part 2 [7] which recommends a special sleeve to further protect the stainless steel corrugated hose against corrosive gases. As an alternative the hose may be protected by a stripwound external stainless steel cover

Connected equipment and apparatus

Some existing apparatus, e.g. kilns or laboratory furnaces, may not have been constructed to modern standards. Though it is not necessary to update such equipment to the most recent standards, it must be safe for use by inexpert students.

Any DIY constructed or modified apparatus must be safe in use. One way of ensuring this is by consulting the appropriate standards and codes of practice, e.g. British Standards or British Gas Standards. The HSE have now published an Approved Code of Practice for Standards of Training in Safe Gas Installation [8].

Safe start-up and shut-down procedures must be detailed and prominently displayed next to any gas powered workshop apparatus. Such details in any case should have been provided by the manufacturer to meet relevant requirements of Section 6 of the Health and Safety at Work Act [1].

If any device uses air or some other gas under pressure admixed with the fuel gas then a non-return valve must be used [9]. It must be of a design acceptable to British Gas (or where relevant the LPG supplier).

Maintenance

Broad requirements

Section 2 of the Health and Safety at Work Act [1] requires regular maintenance of all plant and equipment. Testing and maintenance should be carried out, by competent personnel, on a regular basis and records kept.

Specifics

A tabulated checklist provides a useful summary of specific requirements. A suggested schedule of simple visual inspections, checks and tests is thus tabulated below. The style of this schedule is rather like that of the Appendix to HSE Guidance Note GS23 [10].

The GS23 table deals similarly with the safety testing of portable electrical equipment. Note however that our gas version encompasses both equipment and the piped supply systems to which it is connected.

The table indicates those parts of the overall system which are to be checked. Commonsense will usually and easily determine which staff will have the necessary knowledge and experience required. Many items can form part of a wider system of routine laboratory safety checks. Further advice on this with an indication of the frequencies of such inspections is appended to our table overleaf.

For leak tests do not use soapy solutions made from diluted washing up liquid or detergent. Many of these contain chloride ions which will cause premature corrosion or pinholing, especially in stainless steel

A competent engineer should be either CORGI registered or a British Gas Technical Consultancy Service Engineer

Checklist

Area	Test	Pass condition
1 detachable Bunsen tubing	visual inspection	no damage caused by heat, ageing or by mechanical abuse
		makes tight fit on riffled connectors of burner and on gas taps
2 bench gas-taps plug-in valves	(a) visual inspection	no damage or corrosion; easy to see on or off positions; easily turned on and off, but are not too loose
	(b) test for leaks with leak detection fluid	no smell of gas no leaks
	(c) try to rotate tap or valve	impossible to rotate tap relative to bench
3 pipework	(a) visual inspection	no damage or corrosion
	(b) smell of gas	none
	(c) fuller inspection by engineer (every 5 yrs)	
4 main isolation gas valve	(a) test operation	turns easily on and off
	(b) appropriate notice	clear and correctly sited
5 connections to portable or moveable workstations	(a) gas connectors & pipework on booms	no damage or corrosion to hoses or pipework
	(b) test with leak detection fluid	no leak
6 equipment, e.g., furnace or autoclave	detailed inspection	depends on the design. This may need the services of a specialist engineer

Frequency of Tests

Annual

Tests 1, 2, 3(a), 4 and 5 should be carried out at intervals of not more than one year. Technicians and teachers can carry out these simple visual checks. As with electrical equipment there should be a quick, on-the-spot, check on each occasion the equipment is used. This has always been done by responsible teachers and technicians and is not arduous. If at any time a fault is spotted, e.g. a Bunsen burner is seen to have perished tubing or a bench gas tap is loose on its mountings, then that should not be used until the fault is rectified.

Test 6 will generally require the attention of a competent engineer, depending on the design of the particular item.

Every 5 years

Test 3(b), a full inspection of the soundness of the pipework, will require the services of a qualified gas engineer.

Records and action

Records of the results these tests should be maintained by the school and by EAs.

If any of the above tests result in a fail, isolate the failed section. To do so use the next upstream valve. Post suitable fault notices. Then have the hose, tap, valve or pipework etc. replaced or repaired as appropriate before it is re-connected and put back into use.

Further advice on matters of gas safety or on energy efficiency is available from fuel suppliers, especially the Technical Consultancy Service of each British Gas Region. Note that the Checklist is copyright free.

References (cited)

1. "Health and Safety etc. at Work Act", Part I Sect.2, 1974, HMSO, ISBN 0 10 543774 3.
2. "Gas Safety (Installation & Use) Regulations", 1984, HMSO.
3. "Guidance Notes on Gas Safety in Educational Establishments", IM/25, British Gas and DES, Issued by British Gas, May 1989.
4. BS 6172; "Specification for the installation of domestic gas cooking appliances", British Standards Institution (BSI), 1990. (This will cover rooms used for Home Economics).
5. BS 6173; "Specification for the installation of gas-fired catering appliances for use in all types of catering establishments (1st, 2nd and 3rd family gases)", (BSI), 1990.
6. "Gas taps : anti-rotation devices", SSERC, "Safety Notes", Bulletin 159, March 1988.
7. BS 669:"Flexible hoses, end fittings and sockets for gas burning appliances" (various parts),BSI, 1988/9.
8. "Approved Code of Practice : Standards of training in safe gas installation", Health and Safety Commission, 1987 reprinted 1988, ISBN 0 11 883966 7.
9. BS 4163: "Health and safety in workshops of schools and similar establishments", BSI, 1984 (2 amendments AMD 4850 July 1985 and AMD 5394 Dec.1986).
10. "Electrical Safety in Schools (Electricity at Work Regulations 1989), Guidance Note GS23", Health and Safety Executive, 1990, HMSO, ISBN 0 11 885426 7.

Further reading

The following additional sources have not been cited in the text. They do not cover matters with which teachers and technicians are likely to be concerned. They may be of interest to EA architectural services staff, Health and Safety Officers etc.

BS6644: "Specification for the installation of gas-fired hot water boilers of rated inputs between 60 kW and 2 MW (2nd and 3rd family gases)", BSI, 1990.

IM/2 "Purging Procedures for Non-Domestic Installations" (Recommended procedures for introducing and removing gas from gas supply pipework in premises), British Gas, 2nd edition (2nd impression) 1989.

IM/5 "Soundness Testing Procedures for Industrial and Commercial Gas Installations", British Gas, 3rd Edition, 2nd Impression, 1989.

IM/12: "Code of Practice for the Use of Gas in High Temperature Plant." British Gas, 2nd Edition, 1989.

IM/14: "Standard for non-return valves" (A guide to the design of non-return valves), 1st Edition, 2nd Impression, 1989.

IM/15: "Manual Valves - a Guide to Selection for Industrial and Commercial Gas Installations." (Provides guidance on the selection of suitable types of manual valve for industrial and commercial applications). British Gas, 1st Edition, 2nd Impression, 1989.

IM/16: "Guidance notes on the installation of Gas Pipework, Boosters, and Compressors in Customer's Premises." (This provides a guidance on the installation of gas pipes and ancillary equipment in industrial and commercial premises). British Gas, 4th Edition, 2nd Impression 1989.

IM/21: "Guidance Notes for Architects, Builders, etc on the Gas Safety (Installation and Use) Regulations 1984." (Gives guidance on the application and interpretation of the Gas Safety (I & U) Regulations 1984 in order to ensure compliance). British Gas, 1st Edition, 1985.

Autoclaves

Electrical safety

Testing work by Trading Standards Officers in a London Borough has revealed potential problems with some samples of an autoclave model manufactured by Dixons and sold by a number of the specialist educational suppliers.

These problems involved failure (by a relatively narrow margin) of a high voltage insulation test and other minor difficulties over detailed design features of ceramic terminal blocks etc. The manufacturer has now made arrangements to modify free of charge any autoclaves which were made when the firm was controlled by its present owners. For others a modification kit is being made available.

We have now sent out a safety circular on these points to all Scottish EAs and nominated Health and Safety contacts. Teachers and technicians in Scottish EA run schools will therefore be informed on the detailed arrangements for checking and modifying this particular model of autoclave. For further comment on electrical safety, and other, features of autoclaves - look out for our full review in the "Equipment Notes" of the next issue.

Autoclave maintenance

Some time ago we circulated sample check lists and inspection schedules which, amongst other pieces of kit, covered small portable laboratory autoclaves. These test and inspection schedules were intended to assist Scottish EAs implement some of the requirements of the "Pressure Systems....Regulations, 1989" [1] as outlined in Bulletin 167 [2].

Some of our advice concerned interpretations of *competence* in those delegated to carry out some of this work. Now further information is to hand in the shape of part of a new British Standard.

Much of Part 4 of BS 2646: "Autoclaves for sterilisation in laboratories - Guide to maintenance" [3], is concerned more with large scale sterilisation procedures (micro-biological - not medical - that is!) in hospitals or large public health or other micro-biological plants or laboratories.

Only a few sections are thus likely to be of direct interest to schools and colleges. These are: Section 3 on staff training, parts only of Sections 4 and 6 which deal with instructions for use, and maintenance respectively.

SSERC is willing to provide further advice and training according to such relevant requirements of BS2646. Enquiries to the Director in the first instance please.

References

1. "Health and Safety Commission : Safety of Pressure Systems and Transportable Gas Containers Regulations 1989 : Approved Code of Practice (ACoP) COP 37, HMSO, ISBN 0 11 885514 X.
2. "Pressure vessel checks - new regulations", SSERC, "Safety Notes", Bulletin 167, September 1990.
3. BS2646 : "Autoclaves for sterilisation in laboratories : Part 4. Guide to maintenance", BSI 1991.

Technical articles

Strain gauges

A family of four articles on strain gauges is presented. The first two are of general application and cover background theory and techniques for mounting. The third and fourth pieces describe specific educational uses - firstly for physics then for technological studies.

Strain gauge introduction

This article introduces a series of four articles on strain gauges. Here we discuss their structure and principle of operation, and advise on gauge selection.

Preamble

The discussion is deliberately kept simple, with little attempt being made to go into the complexities of how strain gauges work. We trust that our simplified treatment does not lead to errors or misconceptions. A fuller description can be found by referring to the suggested further reading.

Gauge structure

The typical structure is shown in Figure 1. The grid consists of a foil of linear conductors produced by photo-etching techniques. The conductor material is usually the copper-nickel alloy, constantan. It tends to be chosen because the resistance change of a constantan grid line is virtually proportional to the applied strain. The foil pattern is mounted on a backing material, often polyimide, which is tough and flexible.

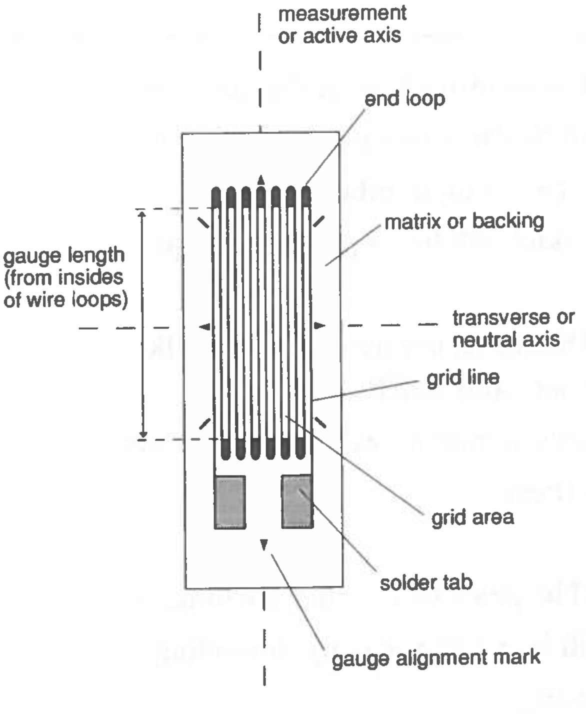


Fig.1 Gauge structure

Operating principle

The gauge is sensitive to strain along its measurement axis. The conductors parallel to this axis are long and thin, whereas along the transverse axis the end loops are broad and are relatively insensitive to strain. Similarly, the broad solder tabs are considered to be insensitive to strain.

Definitions of the terms used in the description are given:

l unstressed length

Δl change in length caused by stress

R resistance of unstressed gauge

ΔR change in resistance from unstressed value

K gauge factor

ε strain

$\mu\varepsilon$ microstrain

Hooke's Law applies. Stress causes a strain. Similarly the existence of strain indicates the presence of stress. It follows that a volumetric change caused by free thermal expansion and which does not cause stress does not therefore cause strain. By definition

$\varepsilon = \Delta l/l$

Strain is a dimensionless quantity. It is more usual to work in *microstrain* ($\mu\varepsilon$) where

$\mu\varepsilon = 10^6 \cdot \Delta l/l$

or *percent strain* where a strain of 1% describes an extension of 1 part in 100. Therefore a strain of 1% corresponds to $10^4\ \mu\varepsilon$, or 0.1% corresponds to $10^3\ \mu\varepsilon$.

The typical yield value of mild steel lies between 900 and 1500 $\mu\varepsilon$ whereas spring steel has a yield value of around 6000 $\mu\varepsilon$.

How does the gauge work? If stress is applied, this causes a strain, which is a relative change in length by $\Delta l/l$. A change in length causes a relative change in resistance $\Delta R/R$. The circuit to which the gauge is connected detects this relative change.

The gauge factor K describes the sensitivity, defined by

$K = (\Delta R/R)/(\Delta l/l) = (\Delta R/R)/\varepsilon$

For a typical gauge factor of 2.0 and resistance of the unstressed gauge of 120 Ω a microstrain of 1 produces a resistance change ΔR of

$\Delta R = K \cdot R \cdot \varepsilon = 2 \times 120 \times 10^{-6} = 240\ \mu\Omega$

Most resistance foil gauges have a gauge factor of around 2. Modern semiconductor gauges using piezo-resistive materials can have gauge factors of 100 or more. They are much more sensitive than traditional gauges, but tend to have poorer linearity.

Performance

Range and linearity

Linearity tends to be 1% or better up to microstrains of 3000. Greater non-linearity can be expected at higher strains. The upper working limit tends to lie between 1% and 4%, at which point the gauge generally peels off or disconnects.

Frequency response

Gauges can be used to investigate dynamic phenomena. The transmission of strain from surface to gauge is rapid and is unlikely to cause any discernible problem.

Current

Current applied to gauges should not normally exceed 20 mA. Therefore with 120 Ω gauges the usual operating voltage should be 2.4 V across a gauge, or 5 V across a bridge circuit[1].

Selection criteria

Temperature effects

The foil material has a low and controllable temperature coefficient. Foils are manufactured to match the materials to which they are to be bonded. You thus have different gauges for aluminium, brass, steel, etc. A gauge for bonding to a steel surface is designed to so expand with temperature to match the free thermal expansion of the steel surface it's attached to. Thus the free thermal expansion of a surface should not generate an apparent strain in a properly designed and used gauge.

[1] We have broken this rule in our impulse article circuit

The apparent microstrain in two different gauges bonded to an aluminium surface is shown (Fig.2). Each graph is labelled with the gauge's linear expansion coefficient. These for aluminium and steel are $23 \times 10^{-6}/°C$ and $11 \times 10^{-6}/°C$ respectively. The near absence of apparent strain in the gauge that matches the surface, and the production of apparent strain in the mismatched gauge, are clearly shown.

