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Electronics, Universities and Institutions

The Presidential Address of

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The Institution, until this year at least, has been very fortunate, or wise, in its selection of Presidents. The list of holders of this office makes impressive reading with such names, to take only recent years, as my immediate predecessor Dr. Percy Allaway and before him HRH The Duke of Kent, Sir Ieuan Maddock . . . and so on. The Institution owes a great debt to these distinguished persons who gave so generously of their time and energy in its service. I follow in their footsteps with a deep sense of humility and appreciation, being conscious both of the daunting prospect and of the high degree of responsibility involved. I cannot help wondering whether the Council's normally high standard of judgement has slipped a little for once but note that they limited the amount of harm I could do by nominating me for the office at a time when I was committed to spending nearly three months abroad, mainly in Japan.

The most awesome aspect of being elected President of an Institution is, to my mind at least, the fact that one is expected to make a Presidential Address. The temptation to become profound, all-embracing and pontifical, especially in such a broad and important subject as electronics, is strong indeed. There is a danger of succumbing to what Alistair Cooke[1] has called the 'Sullivan/Conan Doyle' syndrome. Sir Arthur Sullivan broke up his partnership with W. S. Gilbert because he felt that the Savoy operas were frivolous and he wanted to establish himself as a great classical composer. So having scored for a small orchestra more exquisitely than anyone before him and written perhaps the greatest light opera ever, he reverted to his earliest ambition and wrote sacred music of deafening mediocrity.

Conan Doyle was a victim of similar bad judgement. After creating the pure detective thriller and the most famous sleuth in history he devoted himself, in Alistair Cooke's words, to martial epics of stupefying dullness. There are other examples of the same kind but the point is that there comes an urge, if the opportunity arises, to leave a well-developed path in order to become profound and statesmanlike. In other words there is a strong temptation to rise to the occasion. I shall take Mr. Cooke's advice and try *not* to rise to the occasion. Instead I shall make a few simple comments which will not be profound, they may even be obvious, but I believe they are worth saying for all that.

ELECTRONICS

Firstly, what is there to say about electronics that has not been said before? One of my predecessors, Emrys Williams, may have been right in describing it as 'the greatest nosey parker of all time'.[2] He was not referring to eavesdropping for which there are some extremely sophisticated devices, but the fact that electronics is all-pervasive and makes an important contribution in many walks of life from the kitchen to the cowshed and from space probes to surgery. Try to imagine what would happen if all electrons could suddenly be commanded to stop moving, at least with a frequency above 50 Hz.

However before embarking too far on my Address I should, like a good academic, try to define my terms. We all know what is meant by electronics but there is no adequately precise definition. The name was coined at a time when active devices consisted of electron tubes in which the flow of free electrons was controlled so as to produce amplification of an electrical signal. Nowadays electronics involves the use, for the same purpose, of

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photons, phonons, valence and conduction band electrons in solids, electron spin and other quantum states. A better definition comes from a consideration of the function of electronics which is concerned with the transmission, storage, control and processing of information. A more appropriate title might therefore be 'information engineering' although the term 'electronics' is now so widely accepted that it is unlikely to be displaced in the near future, despite the fact that its description of our subject will become even less precise as 'electronic' techniques become more varied and spread from physical to perhaps physiological[3] ones while the applications and complexities of the subject continue to expand.

The title of the Institution also includes the word 'Radio' and here one might feel on safer ground but perhaps not. The Oxford Dictionary defines 'radio' as the transmission and reception of electromagnetic waves without connecting wires, but what are the frequency limits? Presumably we must exclude 0 Hz but where do we start, 10^{-6} Hz, or 50 Hz, and where is the upper boundary: optical waves, X-rays, gamma rays? Perhaps one could ask whether extra-sensory perception comes under the heading of 'radio communication'?

Having failed dismally in my attempt to define our subject let me take the oblique approach by trying to describe what it does and here I cannot do better than quote from the excellent, stimulating and wide-ranging Address[4] of our Jubilee President, HRH The Duke of Kent. He described the role of Electronics as:

Firstly: an extension of the human senses to see, hear and observe—at a distance, at speed, with precision, in complexity and under all conditions.

Secondly: an extension of the human intellect to absorb, to manipulate and present information at all levels of complexity.

Thirdly: to inform and entertain simultaneously large numbers of people and conversely for large numbers of people to communicate with each other and to influence a single point of decision.

Fourthly: by performing complex, repetitive and unpleasant tasks to take the drudgery out of work and to improve the quality of life at work, at home and at leisure.

Doubtless additions can be made to this list but already it covers a