Gauge length

Where possible use a largish gauge because they are easier to handle and are better at dissipating heat than miniature ones. However if the structure is small, or the stress area is steep, use a short gauge length. In general the gauge length should be no longer than one tenth of the radius of a circular surface feature, or the corresponding dimension of any other stress raiser at which strain measurement is to be made.

Gauge pattern

A single grid gauge is used if trying to measure strain in one axis. However for general investigative work where the stress pattern cannot be presumed to be known a two- or three-element rosette is normally employed.

Gauge resistance

The typical gauge resistance value is 120 Ω, but some are available at a higher resistance, having the advantage that they dissipate less heat.

Sources of supply

General

Of the general distributors of electronic components, gauges are currently stocked by JPR and RS, but not by Farnell, Maplin or Rapid. JPR presently lists one type only (stock no. 594-050), a uniaxial gauge with a temperature coefficient to suit bonding to steel. Its

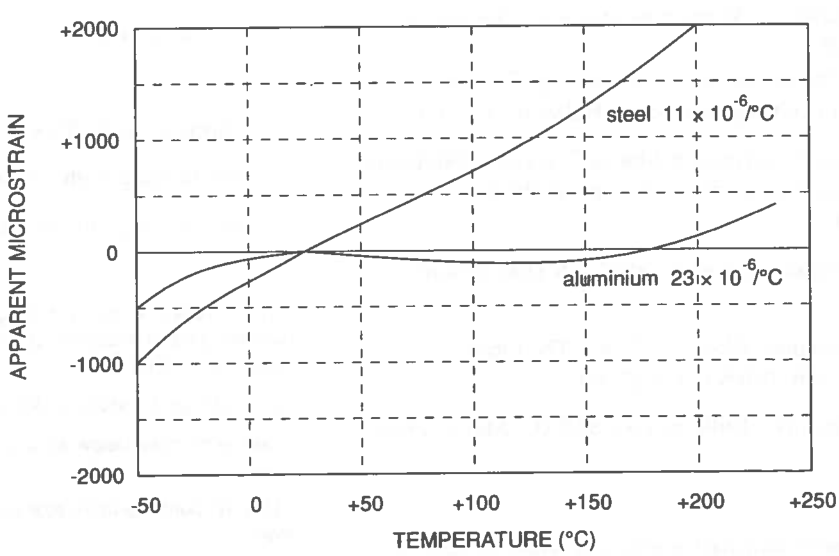


Fig.2 - Thermally induced apparent strain

one-off price is £1.95. RS currently list six uniaxial and four rosette types, prices starting from £2.79. They comprise types which compensate for aluminium or steel in lengths of 2 mm, 5 mm, or 8 mm.

Specialist

There are two specialist suppliers of gauges we know of. One is the Measurements Group UK Ltd., formerly known as Welwyn Strain Measurement Ltd. Their stock range is extensive. It also includes ten types of educational gauges such as stock number EA 06 240LZ 120, a uniaxial gauge, without leads, of 6 mm length, temperature compensated for steel. This is sold in packs of ten at £10 a pack. Ask for the educational discount, which is 2.5%, and specify normal delivery, which is free. A further benefit of dealing with this company is their excellent, free, technical notes and newsletters produced for education. They also supply practice patterns[2] free of charge. These give the first-time user the opportunity to practise the techniques described in the following article.

The other specialist company is Graham & White Instruments, suppliers of Kyowa gauges. Following consultation with SSERC, they also now offer to schools a student pack consisting of ten uniaxial gauges at only £11 a pack, with the normal £3 delivery charge being waived in this special deal. The specification states: gauge length: 5 mm, temperature compensation: steel, gauge factor: 2, with leads attached. An instruction manual (referred to below) and an extensive range of other gauges from Kyowa are also available.

The educational offers from both the Measurements Group and Graham & White are the cheapest sources of gauges of which we know.

Further reading

"Student Manual for Strain Gauge Technology", Measurements Group.

"Strain Gauge Selection: Criteria, Procedures, Recommendations", Measurements Group Technical Note, TN-505.

"Surface Preparation for Strain Gauge Bonding", Measurements Group Instruction Bulletin, B-129-5.

"Strain Gauge Instruction Manual", Kyowa (photocopy version available at £6 from Graham & White Instruments).

"Strain Gauges and Load Cells", RS Data Library, no. 8155.

"Instrumentation: Block 1", T292, The Open University, 1986, ISBN 0 335 17260 1.

"Bridge circuits", Bulletin 150, SSERC, March 1986.

[2] Practice patterns have inactive grids and cannot be used to measure strain.

Strain gauge installation

This article describes how to fasten gauges to surfaces and how to attach leads.

Introduction

Materials

A list of materials, substances and tools required in the procedure is shown below. Apart from the gauge itself, specialized proprietary products aren't strictly necessary. All other listed materials are commonplace and relatively cheap.

strain gauge (with or without leads)
strain gauge terminal pad
wire, 10/0.1 mm
wire[1], 7/0.2 mm
silicon carbide paper[2], RS 567-979
aerosol solvent degreaser[3], based on 1,1,1-trichloroethane, RS 513-691
weak acid, either phosphoric acid or vinegar (for conditioning)
sodium hydroxide solution, 0.1 N (for neutralizing)
4H pencil, or ballpoint pen[4] (marker)
cotton buds
tissues
Sellotape
glass microscope slide, cleaned and degreased
cyanoacrylate adhesive[5], RS 567-159
insulating tape (for fastening flying leads)
soldering iron, miniature tip
solder, 22 s.w.g.
tweezers
side cutters, light duty

Surface preparation

Surfaces must be chemically clean and free of contamination. The usual procedure for preparing a surface prior to bonding is as follows:

- solvent degreasing
- abrading
- marking layout lines
- conditioning with a weak acid
- neutralizing with an alkali

[1] This wire is only required for gauges without leads. One 0.2 mm diameter strand is used to connect a gauge solder pad to a separate terminal pad.

[2] Use 240-grit for steel, or 400-grit for aluminium.

[3] See references below as to environmental hazard and risk to user.

[4] Use 4H pencil to mark aluminium. Use ballpoint pen to mark steel.

[5] Must be new or freshly opened tube.

At the end of the preparation, the surface should be chemically neutral or, failing that, slightly alkaline. A weak acid is therefore applied at the penultimate stage so that the surface is known, then, to be slightly acidic. An alkali is then applied to achieve the desired final condition.

By omitting any of these steps, or by not being sufficiently thorough, you run the risk that your gauge won't stick to the surface, or will peel off. You also have to guard against contaminating a freshly cleaned surface. The following practices should be avoided:

- touching the cleaned surface with fingers;

- wiping back and forth with a swab;

- re-using a swab;

- dragging dirt into the cleaned area from the uncleaned surroundings;

- allowing a cleaning solution to evaporate on the surface; and

- allowing a period of five or more minutes to elapse between cleaning stages or between the final cleaning stage and bonding the gauge.

Wiring

Leads to gauges, whether bought attached to the gauge, or separately connected, are delicate. They have to be secured so as not to be under any mechanical stress. The particularly sensitive parts are the solder tabs on the gauge.

One way of wiring a gauge is to make use of a terminal pad as an intermediary junction between the delicate wires bonded to the gauge and the more robust wires leading to the amplifier circuit. The terminal pad is usually bonded to the surface near to the gauge, perhaps only 2 mm away, and extra-thin wire is looped to link this with the gauge (Fig.1). If the gauge does not have integral leads, links can be made from a single strand of 7/0.2 mm wire.

For gauges provided with lead wires, the terminal pad could be sited remote from the gauge and the lead wires taped down to the surface leaving small loops at the ends (Fig.2). However, by siting the terminal pad near to the gauge, only one surface need be cleaned. Integral wire leads would then have to be shortened as appropriate to connect to the terminal pad.

For ongoing leads from the terminal pad, use 10/0.1 mm insulated wire, which should be secured to the surface by adhesive tape (Fig.2), or by some other means.

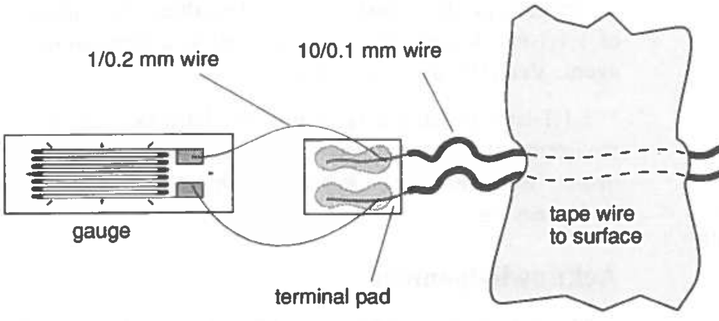


Fig.1 - Gauge and terminal pad

Procedure

Choosing the site

The site where the gauge is to be bonded should normally be where considerable stress is known or expected to occur, for instance on a cantilever arm near to the point which is clamped. Bear in mind that the pattern of stress in a structure can vary. Some parts may not be under any stress. Photoelastic analysis can be employed to investigate stress patterns in structures.

The area to be cleaned should extend by at least a centimetre from the edges of the gauge and terminal pad, if fitted.

Degreasing

Apply the degreasing agent, preferably by aerosol, to the surface and wipe dry using a tissue taking care not to stroke back and forwards.

Abrading

Initially dry abrade the surface by rubbing to and fro with silicon carbide paper. Then add some conditioner (either of the weak acids recommended) and wet abrade the surface. Wipe dry from the centre outwards with a tissue. If the tissue shows dirt, apply more conditioner and continue wet abrading.

Marking

With a 4H pencil on aluminium, or a ballpoint pen on steel, draw a ruler line to mark the transverse axis of the gauge. If necessary,

Fig.2 - Secure attached leads to the surface

draw a second line perpendicular to this to mark the measurement axis. Apply more conditioner and scrub the surface to and fro with a cotton bud. Finally remove any remaining contamination and conditioner with a tissue, again wiping out from the centre. Apply more conditioner and rescrub and rewipe if any trace of dirt is found remaining on the wipe. Take care not to let the surface evaporate dry.

This action should result in alignment marks being burnished on the surface. The surface should not be marked with a scribe because this would cause scoring.

Neutralizing

Apply a liberal amount of neutralizer and scrub to and fro with a cotton bud. Use a tissue to wipe dry, again wiping out from the centre.

Your surface is now prepared.

Positioning the gauge

Remove the gauge from its package with tweezers and place it bond side down on the middle of a clean microscope slide. Similarly place the terminal pad alongside, if this is being used. Cut a length of Sellotape about 100 mm or more long and carefully fasten it to the glass surface, covering the gauge and pad. With firm finger pressure at point *X*, prize up edge *Y* and gently lift the tape whilst maintaining it at an angle of about 45° to the glass surface until completely free (Fig.3).

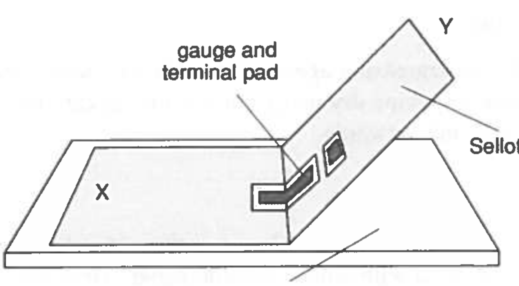


Fig.3 - Lift gauge off glass slide

Now carefully position the gauge on the prepared surface, lining up the gauge alignment marks with the burnished markings. If there is a misalignment, peel off and try again.

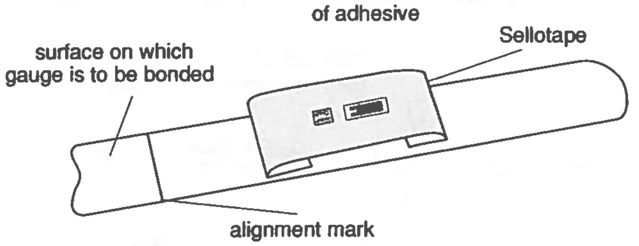


Fig.4 - Ready to apply adhesive

Applying the adhesive

Carefully peel off the tape working from the gauge end. Keep it fairly taut at 45° to the surface. Roll it back on itself as shown (Fig.4). Apply a spot of adhesive to the gauge and terminal pad near to the leading edges which will make first contact with the prepared surface when the Sellotape is unrolled. Don't try to spread the adhesive as that will cause it to harden.

Bonding the gauge

Immediately swing the tape round in an arc so that it is held semi-taut over the surface at a 30° angle. With a wad of tissue make a slow but firm single stroke across the tape bringing the gauge down on the alignment marks. Apply firm thumb pressure over the gauge and terminal pad area for about a minute. Wait a further three minutes to allow the gauge and pad to become firmly bonded. Then slowly peel off the tape from all surfaces.

Attaching leads

To prevent solder tabs being contaminated with grease neither the gauge nor terminal pad should be touched. Using a fine tipped soldering iron, tin the solder tabs, making a single dab with the iron on each. Firstly solder the 10/0.1 mm leads to the terminal pad and tape down to the surface leaving a small loop between the terminal pad and tape. If using a gauge with attached leads, these should then be soldered to the terminal pad to connect to the larger conductors. If using a gauge without leads, cut a single strand from 7/0.2 mm wire and make the connection between the gauge and terminal pad, leaving the solder joint on the gauge to the last. Figures 1 and 2 illustrate these points.

Hazards

Avoid skin contact with, and breathing vapour from, the cyanoacrylate adhesive. Avoid breathing the vapour of 1,1,1-trichloroethane, if this is used as a degreasing agent. Ventilate the work area.

1,1,1-trichloroethane is particularly hazardous to the environment as it is an agent which destroys stratospheric ozone. Methanol can be substituted, but is not as effective at degreasing.

Acknowledgement

This article has been prepared by consulting technical literature from the Micro-Measurements Division of Measurements Group Inc., who used to trade in the UK under the name of Welwyn Strain Measurement.

Technical Articles

Capturing impulse with strain gauges

A description is given of apparatus designed to sense the changing force of impact during an impulsive blow exerted by a linear air track vehicle. The apparatus comprises a side-arm beam on which are mounted a pair of strain gauges linked to a bridge circuit.

Introduction

One of the recommended experiments in the Revised Higher Grade Physics syllabus is the observation of the variation of the transitory force of impact versus time. This provides the curricular context for the article. Several years ago we worked out a means of observing impulse with Kynar piezoelectric film [1] - apparatus with which, because of its exceptionally high impedances, it is not easy to work. This strain gauge apparatus should prove more reliable. It's also unquestionably simpler. If things go wrong, the fault should be easier to find and put right.

Looking beyond the basic need to observe how force varies with time, the apparatus can be accurately calibrated to provide plots of force in newtons versus time in milliseconds. It can therefore be used to show the equivalence of impulse in newtonseconds and change of momentum in kg m s^{-1}.

Apparatus description

Mechanical arrangement

The apparatus comprises a spring steel beam mounted in a vertical plane with its longitudinal axis horizontal (Fig.1). We therefore call it a *side-arm beam*, or *arm* for short. A pair of strain gauges are bonded to it and sense the amount of flexing. The arm is clamped alongside a linear air track in such a way that its tip protrudes above the centre of the track. The height of the arm is arranged so that it is level with a blade or prow attached to an air track vehicle.

We made our side-arm beam out of a hacksaw blade (Eclipse, AM46B, 30 cm), material which is both inexpensive and ubiquitous. It also has an end hole, of which use is made in calibration.

We found that if this material is clamped about 50 mm from one end it will comfortably accommodate strain gauges and adequately extend over the air track. It has the right amount of stiffness for our purpose and the amplitude of its oscillations after impact are sufficiently low that they do not interfere unduly with the impulse signal. An equivalent blow to a longer arm causes low frequency, large amplitude, oscillations. These swamp the signal we are trying to detect.

Two score marks should be made on each side of the hacksaw blade at 40 mm and 50 mm distances from the centre of an end hole (Fig.2). The former (BB') should be made with a ball point pen to mark where the centres of the gauges are mounted. The latter (AA') should be scribed to mark where the blade should be clamped in the jaws of a small vice (e.g. Rapid, 85-0380).

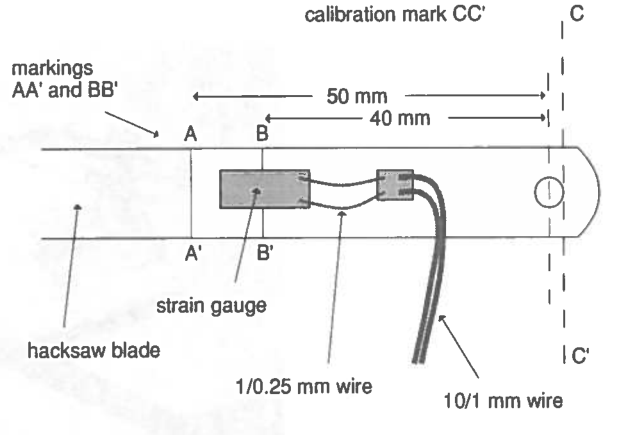


Fig.2 - Markings on hacksaw blade

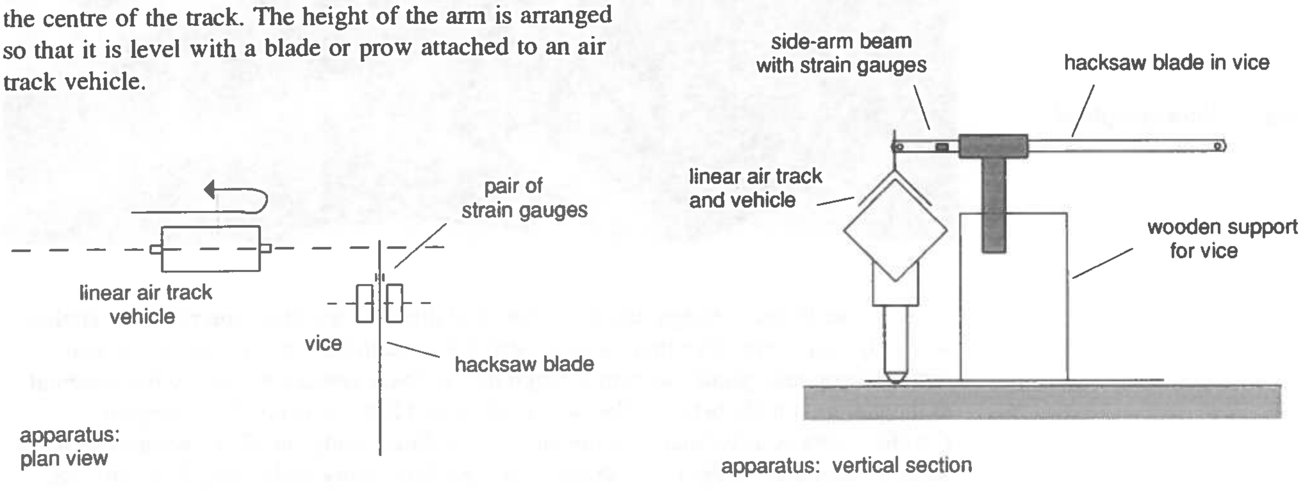


Fig.1 - Apparatus: plan and section

The method of fixing strain gauges to surfaces, and wires to gauges, is explained in an accompanying article. Since it is absolutely essential that this is done properly, and since to do so takes care and time, the Centre is prepared to supply to schools, through our Surplus sales service, hacksaw blades with strain gauges attached, as per our description here. A charge to cover the cost of assembly is included in the purchase price. Details can be found in the section headed 'Surplus' in this issue of the Bulletin.

The side-arm beam, or hacksaw blade, is clamped in a small vice mounted on a specially built wooden stand that sits on the laboratory bench alongside the linear air track (Fig.3). The stand height depends on the height of the vehicle on the linear air track and the size of the vice. We built ours out of 6 mm plywood which had been cut into strips 200 mm broad. Two boards of 9 mm MFD were added for reinforcement. The design is shown in Figure 4. Neither the design nor materials greatly matter. Only the vertical dimension is critical. Once made and in use, a couple of 2 kg masses loaded on the base give the structure some added inertia. This is to withstand the force of impact exerted on it by air track vehicle collisions.

A small blade measuring roughly 8 mm high by 20 mm long should be fastened to the end of the vehicle that

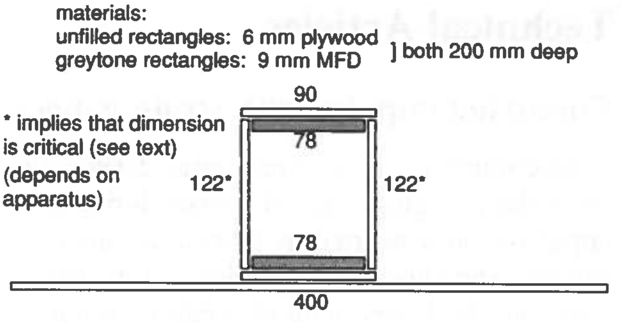


Fig.4 - Design of stand

collides with the side-arm. Some air track kits provide a suitable part. Failing such provision, a blade can be cut from sheet aluminium and wedged into a saw-cut in the head of a small cork. The cork should then be fastened to the upright of the vehicle so that the blade projects horizontally with its front edge vertical.

Circuit design

The circuit (Fig.5) resembles an out-of-balance resistance bridge with differential amplifier gone wonky. There are two missing resistors! How does it work?

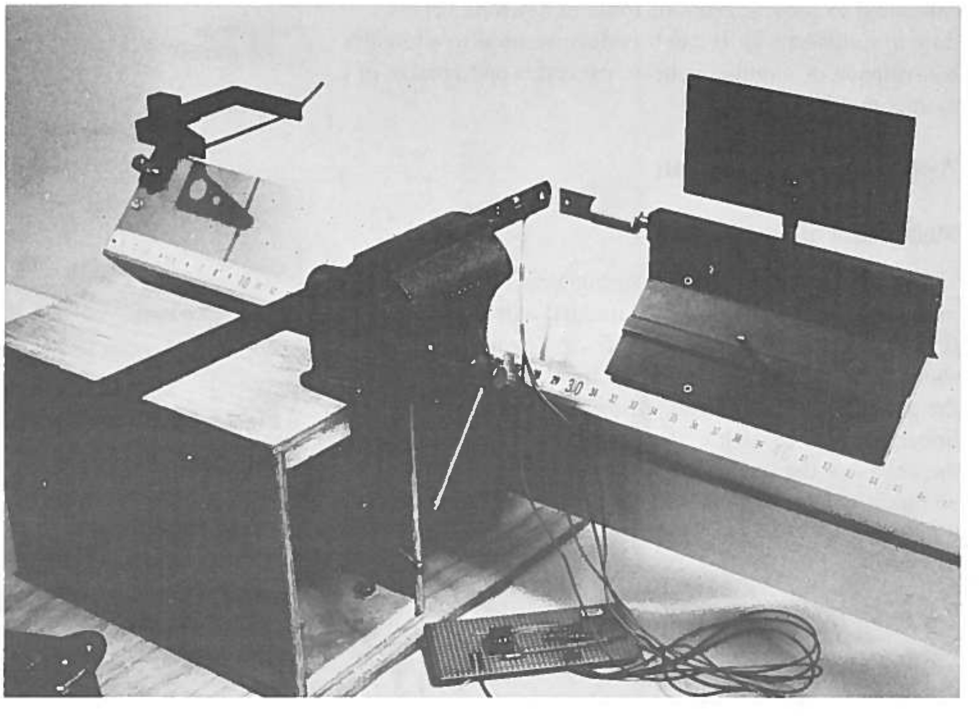
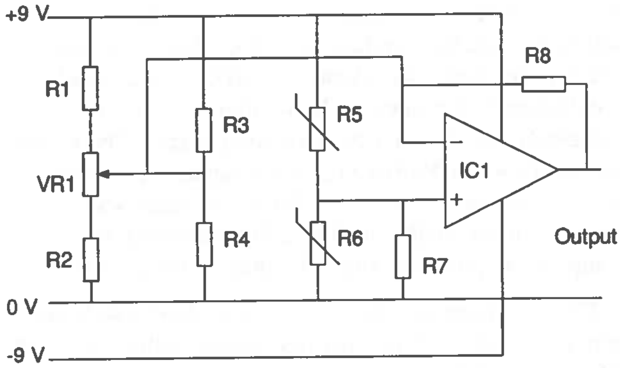


Fig.3 - Photograph of apparatus

A change in strain brings about, by potential division, a shift in the potential applied to the op-amp's non-inverting input. In striving to maintain zero p.d. across its two inputs the op-amp pumps current through the feedback resistor to modify the potential at the common node between the two fixed value 120 Ω resistors. The bridge is therefore always in balance. It's not an out-of-balance bridge at all (sometimes called a *passive* resistance bridge). It's an *active* bridge. The theory underlying these circuits, and the advantages relative to different types of resistive sensor, were explained in a Bulletin issue some years ago [2].



R1,2	560R	0.25 W, 5% Resistor
R3,4	120R	0.25 W, 5% Resistor
R5,6	120R	Strain gauge, Graham & White student gauge or CEA-06-240UZ-120, Micromeasurements
R7,8	22K	0.25 W, 5% Resistor
VR1	5K	10 turn Potentiometer, RS 160-219
IC1	741	Op-amp

Fig.5 - Circuit diagram

Briefly, since large changes in strain produce small changes in resistance, strain gauges can be thought of as being electrically insensitive (although they can be highly sensitive as sensors). This means they can be quite difficult to work with. Signals taken from them need lots of amplifying, and are easily swamped by noise and drift.

We therefore need to optimise on bridge sensitivity. The bridge with the greatest sensitivity is one where all its arms have the same nominal resistance - hence its adoption here. The transfer function of a bridge is the relationship between its voltage output and change in strain (or whatever other physical quantity is being measured). Since, of the two types of bridge, only the active one is linear, that's why it's used here.

Sensitivity is further increased by two other means:

(1) the use of two gauges mounted on opposite sides of the side-arm beam so that if one is compressed, the other is extended; and

(2) a highish supply voltage of 9 V across the bridge.

Power is drawn from a dual rail ±9 V regulated supply capable of delivering 75 mA. If you don't have a regulated supply with this specification, do not work at a higher operating voltage because the gauges and resistors will overheat. Either work off a lower dual rail voltage of ±6 V, or ±5 V, or add 22 Ω, $^{1}/_{4}$ W dropping resistors between a ±12 V power supply and the circuit's supply rails.

DC offset

Ideally, with a perfect op-amp and matched resistors and gauges, the output signal will be 0 V under zero strain. Really, though, it's not! To compensate for this, a potential divider has been connected to one part of the bridge to slightly moderate the feedback current. A ten turn pot is needed to give sufficiently fine adjustment.

Circuit performance

By applying moderate finger pressure to the side-arm beam, you should satisfy yourself that the circuit works. Note its bipolar nature and note the amount of pressure sufficient to produce an output of 4 V. This is as large as the output should be allowed to swing to.

The circuit isn't sophisticated. It strikes a balance between trying to be simple and providing the minimum required to get you by. Its chief defect is drift due to temperature. Both the gauges and fixed value 120 Ω resistors generate about 0.17 W of heat each. By being bonded to the hacksaw blade, the gauges dissipate this heat quite effectively. However the fixed value resistors swelter due to their internal heating. Any draught of air can greatly affect their temperatures, and quite possibly the bridge output.

In practice, this isn't usually too bad. In the still air of our laboratory, we expect to get drift of no more than about 1 mV per minute, or about 30 mV an hour. This is trivial compared with the usual impulse signal, which is 4 V in 25 ms, a ratio of 20 µV s^{-1} to 160 V s^{-1}. Occasional fine adjustments to the offset pot should be made to annul the effects of this drift.

Only on one occasion has the circuit let us down - as luck would have it, in front of an audience of 230 at an Institute of Physics (IOP) meeting. The cause of the problem was air conditioning in the lecture theatre. Periodically, ferocious blasts of Arctic air would descend on the apparatus causing resistors to shiver. This would send the output cantering off at a rate of up to 1 V a minute. Only if you work under adverse conditions like that, that is giving lecture demonstrations to the IOP, need you consider improving on this circuit to reduce drift.

It may be useful to conclude this discussion by pointing out that crudish circuits such as this are usually quite satisfactory for dynamic

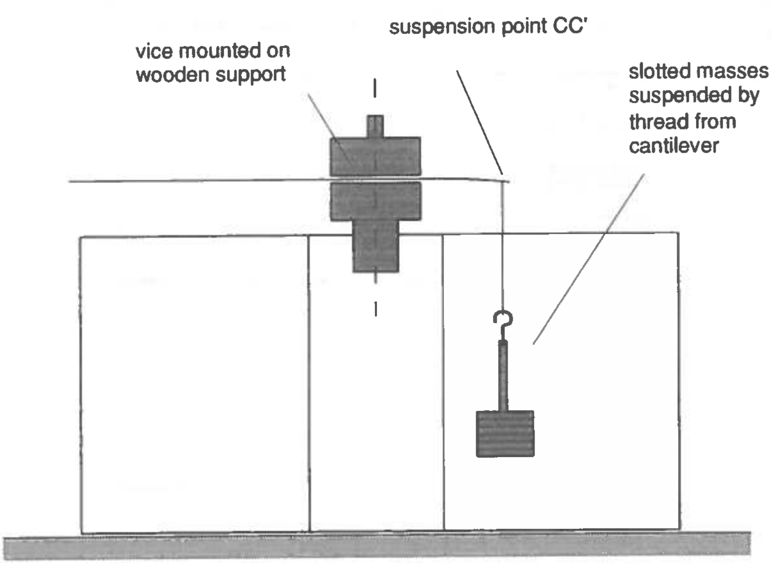


Fig.6 - Calibrating the apparatus

applications of strain gauges, but are of little use in static applications, where this degree of drift would be intolerable (see also next article).

Testing and calibration

The stand supporting the vice and hacksaw blade was turned through 90° so that the blade became a cantilever. A 50 g mass carrier was suspended by thread tied to the mid point of a steel pin inserted through the hole at the end of the blade (Fig.6). The pin was carefully placed transversely across the cantilever at the part of the hole furthest from the clamping point (CC', Fig.2). This marks the place at which the side-arm beam is calibrated in newtons to quantify the impact force. (In any case, when the cantilever is fully laden as described below, the pin tends to creep across the surface to rest against the downhill lip of the hole.)

Firstly, the voltage output under zero load (no carrier) was noted. A series of nine 50 g masses was then added to the carrier to a total maximum load of 500 g and the output voltage versus mass recorded. A digital multimeter was used to measure voltage. The load was then removed and the output under zero loading retaken to find out whether there had been significant drift.

Under normal conditions a drift of a few millivolts might occur during this calibration procedure. Such a magnitude would be trivial. Were, however, drifts of, say, 50 mV or more to be experienced, both ascending and descending readings of mass and voltage should be taken and corresponding readings averaged before drawing a calibration graph.

From a graph of the readings the cantilever was found to behave linearly for loads up to 350 g, or 3.5 N. The sensitivity was around 1.2 V N^{-1}. This sets the effective working range for accurate, quantitative usage at outputs lying between 0 V and 4 V.

Performance

Data logging specification

The circuit output should be connected to a datalogger capable of sampling at 1 kHz or faster. The examples shown (Fig.7) were obtained with Unilab's *Grapher* software, a Unilab Interface and BBC Microcomputer. The bipolar input was selected to display the residual oscillations of the side-arm beam after the impact. Triggering was set on a positive-going signal. The y-axis sensitivity was 1 V/division, with a capacity to display positive voltages up to +5 V. The x-axis scale was 10 ms/division. With a total of 250 measurements to compose the plot, the sample frequency was 2.5 kHz.

Thus one example has an impulse peak of 3.96 V and period of 38.8 ms. The other has corresponding values of 3.84 V and 52.8 ms.

Physical interpretation

Figures 7a and 7b show typical examples of the plots obtainable by this method. Both were obtained with a 0.3 kg air track vehicle moving with an initial speed of 0.16 m s^{-1} before impact. The one differing condition was the place of impact - 36.5 mm (Fig.7a) and 46.5 mm (Fig.7b) from the jaw clamp on the hacksaw blade. Thus the place of impact determines the effective dynamic length of the side-arm beam. The shorter the arm, the greater the stiffness, the lower the sensitivity and the lower the period. Indeed it was observed that the period depends almost entirely on the place of impact for any given vehicular mass.

Another way of looking at this is that, whilst in contact, the side-arm beam and air track vehicle act as a coupled mechanical system with a resonant frequency determined by the length of arm between the place of impact and jaw clamp, and the mass of the air track vehicle.

Impulse and change of momentum

The equivalence of these quantities can readily be shown. Also required are a light gate and digital timer with which to measure the air track vehicle's change of velocity.

Because the process depends on many separate measurements, all of which can be reasonably accurate, and several calculations, it is well suited to carrying out a formal assessment of the errors at each step. An

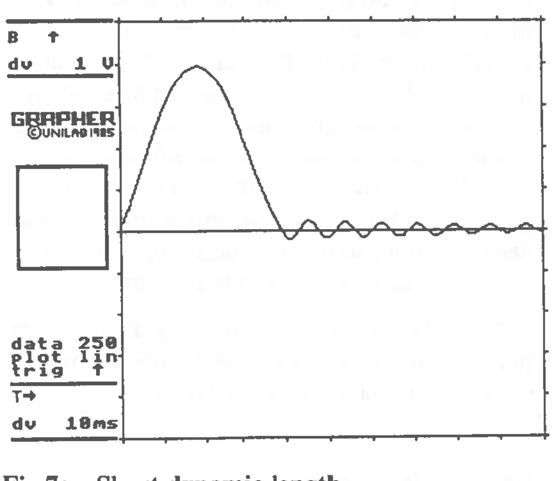


Fig.7a - Short dynamic length

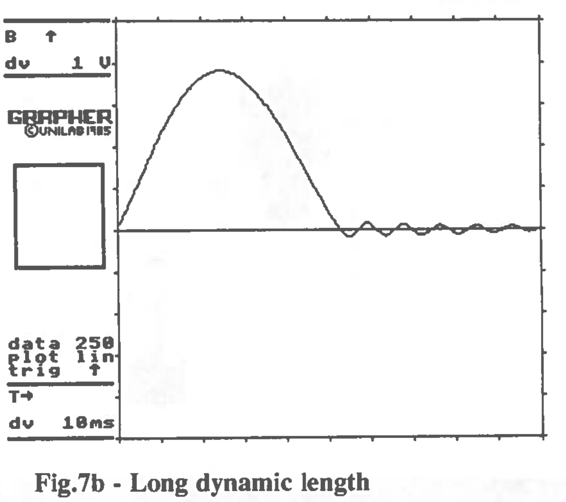


Fig.7b - Long dynamic length

Analysis	Percentage error	Error type
Impulse		
Determining the area	± 1.5%	random
CRO time	± 0.5%	random
CRO voltage	± 0.5%	random
	0.5% high	systematic
Position of hit (± 1 mm)	± 1.7%	random
Calibration of gauge	± 0.2%	random
Non-linearity at high *F*	0.4% low	systematic
Voltmeter	± 0.5%	random
Total errors	± 4.9%	random
	0.1% high	systematic

Best reckoning of impulse = (0.1433 ± 0.0070) N s

Change of momentum		
Length of card	± 0.5%	random
Time	± 0.1%	random
Mass	± 0.1%	random

Best reckoning of change of momentum = (0.1402 ± 0.0010) kg m s^{-1}

Table 1 Analysis of errors

illustration of one such assessment is given in Table 1. This identifies errors as being either random or systematic, and shows the percentage tolerances assigned to each quantity. In carrying out such an analysis, many of the learning outcomes associated with errors (4.4.2) in the Revised Higher Physics syllabus are met.

In obtaining these results we substituted a storage oscilloscope for the computer interface because we had just recently calibrated it. The non-linearity factor arose from overshooting the 4 V limit.

It can be seen from the results that there is no cause to question the continuing usefulness of Newton's Second Law of Motion.

Other experimental work

We refrain from mentioning any of that because to do so would only spoil your own, and, trustfully, your pupils', fun. There are many more matters which can be investigated with this apparatus. Clues for further research can be found in the text. Good hunting!

PASCO Scientific

If you don't have either the time or skill to make your own apparatus and, what's more important still, get it working, there is an independently designed commercial version available. It comes from PASCO Scientific, a US company. Their apparatus is known as the *Dynamic Force Transducer*, stock number ME-9212. It's priced at £169, to which should be added, as they say, shipping costs.

References

1. "Force-time plots and measurement of impulse", SSERC, Bulletin 155, January 1987.
2. "Bridge circuits: Section Two - Active bridge", SSERC, Bulletin 150, March 1986.

[For a copyright free master of a "Contents" list for the SSERC Resource File - see page 32 of this Bulletin. Fully cross-referenced indices are also planned for both Resource File and Case Studies]

Strain gauges

Technology education applications

Suggestions are made for the application of strain gauges in measuring or monitoring strain within the curricular context of the SEB Technological Studies syllabus at the Higher Grade. The general approach is consistent with that adopted in earlier SSERC *Case Study* materials.

Introduction

Within the constraints of Technological Studies most of the applications of strain gauges should be in measuring or monitoring dynamic or short-term static strains rather than in investigating long-term load conditions.

Strain gauges and measurement

The opening article in this family of four provides a simple (believe it!) treatment of strain gauge theory. It should be apparent - even from that simplified account - that any designer, or stress analyst, responsible for strain measurements would carefully choose both gauges and instruments as well as any methods for data analysis and error reduction. Measurement of static strain is more technically demanding than measurement of dynamic strain.

In most technology education departments (or in science ones for that matter) there is currently neither the time, money nor expertise to allow the accurate, long-term measurements of static strains.

Methods for the measurement of forces suggested in the SEB documentation for the course include the use of computer programs, the method of section etc. While it is reasonable to expect pupils to be aware of how strain gauges may be so used to measure static strain, it is not within the ken of many teachers to build and calibrate the necessary sensitive electronic circuitry.

Strain gauges as dynamic sensors

A more useful purpose will be served by using foil strain gauges as sensors to measure deflection, monitor movement or mass, record changes in pressure, measure torque or detect vibrations. (see Fig. 1).

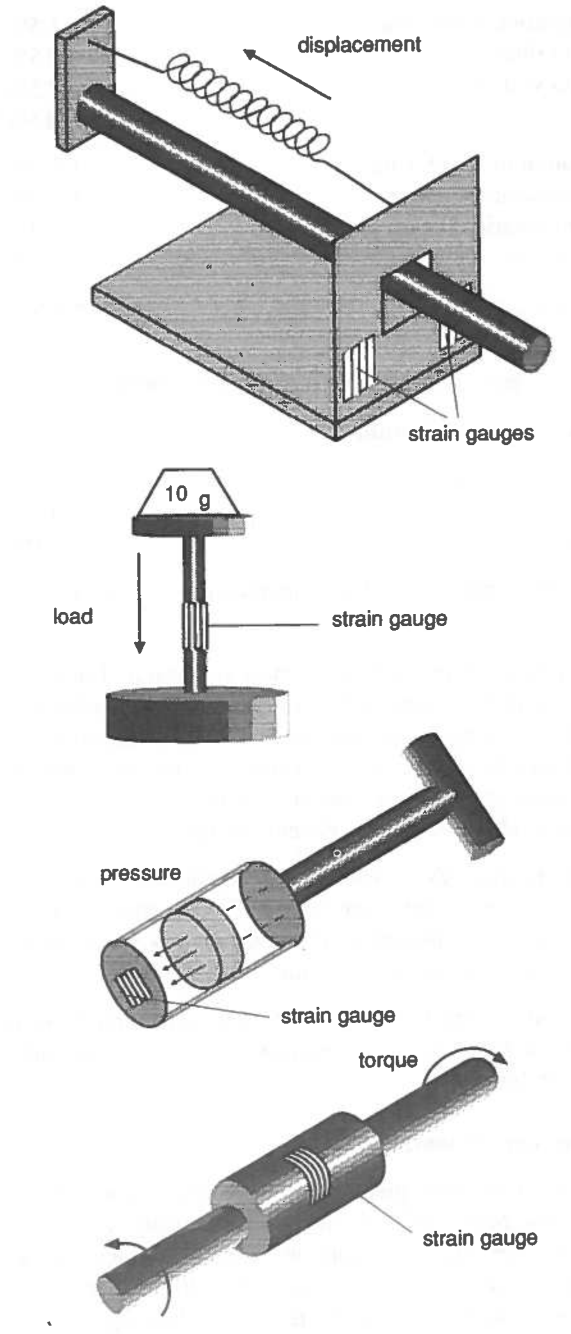


Fig. 1 - Strain gauges as sensors

An integrated approach

In the *Dry Feeder System*, one of our published Case Studies for 'H' Grade Technological Studies [1], we have used a strain gauge on a cantilever arm to monitor the mass flow rate of feedstock moved by conveyor (Figs. 2, 3, 4 and 5). With suitable signal conditioning, the strain gauge bridge output may be easily displayed on a multimeter or recorded on a data logger for later transfer to a computer.

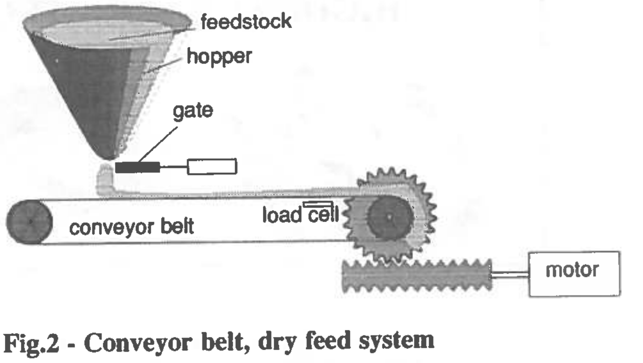


Fig.2 - Conveyor belt, dry feed system

In a suggested extension to the work offered in that Case Study, the signal from the gauge may be used to control the position of a hopper gate and thus the flow of a granular feedstock. This allows for the possible introduction of additional concepts and techniques related to stepper motor control, programming in BASIC and signal conditioning.

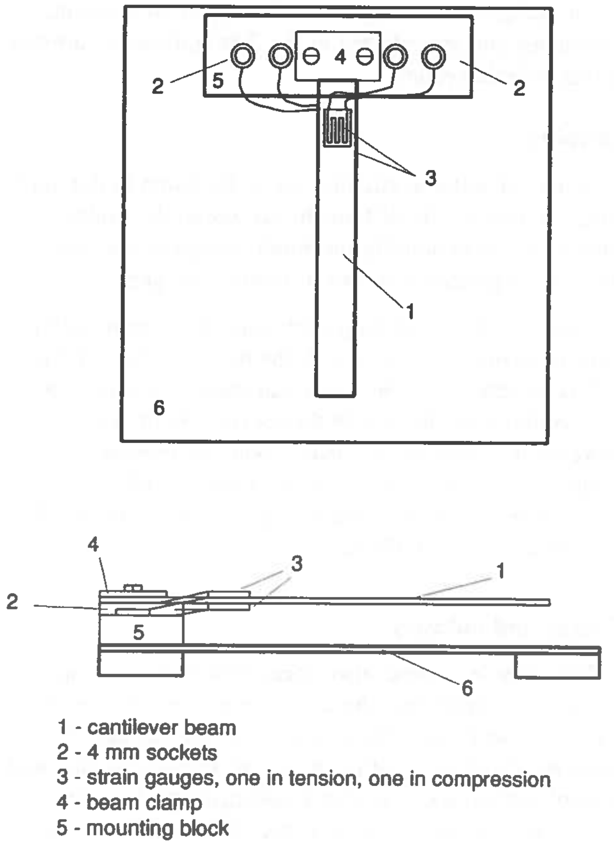


Fig. 3 - Cantilever beam and strain gauge sensor

Other extensions

A current weakness in some parts of our four existing Case Studies is insufficient integration of problems related to structures, mechanisms and energy studies with others requiring knowledge and practical application of electronics, instrumentation and control techniques. By making use of strain gauges, links may be made between these seemingly disparate aspects of the course.

Some teachers, in trialling earlier versions of SSERC materials, also saw these gaps and developed ideas of their own for suitable extensions. Hints on one or two of these were then included in the printed version of our *Teachers' Guide* [2]. One of these requires the application of strain gauges.

Washing machine model

One such piece of work provides an additional *Research and Investigation* activity based on an automatic washing machine. This is part of a modified version of the SSERC *Dishwasher* Case Study [1]. The problem set is that a grossly unbalanced washing load is to be detected. The motor driving a spin drier or wash drum is to be shut down, or otherwise controlled, should the degree of vibration exceed a set limit.

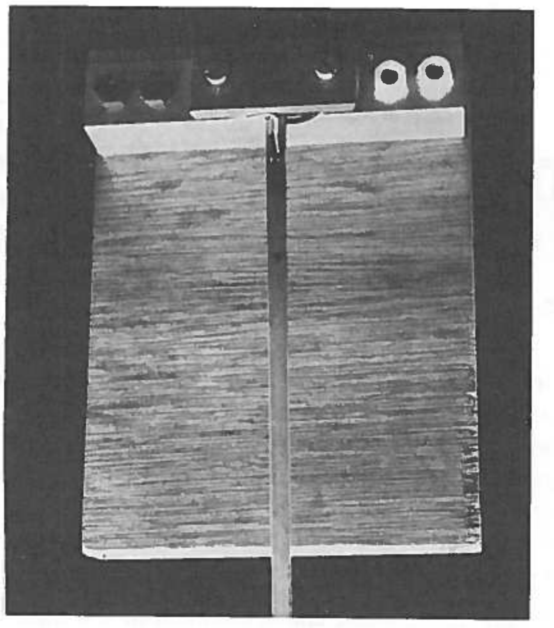


Fig. 4 - Cantilever beam and strain gauge sensor

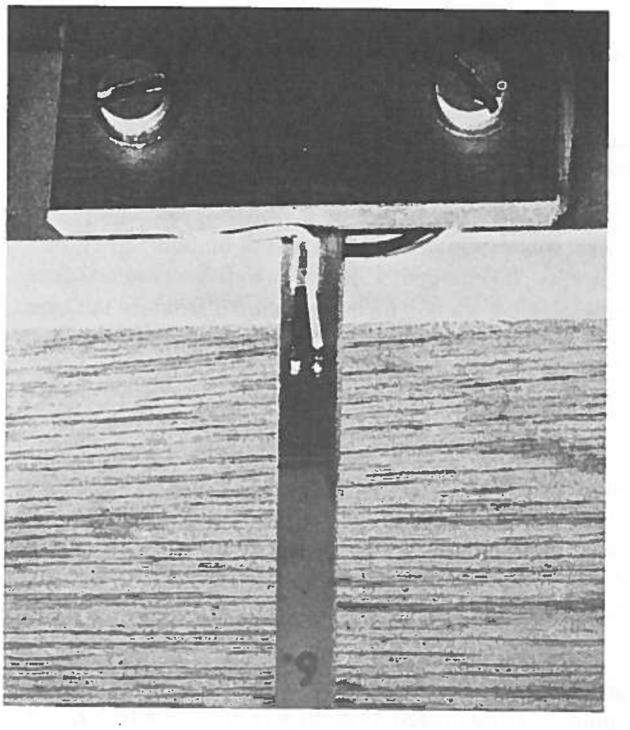


Fig. 5 - Close-up view of strain gauge

One solution to this problem is the mounting of a strain gauge or a pair of gauges - one in tension the other in compression - on a thin beam or strip of metal. This strip forms part of the suspension system for the drum and is coupled to it. Small scale models simulating such a system are relatively easily constructed (Fig.6/over).

The gauges are part of a bridge circuit. Suitable additional circuitry may then be used to detect excessive vibration and to simply cut the power to the drive motor and shut it down. This is a crude, all on, or all off, system. Further work in electronics is possible in designing and building, or just applying, a more sophisticated control circuit.

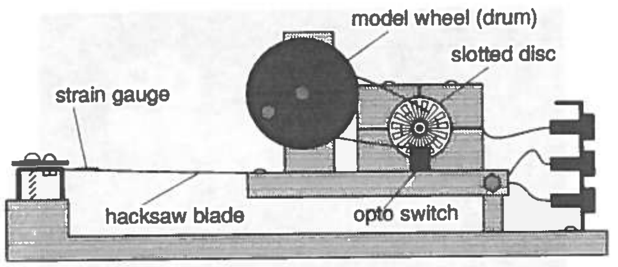


Fig. 6 - Model of washing machine sub-system (off balance load detector to the left)

In a more advanced solution the strain gauge output would be used as part of a closed loop system. The vibration produces what is an essentially a.c. signal. Signal conditioning with conversion to d.c. and use of a comparator will provide crude pulse-width modulation and hence some control of motor speed sensitive to an out-of-balance load condition.

Fitting a slotted disc and opto-switch (to the right of Fig.6) or a tacho-generator will make for a multi-purpose model which will allow for separate investigation of other motor speed control techniques.

A fifth Case Study

Such ideas are in the spirit intended for development of this H grade course. However they only partially address some deficiencies in the SSERC materials.

We would now suggest an additional Case Study which more fully encompasses work on both structural concepts and energetics. This is a well-kent context for technological study which has featured strongly in Open University course materials (see "Further reading").

The bicycle

Our version of such a case study would start with a simple cantilever beam (as for the conveyor belt problem, Figs 3 and 4) and move on to lattice structures. Here strain gauges may be used to monitor and interpret changes in compressive or tensile loads. The bicycle frame offers a relevant structure.

It can also be used with the outputs from attached gauges input to a portable datalogger so that dynamic strains may be logged. Dataloggers such as *EMU*, *LogIT* or *Sense and Control* are all possibilities for such applications (see Bulletin 169 [3] for reviews).

Structures

Questions posed could include:

- where to attach the gauges to the frame to gather the most useful information?

- how can we test a simple triangulated or diamond framework?

- how does the design of the frame affect the strain in the individual members?

Technicalities

Basic techniques

For background theory and information on mounting techniques you are referred to the first and second articles in this bulletin section.

Circuitry

Details of suitable circuitry are to be found in the third article of this family of four. In particular, the bridge circuit we use to amplify the small change in out- put from strain gauges is shown in figure 5 on page 15.

This circuit, if built on prototyping board, may suffer from problems associated with the heating effect in the 120 Ω resistors, and the additional resistance caused by poor contacts on the boards themselves. With care however it is possible to obtain good and repeatable results. If troubles persist it may be worthwhile hardwiring the circuit. This in our experience invariably overcomes any such difficulties.

Energy and industry

This bicycle context also offers a further move into energy investigations. These may in turn be coupled to the earlier work on structures and carried forward into areas requiring study of mechanisms, instrumentation and control techniques. It is also a potential lead-in to an industrial study as required by the SEB Conditions and Arrangements.

These aspects of our fifth Case Study will be pursued in a future bulletin article.

References

1. "Higher Grade Technological Studies : Case Studies", D. Burns, Series Editors SSERC, Publishers SCCC and SSERC, 1991.
2. "Teachers' Guide for SSERC's Case Studies in Higher Grade Technological Studies", D.Burns and SSERC, Publishers SCCC and SSERC, 1991.
3. "Interfacing - The datalogger cometh", "Equipment Notes", Bulletin 169, SSERC, 1991.

For further information on strain gauges see the reading list on page 10.

Further reading

Some more general sources:

"Engineering instrumentation and control", Haslam, Summers and Williams, 1981, Arnold, ISBN 0 7131 3431 3

"Design : Processes and Products", Course code T263, Open University, 1986.

"Design", EPT 593, Open University.

Acknowledgement

We are grateful to Mr.J.Cassidy, Principal Teacher, Technology, Penicuik High School for suggesting, and discussing with us, a number of the basic ideas described in this article.

Equipment Notes

Interfacing - First Sense

This article continues our series of updating reviews on commercial equipment and software for interfacing in science and technology education.

Introduction

In Bulletin 169 [1] we provided an overview of recent developments in interfacing for instrumentation and control. That general up-date was followed by more detailed reports on three dataloggers - *LogIT*, *Sense & Control* and Unilab's *Simple Logger*.

Now we look in more detail at two complementary items, only touched on in our general review. Both have been developed by Philip Harris:

Universal Interface - a hardware device providing a serial communication route from sensors and dataloggers to a wide range of types and models of computer.

First Sense - a range of sensor and software options, also available for several different models of computer.

For some of the background to developments such as trends toward serial communication, and sensor recognition techniques, interested readers are referred to Bulletin 169 [1].

Universal Interface

This provides a link between *First Sense* (and other e.g. *Blue Box*) sensors and "almost any other type of computer found in schools". What are however likely to be specific to any particular computer are the software and the connecting lead.

The Universal Interface can also be used with currently available BBC B/Master versions of other Philip Harris interfacing software, namely *Datadisc Plus*, *Datadisc 40* and *Dataplot*. It also provides a route for data transfer from the dataloggers *EMU* and *VELA*.

In the late to final stages of development is *First Control* software which will allow use of the Universal Interface to bridge between almost any computer and control interfaces such as the *LEGO Interface A* or *Deltronics Control IT*.

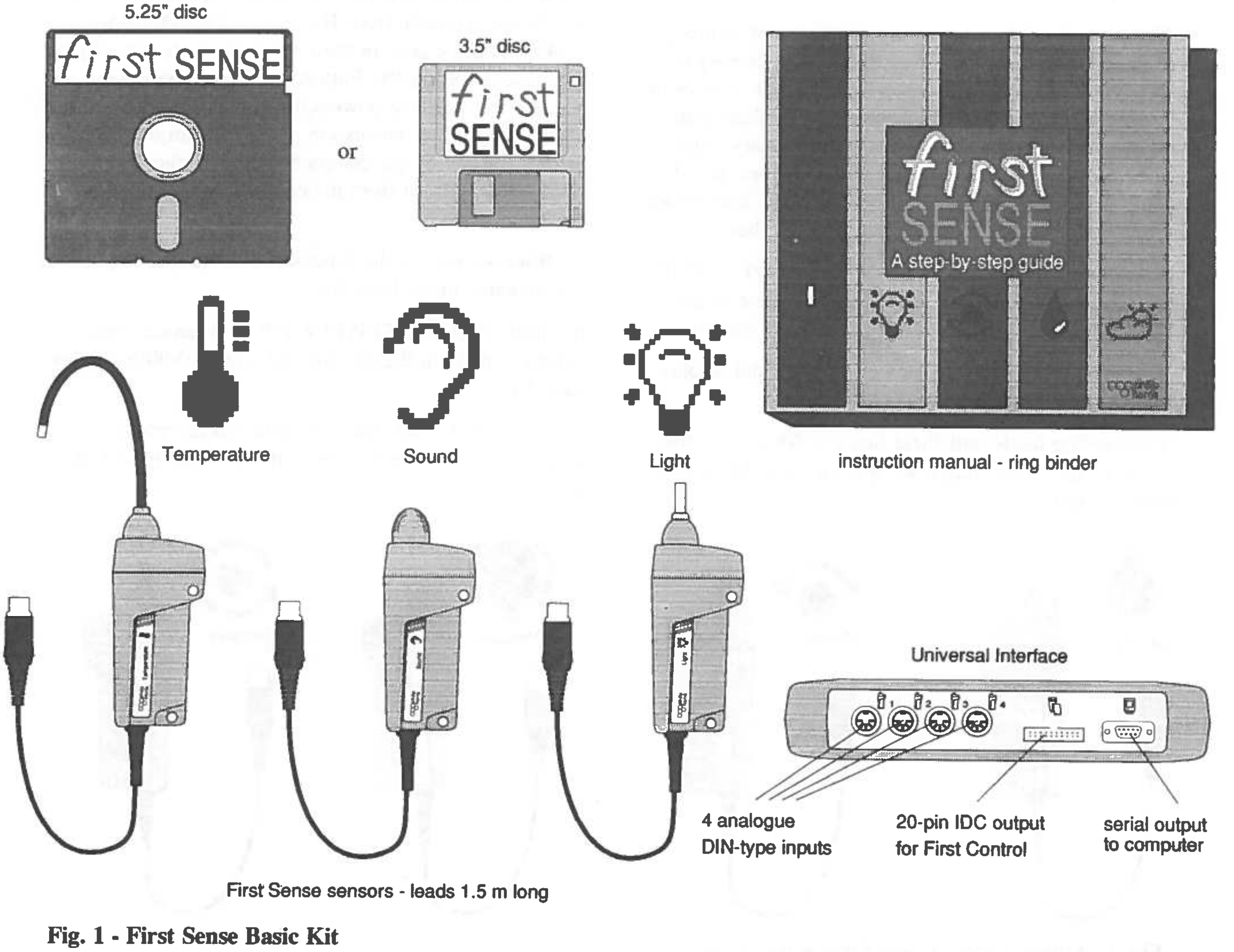


Fig. 1 - First Sense Basic Kit

First Sense

First Sense is an interfacing package intended mainly for use by younger pupils and thus currently chiefly of interest here in Scotland against a background of curriculum development at the 5-14 age range.

The complete First Sense range includes sensors which, at the time of writing, allow measurement of the following parameters:

temperature; light; humidity; pressure; sound; rotation and position.

These sensors can also be used with the latest versions of Datadisc Plus and Dataplot.

This review

Here we report mainly on the *First Sense Basic Kit* which comprises one Universal Interface; three First Sense sensors; software and an instruction manual (Fig.1). The style of the report broadly follows that of our datalogger reviews in Bulletin 169.

Description:- First Sense Basic Kit - one Universal Interface, temperature sensor (range -20 to 110°C), light sensor (moonlight to bright sunlight), sound sensor (quiet class to noisy playground) and instruction manual in a ring binder.

The sensors are ergonomically pleasing and fit nicely into the palm of the hand. They should also be easy to grip with retort clamps. There are no external controls on any of the sensors nor on the Universal Interface itself. This is to be welcomed, particularly for Primary pupil usage. In our opinion, sensor legends and labels could usefully have been made a bit larger to aid in distinguishing one very similar shaped sensor from another.

Supplier:- Philip Harris (Cat. No. T13660/9, £232.00), per kit as described above. A lead and software to suit your particular computer are extra - see next section.

Essential accessories for power, transfer and display of data to or on the host computer:-

Connecting leads and First Sense software - software and serial link connecting lead, specification depends on computer type:

BBC B/B+ and *BBC Master* - A package of two 40-track, single-sided, $5^{1}/_{4}''$ program discs (Cat. No. T18050/7, £15.00) and connecting lead (Cat. No. T14020/0, £9.56). BBC B software runs twice as fast with a 6502 second processor attached. The BBC B software is upwardly compatible (as the jargonists would have it) i.e. it will run also on a Master. Note that the Master software is not downwardly compatible - it will not run on a BBC B.

Archimedes - $3^{1}/_{2}''$ program disc (Cat. No. T18055/6, £15.00) and connecting lead (Cat. No. T14030/3, £12.33). An A3000 must have a serial upgrade fitted, the approximate cost of which is £17).

IBM Compatibles - A - $3^{1}/_{2}''$ program disc for e.g. Nimbus 286 (Cat. No. T18060/9, £15.00) or $5^{1}/_{4}''$ program disc (Cat. No. T18065/9, £15.00), and connecting lead for computers with 25 pin serial connectors e.g. Nimbus PC 286/386 (Cat. No. T14040/6, £16.11).

IBM Compatibles - B - $3^{1}/_{2}''$ program disc (Cat. No. T14050/9, £15.00) and connecting lead for computers with 9 pin serial connectors e.g. IBM AT, PS/2, Nimbus & VX/AX (Cat. No. T14040/6, £16.11).

Nimbus PC186 - $3^{1}/_{2}''$ program disc (Cat. No. T18070/2, £15.00) and connecting lead (Cat. No. T14040/6, £16.66).

Battery power for interface - Universal Interface requires 8, AA (or equivalents HP7, MN1500) dry cells. Packs of 4 cells are available from Harris (Cat. No. P69385/1, £3.45) but these cells or their equivalents should also be available more locally. Battery life should be long because the interface powers down during periods of inactivity. All the sensors are powered from the interface battery and not by the computer. The interface is electrically isolated from the computer and any mains voltages within it.

Other sensors in the First Sense range (see Fig.2), but **not** included in the basic kit are:

Humidity (Cat. No. T13540/9, £49) - measures water vapour content in the air over the range 10-90% relative humidity.

Pressure (T13560/5, £62) - measures atmospheric pressure 850-1150 mB or pressure in water up to 1 m deep.

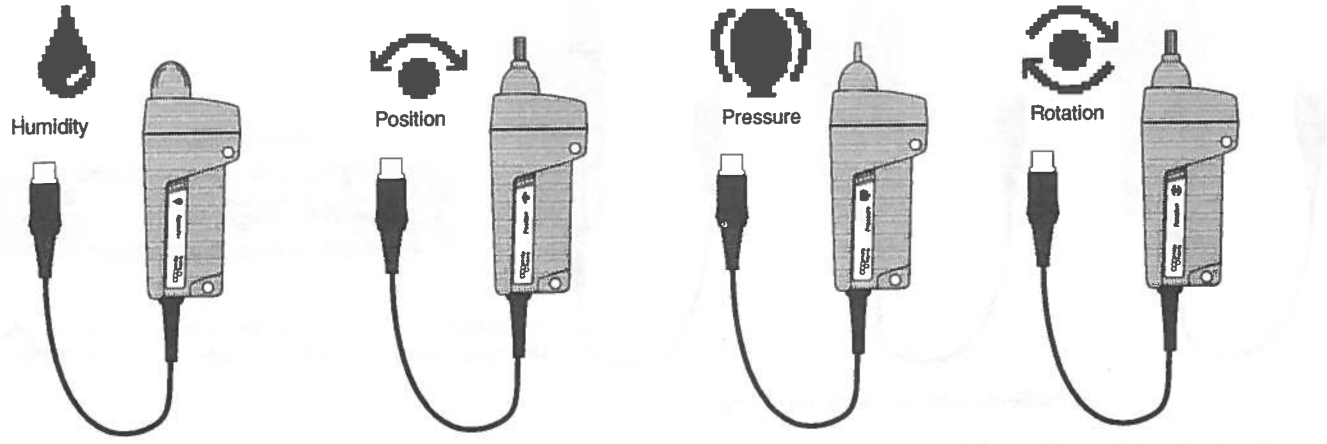


Fig. 2 - Other sensors in the First Sense range

Rotation (T13600/2, £36.86) - measures revolutions per second (0-100) or *windspeed* in km/hour (0-100). The shaft of this sensor fits *LEGO Technic* constructions. Philip Harris warn in the documentation however, that the rotating shaft should not be subjected to sideways strain e.g. by connecting a shaft directly to a motor, wheel or pulley.

Harris suggest *LEGO* couplings (universal joints) should be used. Given that this is the case they should perhaps consider the supply of such a coupling with the sensor. Unfortunately the manual includes an illustration with a direct pulley and fixed axle coupling, a mere two pages on from that very warning.

Position (T13620/8, £36.86) This measures angles 0-360° corresponding to a scale of 0-100. The shaft of this sensor also fits *LEGO Technic* constructions. This sensor is, we are assured, robust but very sensitive (a bit like ourselves really!).

A 3 m *Sensor extension lead* is also available (T13620/2, £5.71).

Hardware features

Universal Interface

Weight (with/without batteries): 0.398/0.578 kg

Connections (see Fig.1):

4 analogue DIN-type inputs are provided on the Universal Interface for incoming data signals. These can be from either First Sense sensors or 0-1 V signals from earlier Harris *Blue Box* sensors. Using the latter means buying a *Blue Box to Universal Interface connecting lead* (Cat. No. T14158/7, £5.55 each or pack of 4, Cat. No. T14160/5, £18.88). Alternatively you can use instructions provided with the Universal Interface, for making your own Blue Box leads.

Note that the interface is intelligent, recognising sensor type and identifying which sensor, if any, is plugged into each of its sensor inputs.

A D-type serial output provides a link with the computer through a suitable lead plugged into the computer's RS423 input or on a few models, some other serial input port.

An IDC 20-pin socket is provided for use with *First Control* software to control buffer boxes such as the LEGO Interface 'A' or Deltronics Control IT. As we go to press we hear that such software is now on the market.

Portability between computer systems:- We tried the Universal Interface on BBC B, Master and Archimedes A3000 systems with each relevant version of the software. In so far as we can test it, the interface certainly appears 'universal'. Because it is battery powered, the setting up time is minimal since the serial connection leads can be left on each computer system. We had a minor criticism of the battery holders. They weren't securely housed in the compartment at the rear of the unit and could be shoogled about when the interface was moved. Philip Harris tell us that as luck would have it we received a Universal Interface which was part of a batch *sans* foam insert pad.

If you have a mix of BBC Bs and Masters then your £15 buys both versions of the software. The BBC B version can be run on a Master but the version for the latter has greater capabilities.

Accuracy

Note that the figures and comments which follow refer to the accuracy of the Universal Interface itself in interpreting incoming analogue signals as voltages or as to its timing. We have not yet fully tested the First Sense sensors for accuracy, linearity etc. This is partly because such tests, properly carried out are very time-consuming and partly because we anticipate that with their *own* software initial usage will be largely comparative rather than demandingly quantitative.

Voltage:- very satisfactory. Well within 1% error using 0-1 V *Blue Box* sensor assuming 1 V f.s.d. Measurements of voltage were within 3 mV over 0-1000 mV.

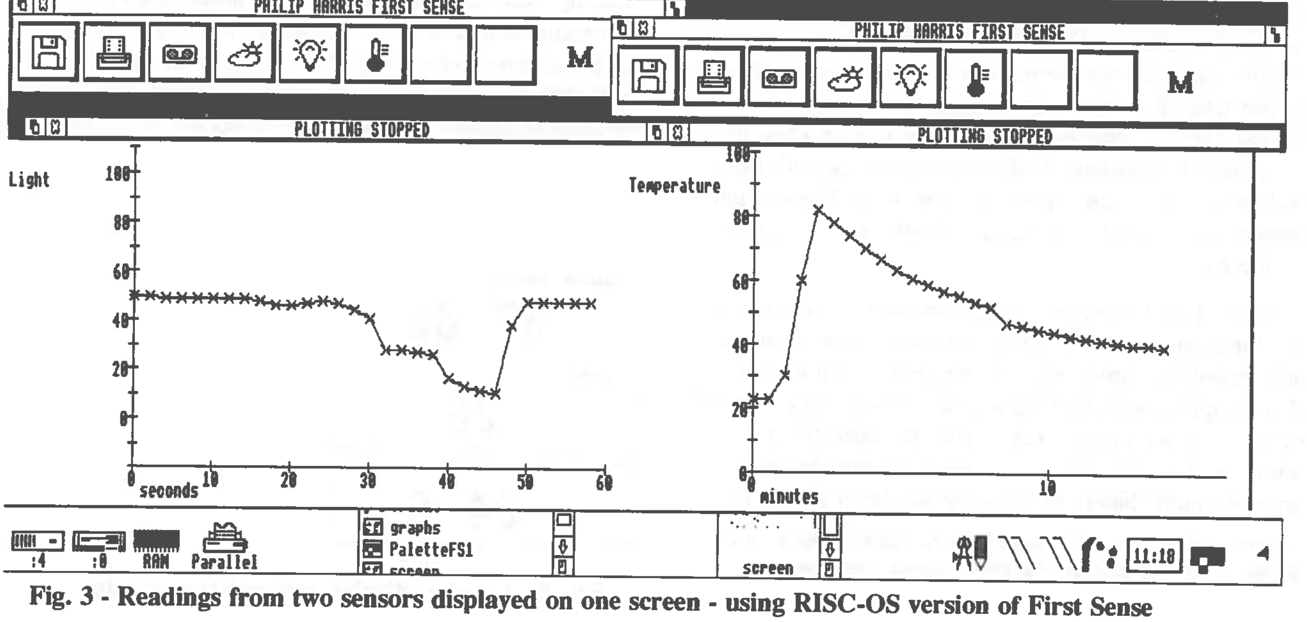


Fig. 3 - Readings from two sensors displayed on one screen - using RISC-OS version of First Sense

Resolution was approximately 1 mV. Software and sensors can actually be used up to 1.2 V f.s.d. with no loss in accuracy or resolution.

Timing: very satisfactory. Well within 1% error over 2 hour test. A maximum of 30 readings may be taken for any one sensor. On the BBC B and Master versions of the software, the computer can log readings from only one sensor at a time. New versions of the First Sense software, currently under development, exploit the Arc's multi-tasking abilities and allow two or more programs to be run at the same time. Therefore readings from the separate sensors can be displayed concurrently (Fig.3).

When used to automatically log results from a sensor, the program logs the maximum 30 readings in the following way:

Logging rate (1 reading every _s)	Total logging time (up to _s)
1	30
2	60
4	120
8	240
16	480
32	960
64	1920
128	3840 (maximum)

Therefore if the logging time goes over any of these thresholds, pairs of readings are averaged. The logging rate is thus effectively halved. This is a similar method of timing to that used by the *LogIT* whilst in *Autolog* mode (see Bulletin 169).

Triggering:- There are no, now almost traditional, facilities available for starting logging by reaching or passing through a given level. However, if any sensor experiences a large change in the parameter measured, this can be used to start and stop a timing routine.

Software features

Menus:- A menu bar along the top of the screen (Figs. 4, 5 & 6) is available for much of the time when the program is running. Note that the screen displays shown in this article are representations of what appears on screen when First Sense is running, not genuine screen dumps. Graphs generally appear as yellow or white lines on a black background. Unfortunately this doesn't print well so we did *Draw* representations of the Beeb B and Master screens and used *Paint* to fiddle with the colours on the Arc versions.

Icons[1] 1 to 3 represent operations carried out when the red function keys are pressed and signify disc, printing and recording/display respectively. Pull-down menus (Fig.4) appear with highlighted bars which can be moved up or down with cursor keys (BBC B/Master/Arc) or a mouse (Arc only). The menu selections can also be accessed immediately by pressing any letter shown on

[1] Icons - wee pictures which represent facilities available on First Sense or sensors plugged into the Universal Interface.

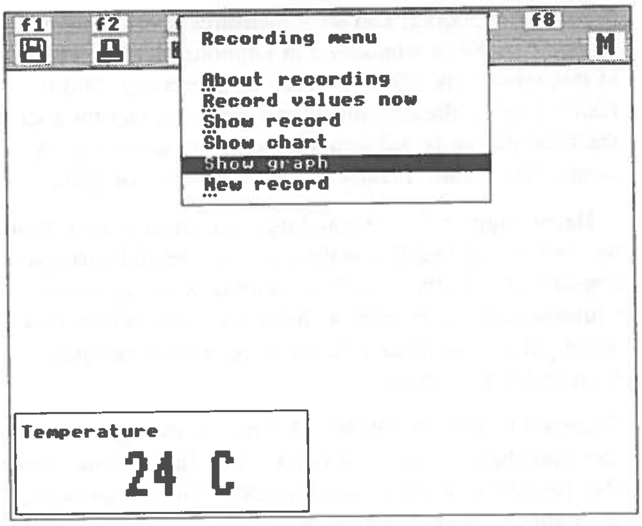


Fig. 4 - Pull-down menu

screen underlined with a dotted line. <SHIFT/function key> combinations allow quick ways of enabling certain operations available on the function key menus e.g. print the screen, log a reading, measure now from a sensor etc.

Note that the software facilities vary depending on the sophistication of the computer used. It is obvious that the software developer has greater scope when programming a machine with 30 times the memory viz a viz the basic Arc compared to the BBC B. For example the BBC B version can only use one screen colour, cannot calibrate Blue Box sensors, cannot save to word processor or *Datadisc Plus* and has no 'quick-key' facilities.

Each menu has a help selection which explains briefly what the menu is about - a particularly good feature. A function key strip is supplied. Icon 4 provides a separate routine for handling data from weather-related sensors such as light, humidity, temperature etc. Icons 5 to 8 appear only when the sensor pertinent to that parameter is connected to the Universal Interface. For example, in Fig.5, there were temperature, light level and sound level sensors connected. Note that the BBC B version of the software does not detect when a sensor has been changed during a session. The *M* at the right hand edge of the icon bar signifies that there is data in memory. The full range of parameters and icon symbols is shown in Figs.1 and 2.

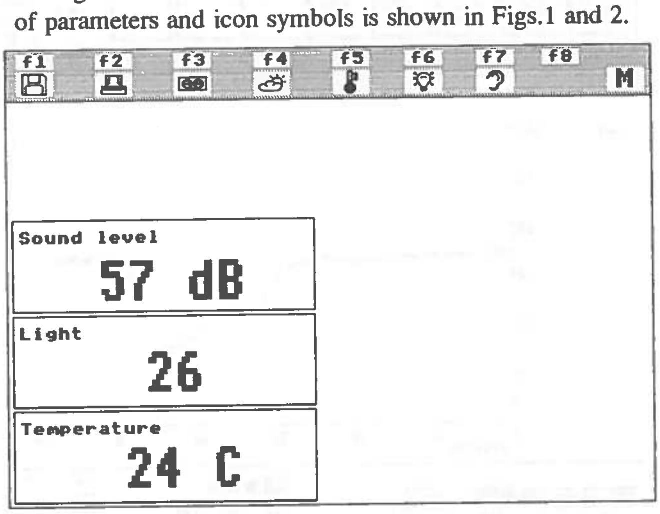


Fig. 5 - Icon bar display and real-time display

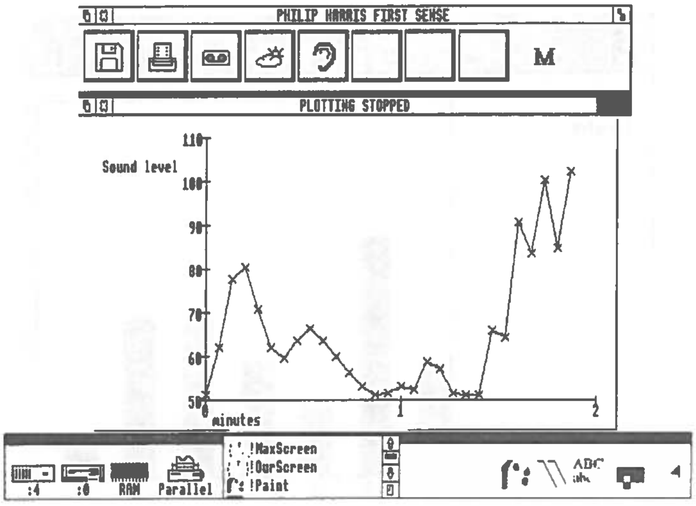


Fig. 6 - Real-time graphical display - Arc version

Display options

Real-time:- A real-time graphical display (Fig.6) is obtained by selecting the *Time graph* option from any sensor menu. This option is only available when no previously recorded data is present. The fastest rate of automatic data capture, for times up to 30 s, is 1 reading/ second and is only possible on one channel at a time. When logging data automatically, the x-axis time scale is changed as each time threshold is passed (see *Timing section* above). Therefore if you happen to stop the logging at 31 seconds you only have 16 readings displayed whereas at 30 seconds you would have had 30. Beware logging for anything more than an hour or the program tries to cram too much into the x-axis (see Fig.7). The time scale would be improved if rationalised into hours. Conversely, if you log for less than 10 seconds and re-display the graph via the *Recording Menu* there will be no time scale on the x-axis!

Analogue readings from up to four sensors can be displayed concurrently on screen in large type (Fig.5) by pressing the relevant combination (Shift/sensor function

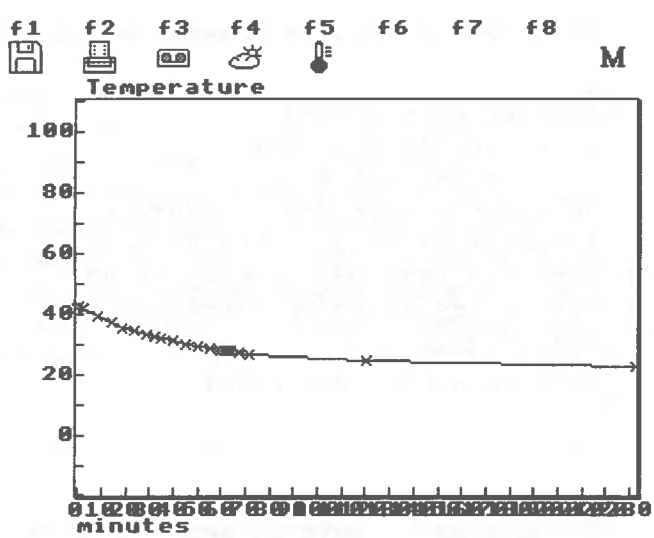


Fig. 7 - Timing for more than an hour!

key) or selecting *Measure now* from the sensor menu. The readings appear to be updated about every second. This facility is extremely useful for checking outputs from sensors. Also available on the same menu is a facility to show maximum and minimum values recorded by each sensor during the current logging session. We like how the software customises the menu to suit the sensor e.g. highest, brightest, hottest, fastest etc. Such information is particularly useful when recording weather data e.g. maximum and minimum daily temperatures and highest recorded windspeed.

Recorded data:- This can be displayed in three ways. A **graphical display** may be accessed from the *Recording menu* (f3) by selecting *Show graph*. See Fig.8 for a typical screen. This data was taken at irregular intervals. The default style is to join the data points (*X*s) no matter how nonsensical this makes a graph appear.

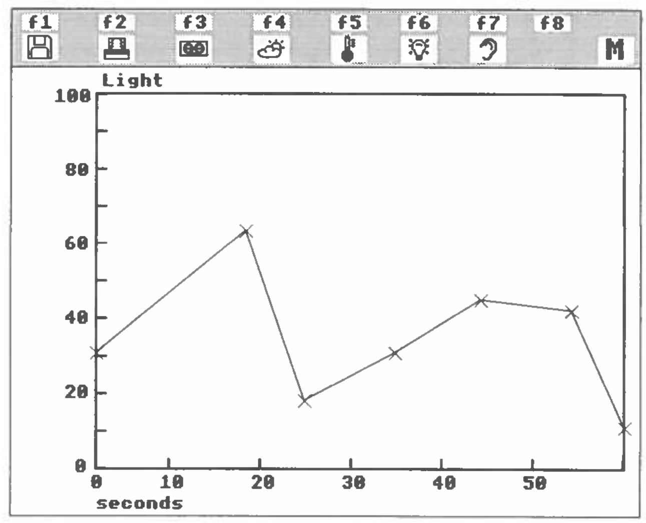


Fig. 8 - Graphical display of recorded data

The manual does however warn that "It is important to explain to children that this smooth line .." (between data points) "...is only indicative of the passage of time and has no significance in relation to the vertical axis." This trend towards joining the dots is OK for software like *Datadisc Plus* where around 1000 readings generally mean you don't see the joins! We would like at least to have seen an option to toggle the lines off. Philip Harris say that they decided that this *low-end* software was designed with the minimum of decisions presented to the user.

If the output from a *Blue Box sensor* (or in this case a simple voltage divider circuit) is calibrated to read say 0-1000 mV, the software takes account of the 0-1.2 V range and displays up to 1200 on the y-axis. It quirkily divides this however into 5 divisions giving scale points of 240, 480, 720 and 960. Perhaps divisions of 200 would look neater?

When recording graphical data from the *Rotation* sensor there is a potential for confusion as the y-axis is not labelled with any units. You could therefore be measuring in revs/s or km/hr. The only clue is the *Rotation* or *Wind Speed* legend above the graph. Confusingly you have to select *Wind Speed* on the sensor menu a second time to change back to measure revs/s from km/s.

Tabular information can be accessed from the *Recording menu* (f3) by selecting *Show record*. See Fig.9 for a typical screen. The data from up to four separate channels can be displayed. The BBC B & Master versions of the software take an inordinately long time to scroll up and down the 30 readings and at any one time only 7 can be displayed. The Arc version can display 12 at a time and is appreciably faster at refreshing the screen. Tabular information can be dumped immediately to a printer using the <Shift and f2> key combination.

f1 Disc <SHIFT>f2 Print f3 Record

TIME	Light
0	31
18seconds	62
25seconds	19
34seconds	29
44seconds	47
54seconds	45
60seconds	11

Fig. 9 - Display of tabular information

A **histogram** display format is also available from the *Recording menu* (f3) by selecting *Show chart* (Fig.10). Up to 10 readings can be displayed at a time with the others accessed by pressing the left and right cursor keys. There is no vertical scaling. If more than one channel has been recorded the bars representing each channel are colour-coded. If you try to continue taking readings with the histogram chart displayed, the screen ends up in a terrible mess. It is a pity the chart cannot be updated as more readings are taken. You must instead access the Recording menu and select Show chart again.

RISC OS version - We have had sight of an interim, RISC-OS[2] multi-tasking version of *First Sense* for the

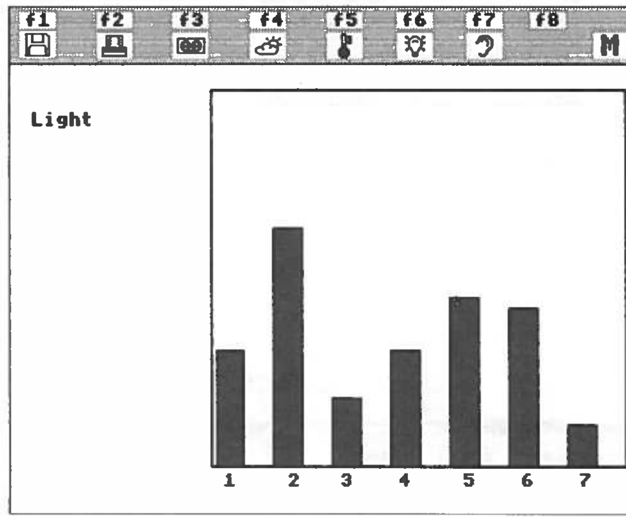


Fig. 10 - Histogram display

Arc. This allows you to install the program more than once on the icon bar[3]. Therefore more than one program can be run concurrently. Hence graphical information from more than one sensor can be simultaneously displayed on screen. We have used one of our specialised screen mode utilities (*!Maxscreen)* from the *SSERC Graphics Library* to allow the display of two graphs with the minimum of overlap (see Fig.3). The screen area in the example shown was captured using *!Paint* and thereafter transferred directly into a *!Draw* window. There it was reduced before printing out. The multi-tasking nature of the Arc is well exploited in carrying

[2] RISC-OS stands for Restricted Instruction Set Computer - Operating System. This is the standard operating system under which all Archimedes computers run. Its big advantage over Complex Instruction Set Computers (CISC) is its ability to process information quickly and therefore appear to run more than one program at the same time - multi-tasking.

[3] The icon bar is the strip along the lower edge of the desktop screen showing icons. These can represent information storage facilities (hard or floppy discs) or applications (First Sense, Paint, Draw etc.) currently accessible from the computer's memory.

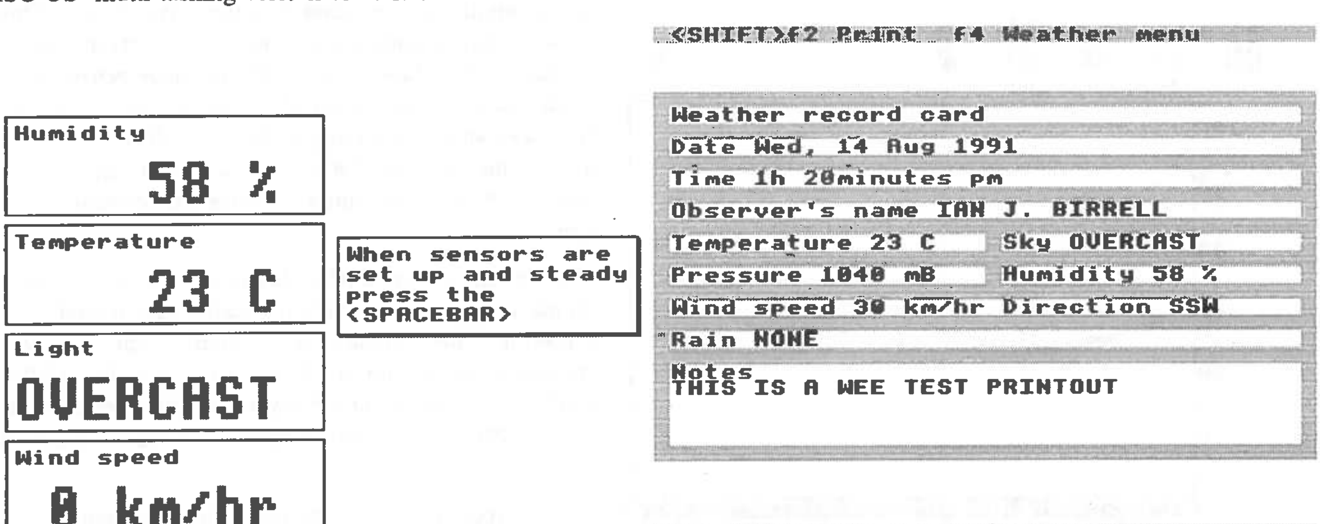


Fig. 11 - Weather data displays

out such an operation. The down side of being able to do all of this is that the timing and logging will go into "suspended animation" if other programs are run or if windows[4] are moved around the screen.

Weather data:- One function key (f4) has been set aside to organise weather related data (Fig.11). Information from up to 4 weather related sensors (temperature, wind speed, light, pressure and humidity) is automatically entered on the weather card. Interestingly the output from the light sensor is interpreted as a description e.g. dark, dull, overcast, bright or very bright. There is also room to enter the observer's name and other relevant notes which may be gleaned from other sources. This section shows particularly imaginative use of captured data. It is therefore to be praised.

Saving, loading and deleting data files:- The first two operations can be easily done from the *Disc Menu* (f1). Pressing <SHIFT/f1> is a short-cut for saving files which is available on the Arc or Master versions of the software. Also available, and only on the aforementioned Beeb computers, are options to save the data (*Saved as*) in various forms. They can be in First Sense, Datadisc Plus or Dataplo*t*, or *Wordprocessor* form. This ability greatly expands the usefulness of any data saved by the system - data can be analysed, manipulated or incorporated in written material without recourse to *cut and paste* techniques. This is a particularly welcome feature and will really come into its own when data can be passed between RISC-OS compatible versions of datalogging programs. Note - the BBC B version of the software has *Saved as* as a menu option but it only saves First Sense data (with the previously saved filename or a new filename).

To a large extent, the user is sheltered from the vagaries of the disc filing system. On the Master, First Sense data is held in an F. library directory. All First Sense files appear first when Saved files is accessed. Unfortunately also displayed are all the program files ($.), any Datadisc files (A.-E.), any Weather files (W.) and any wordprocessor files (T.). This could be a trifle confusing to the novice user who hasn't plucked up courage (see below) to change the default drive. A separate A4 sheet supplied with the manual lists the different types of data files and how they are named. As First Sense and Weather files are the only type which are capable of being re-loaded then they are the only ones which should be displayed. There is no program method by which data files can be deleted without exiting to the operating system.

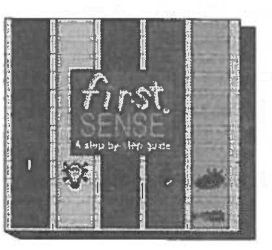
As there are 7 program files, up to 24 separate data files can be saved on the same drive. You can however specify any other drive for data with the *Program Control* section on the *Disc menu*. We wonder how many teachers will be put off trying, and children encouraged, to change things when the following message appears:

```
WARNING
Do not change the program
unless you need to.
This part of the program is
less friendly than the rest!
```

If you are brave enough to go through with it you can change the number of decimal places displayed, specify the drive for data, alter the resolution of screen display (Arc, Nimbus and IBM compatibles only), vary the printer line spacing and finally fix all such settings permanently. This makes the disc pupil-proof, at least in the software hacking, non-physical sense! Make sure you do this with a back-up disc and not your original, for obvious reasons.

Calibration:- The output from any of the Blue Box sensors may be calibrated when used with the Blue Box connecting lead plugged into a sensor socket on the Universal Interface. A Blue Box icon appears on the menu bar and a sensor menu is obtained by pressing the relevant function key. The Blue Box menu has an extra item *Which one?*, which allows the user to enter details of the units, 0 V value and 1 V value. In a similar manner to the calibration procedure on Datadisc Plus the computer assumes linearity of response between 0 and 1 V and scales the parameter accordingly. The documentation has a useful wee table which guides the user on what figures to enter for each sensor.

Documentation:- This is provided in an excellently presented and professionally designed loose-leaf binder. This user manual has clearly defined sections, starting with *Getting Going* and leading on to one such section for each sensor. As you buy sensors beyond the three in the basic kit you are supplied with the relevant sheets to insert in the ring binder. Each section has background information on the parameter measured, step-by-step guides on how to get through the relevant menus and a number of investigations which best apply the sensor. A particularly nice touch is the tag with the sensor name which sticks out at the right hand side and allows relevant sections to be quickly and easily accessed.



The instructions are a model of clarity with liberal use of illustrations, screen displays and menu structures. Although the experiments are aimed at children, the notes are addressed to the teacher and therefore are not suitable for direct use by pupils. They complement the hardware and should encourage the teacher and thereafter pupils to get into datalogging.

The whole approach and presentation of this documentation is highly commended.

[4] Windows are areas of the screen designated for a particular activity or display. Each First Sense program, whether running separately or concurrently, has its own window representing the function keys and another showing the real-time graph (see Fig.3).

Conclusions

Expensive?

For experienced teachers brought up on an interfacing diet of Blue Box sensors, 4-channel analogue port box and Datadisc Plus, this system may seem like a duplication of effort. To pay well-nigh £300 for 3 sensors and an interface with simple software on the face of it does look a bit expensive. This is especially the case when one considers that the dataloggers reviewed in Bulletin 169 offer similar real-time interfacing as well as datalogging. Note that the Universal Interface is **not** a datalogger despite any impression to the contrary we may have given in that Bulletin.

Given these facts should the 'old hand' buy it? If you are thinking of upgrading to Arcs from Beebs and still want to interface with Datadisc Plus then probably the answer is yes. Remember the Universal Interface alone is £125. One of the biggest criticisms we get of Datadisc Plus these days is that it is now too sophisticated. Teachers yearn for something simpler[5]. Read on.

New to interfacing

To those new to interfacing, including primary and secondary teachers and their charges, this package offers a 'no-tears' option for getting started. There are no confusing knobs to twiddle, connections are obvious and the software and documentation offer ample scope for imaginative experimentation. This allows the novice user to forget about the instrumentation side, for the moment, and get on with the science.

The First Sense software is not perfect by any means. We have reservations about 'joining-the-crosses', the speed of scrolling tabular information and the time scaling on short-term and long-term events. We approve of the use of function keys, strangely under-used on many software packages in the past. The use of strong, almost corporate, icon images for each of the sensor parameters adds to the visual impact of the equipment and documentation. This we would see as being important for children new to the interfacing game.

5 Now, more than ever, a general cri de coeur?

Universal?

It is an important consideration that an equipment purchase of this magnitude is not tied to any one piece of software or computer and thereby become obsolete in a couple of years. This package has not been engineered down, either in hardware of software terms, for the primary school market. It has the flexibility to be compatible with more sophisticated software as well as existing gear such as Blue Box sensors and dataloggers like EMU and VELA. The Universal Interface certainly appears to live up to its name. First Sense sensors can be used with the latest versions of Datadisc Plus and Dataplot, both with the added advantage of sensor recognition.

We are also glad to see a recognition that the more sophisticated computer such as the Archimedes merits a version of the software which exploits its hardware and operating system facilities.

Overall verdict

The Universal Interface/First Sense Basic Kit is highly recommended.

Reference

1. "Interfacing - The datalogger cometh", "Equipment Notes", Bulletin 169, SSERC, 1991

Surplus Equipment Offers

Please note that items are not arranged according to the item number sequence. They have been grouped by similarity of application, or for other reasons. Often the item number serves only for stock identification by us in making up orders. Please also note that you will be charged for postage.

Strathclyde customers

The surplus sales service operates at a nominal or trading profit but the associated staff costs are supported by the subvention from local authorities. We run the activity mainly as a service to schools and in order to promote and assist project work etc.

We intimated in the Introduction that Strathclyde Regional Council have cut their 1991-92 subvention to the Centre by about 25%. The Centre is thus obliged to surcharge Strathclyde Regional customers by 25% on orders received since the 1st of September 1991.

Changes in stock

Since most of our stock is bought on the surplus market it is subject to an uncertainty of supply. Some items regrettably become unobtainable. Items recently dropped from our stock list include precision motors at £6.00 (735 and 736), certain capacitor values (696), the solar cell and motor assembly (713) and test-tubes (660). We are sorry for the disappointment this may cause.

Our biggest regret is that the precision motor manufacturer, Portescap, are no longer able to supply us with dead stock. They say we've cleared them out. Our latest purchase was of stock that is not quite dead - hence the colossal hike up in price for tachogenerator motors from £6.00 to £14.00. High though that price is, it still offers you a bargain by being roughly 50% cheaper than comparable new motors from other sources.

Please note that our precision motor specifications now include the back EMF constant, of use in tachogenerator applications in mechanics, or in technology.

Acknowledgements

The Centre is grateful to the companies Griffin and George, and Racal-Guardall, who have donated goods for distribution to schools through our surplus sales.

Motors

590 Stepper motor, single phase, 5 V manufactured for clock or other timing device. Delicate gearing with 40 tooth plastic wheel as output. Suitable for demonstration, or as a method of digital input for control or timing. Uni-directional. Dimens. 30 x 25 x 10 mm. £1.20

591 Stepper motor, 4 phase, 12-14 V d.c., 400 mA, 27.5 Ω coil, step angle 7.5°, powerful motor with 15 mm x 6 mm dia. output shaft. Dimensions 40 mm x 70 mm dia. on 70 mm square mounting plate with fixing holes at 56 mm centres. Circuit diagram supplied. £4.50

655 Precision motor, 0.3 - 24 V d.c., no load current and speed 9 mA, 7000 r.p.m., stall torque 22 mNm, 9 segments, dimensions 39.5 mm x 26 mm dia., output shaft 8 mm x 7 mm dia. steel spline, back EMF constant 3.4 V/1000 r.p.m. Suggested application: tachogenerator. £5.00

749 Precision motor, 0.15 - 15 V d.c., no load current and speed 10 mA and 5250 r.p.m., stall torque 24 mNm, 9 segments, dimensions 47.5 mm x 23 mm dia., output shaft 11 mm x 3 mm dia., back EMF constant 2.8 V/1000 r.p.m. Suggested application: tachogenerator. £14.00

750 Precision motor, 0.08 - 24 V d.c., no load current and speed 3 mA and 5300 r.p.m., stall torque 7 mNm, 5 segments, dimensions 32 mm x 22 mm dia., shaft with pinion 4 mm long x 4.5 mm dia. Suggested application: lemon cell motor. £10.00

592 Miniature motor, 2.5 - 9 V d.c., smooth running, speed governor, no load current 30 mA, dimensions 35 x 40 mm dia., shaft 8 mm x 2 mm dia. £1.00

593 Miniature motor, 1.5 - 3 V d.c., no load current 350 mA at 14800 r.p.m. and 3 V, stall torque 50 mNm, dimensions 25 mm x 21 mm dia., shaft 8 mm x 2 mm dia. 30p

614 Miniature motor, 3 - 6 V d.c., no load current 220 mA at 9600 r.p.m. and 3 V, stall torque 110 mNm, dimensions 30 mm x 24 mm dia., shaft 10 mm x 2 mm dia. 40p

621 Miniature motor, 1.5 - 3 V d.c., open construction, ideal for demonstration, dimensions 19 x 9 x 18 mm, double-ended output shaft 5 mm x 1.5 mm dia. 20p

739 Miniature motor, 1.5 V d.c., dimensions 23 mm x 15 mm dia., shaft 8 mm x 1.7 mm dia. 25p

732 Motor with gear box, high torque, 1.5 - 12 V d.c., 125 r.p.m. at 12 V, dimensions 40 x 40 x 28 mm, shaft 10 mm x 3 mm dia. with key. Suitable for driving buggies, conveyor belt, etc. £5.00

748 Powerful small motor, 0-12 V d.c., no load current 300 mA at 12 V, dimensions 50 mm x 36 mm dia., shaft 15 mm x 3 mm dia. £2.00

625 Worm and gear for use with miniature motors, nylon worm and plastic gear wheel. 35p

378 Encoder disk, 15 slots, stainless steel, 30 mm dia. with 4 mm fixing hole. 75p

642 Encoder disk, 30 slots, stainless steel, 30 mm dia. with 4 mm fixing hole. £1.30

Miscellaneous items

629 Dual-tone buzzer with flashing light, mounted on small p.c.b. The unit has a PP3 battery clip and two flying leads for switch applications. 40p

710 Sonic switch and motor assembly. 1st sound starts the motor, a 2nd reverses the direction of rotation a 3rd sound stops the motor. Driven by 4 AA cells (not supplied). 45p

715 Pressure gauge, ca. 40 mm o.d. case, 25 mm deep and 33 mm dia. dial reading 0 - 4 bar (i.e. above atmospheric). With rear fitting for 1/8" BSP. Suitable for use as indicator for pneumatics circuits in Technological Studies. 75p

746 4 mm push-in fitting, with adaptor for pressure gauge on previous page (Item 715) £1.60

313 Thermostat, open construction, adjustable, temperature range +10°C to +65°C. Rated at 10 A, 250 V, but low voltage switching also possible. 60p

165 Bimetallic strip, length 10 cm or 30 cm. 15p or 40p
high expansivity metal: Ni/Cr/Fe - 22/3/75
low expansivity metal: Ni/Fe - 36/64 (invar)

385 Pressure switch, operable by water or air pressure. Rated 15 A, 250 V (low voltage operation therefore possible).
Dimensions 2" x 3" dia. 65p

419 Humidity switch, operates by contraction or expansion of membrane. Suitable for greenhouse or similar control project. Rated 3.75 A, 240 V. 75p

349 Dual action water valve, 24 V a.c. coil. This is a normally closed, direct controlled, two-way solenoid valve for water. £7.90

371 Ferrite rod aerial, two coils MW and LW, dimensions 140 mm x 10 mm dia. 85p

511 Loudspeaker, 8 Ω, 2 W, 75 mm dia., resonant frequency 250 Hz. 50p

745 Sub-miniature microphone insert, (ex-James Bond?), dia. 9 mm, overall depth 5 mm, connection by solder pads. 40p

723 Microswitch, miniature, SPDT, lever operated. 40p

740 Microswitch, miniature, SPDT, button operated. 25p

353 Reed switch, SPST, 80 mm long overall, fits RS reed operating coil type 1. 30p

354 Reed switch, SPST, 46 mm long overall, fits RS reed operating coil type 3. 10p

645 Ceramic magnets, assorted shapes and sizes. 7p

738 Relay, 6 V coil, DTDP, contacts rated 3 A at 24 V d.c. or 110 V a.c. 75p

742 Key switch, 8 pole changeover. 40p

382 Wafer switch, rotary, 6 pole, 8 way. 70p

688 Croc clip, miniature, insulated, colours - red and black. 5p

741 LES lamp, 6 V. 15p

690 MES lamp, 6 V, 150 mA. 9p

691 MES battenholder. 20p

692 Battery holder, C-type cell, holds 4 cells, PP3 type outlet. 20p

730 Battery holder, AA-type cell, holds 4 cells, PP3 type outlet. 20p

729 Battery connector, PP3 type, snap-on press-stud, also suitable for items 692 and 730. 5p

724 Dual in line (DIL) sockets - 8 way 5p
- 14 way 7p

693 Power supply, switched mode, input: LT d.c., output: 5 V regulated. £2.00

716 3-core cable with heat-resisting silicone rubber insulation, 0.75 mm² conductors, can be used to re-wire soldering irons as per Safety Notes, Bulletin 166. per metre £1.35

714 Sign "Radioactive substance" to BSI spec., ca. 145 x 105 mm, semi-rigid plastic material. Suitable for labelling a radioactive materials store. With pictogram and legend. £2.30

727 Hose clamp, clamping diameter from 8 mm to 90 mm, 101 uses - securing hose to metal pipe, tree to stake, joining wooden battens for glueing, etc. 30p

731 Re-usable cable ties, length 90 mm, width 2 mm, 50 per pack. 12p

612 Beaker tongs, metal, not crucible type, but kind which grasps the beaker edge with formed jaws. £1.20

659 Assorted rubber bungs, 1or 2 hole, per pack. 50p

743 Aluminium evaporating basin, 100 ml. 60p

744 Aluminium evaporating basin, 100 ml, disposable. 30p

728 Pipette pump, should be less messy and more controllable than rubber bulb types, one handed operation, easily disassembled for cleaning. Only 2 ml size left. £5.00

Components - resistors

327 Potentiometer, wire wound, 8 Ω, 25 W, 63 mm dia. 60p

328 " , " , 15 Ω, linear, 36 mm dia. 30p

737 " , " , 22 Ω, linear, 36 mm dia. 30p

329 " , " , 33 Ω, linear, 36 mm dia. 30p

330 " , " , 50 Ω, linear, 40 mm dia. 30p

331 " , " , 100 Ω, linear, 36 mm dia. 30p

421 DIL resistor networks, following values available:

62R, 100R, 1K0, 1K2, 6K8, 10K, 20K, 150K, 125R/139R and 1M0/6K0. Price per 10: 30p

420 5% carbon film, $^1/_4$ W resistor values as follows:

1R5, 10R, 15R, 22R, 33R, 47R, 68R, 82R, 100R, 120R, 150R, 180R, 220R, 270R, 330R, 390R, 470R, 560R, 680R, 820R, 1K0, 1K2, 1K5, 1K8, 2K2, 2K7, 3K3, 3K9, 4K7, 5K6, 6K8, 8K2, 10K, 12K, 15K, 18K, 22K, 27K, 33K, 39K, 47K, 56K, 68K, 82K, 100K, 150K, 220K, 330K, 390K, 470K, 680K, 1M0, 1M5, 2M2, 4M7, 10M. Price per 10: 6p

NB If schools are interested in purchasing values in the E12 range between 1R0 and 10M which are not listed above please let us know so that we can consider extending our stock list.

BP100 Precision Helipots, Beckman, mainly 10 turn, many values available. Please send for a complete stock list. 10-50p

Components - capacitors

695 Capacitors, tantalum,
4.7 µF 35 V, 15 µF 10 V, 47 µF 6.3 V. 1p

696 Capacitors, polycarbonate,
10 nF, 47 nF, 680 nF, 1 µF, 2.2 µF. 2p

697 Capacitor, polyester, 15 nF 63 V. 1p

698 Capacitors, electrolytic,
1 µF 25 V, 2.2 µF 63 V, 10 µF 35 V, 33 µF 10 V. 1p

358 Capacitor, electrolytic, 28 µF, 400 V. £1.00

Components - semiconductors

322	Germanium diodes	8p
701	Transistor, BC184, NPN Si, low power.	4p
702	Transistor, BC214, PNP Si, low power.	4p
717	Triac, Z0105DT, 0.8 A, low power.	5p
726	MC74HC02N quad 2-input NOR gates.	5p
725	MC74HC139N dual 2 to 4 line decoders/multiplexers.	5p
699	MC14015BCP dual 4-stage shift register.	5p
711	Voltage regulator, 6.2 V, 100 mA, pre-cut leads.	10p

Sensors

615	Thermocouple wire, type K, 0.5 mm dia., 1 m of each type supplied: Chromel (Ni Cr) and Alumel (Ni Al); makes d.i.y. thermocouple, described in Bulletins 158 and 165.	£2.20
640	Disk thermistor, resistance of 15 kΩ at 25°C, β = 4200 K. Means of accurate usage described in Bulletin 162.	30p
641	Precision R-T curve matched thermistor, resistance of 3000 Ω at 25°C, tolerance ±0.2°C, R-T characteristics supplied. Means of accurate usage described in Bulletin 162.	£2.60
718	Pyroelectric infrared sensor, single element, Philips RPY101, spectral response 6.5 μm to >14 μm, recommended blanking frequency range of 0.1 Hz to 20 Hz. The sensor is sealed in a low profile TO39 can with a window optically coated to filter out wavelengths below 6.5 μm. Data sheet supplied.	50p
751	Hacksaw blade with pair of strain gauges, terminal pads and leads attached. Suitable for impulse measurement as detailed on pages 13 to 17 of this Bulletin.	£10.00

Kynar film items

See Bulletin 155 for details of applications such as force/time plots and detection of long wave infrared radiation.

502	Kynar film, screened, 28 μm thick, surface area 18 x 100 mm, with co-axial lead and either BNC or 4 mm connectors (please specify type).	£20
503	Kynar film, unscreened, 28 μm thick, surface area 12 x 30 mm, no connecting leads.	55p
504	Copper foil with conductive adhesive backing, makes pads for Kynar film to which connecting leads may be soldered. Priced per inch.	10p
506	Resistor, 1 gigohm, $^1/_4$ W.	£1.25

Opto-electronics devices

507	Optical fibre, plastic, single strand, 1 mm dia. Applications described in Bulletin 140 and SG Physics Technical Guide Vol.1. Price per metre	40p
508	LEDs, 3 mm, red, yellow & green. Price per 10	50p
719	LED, HMLP 3850, 5 mm, yellow. Package untinted and non-diffused.	5p
720	LED, HMLP 3401, 5 mm, yellow. Package coloured and diffused.	5p
721	LED, red, rectangular 5 x 3 mm.	5p

Other components

We also hold in stock a quantity of other electronic components. If you require items not listed above please let us know and we will do our best to meet your needs, or to direct you to other sources of supply.

Items not for posting

The following items are only available to callers. You will appreciate our difficulties in packing and posting glassware and chemicals. We will of course hold items for a reasonable period of time to enable you to arrange an uplift.

Glassware

656	Screw cap storage jar, plastic cap, 4 oz., narrow neck	10p
657	As above but with wide neck.	10p
663	Flat bottom round flask, 250 ml.	50p
664	Flat bottom round flask, 500 ml.	50p
665	Flat bottom round flask, 800 ml.	50p
747	Quickfit vented receiver, 10 ml.	20p

Chemicals

NB: chemicals are named here as described on supplier's labels:

667	250 ml N.H carbamide (Urea).	25p
668	500 ml dodecan-1-ol.	50p
670	500 g Keiselguhr acid, washed.	25p
671	25 g L-Leucine.	25p
672	500 g Magnesite native lump.	25p
673	250 g manganese metal flake, 99.9%.	50p
674	250 g manganese(II) sulphate AR	25p
676	500 g quartz, native lump.	25p
677	100 g sodium butanoate.	25p
678	500 g strontium chloride AR	25p
679	500 g strontium nitrate AR	25p
680	500 g tin metal foil alloy, wrapping quality, 50% lead.	50p
681	zinc acetate AR	25p
682	2.25 litre ammonia solution.	50p
683	500 g carborundum powder, 180 - 620 mesh.	25p
685	500 ml N-decanoic Acid.	25p
712	Smoke pellets by Brocks. For testing local exhaust ventilation (LEV) - fume cupboards and extractor fans, etc.	
	Large (each)	50p
	Small (each)	40p

SSERC MATERIALS FOR TECHNOLOGICAL STUDIES AT THE HIGHER GRADE

RESOURCE FILE

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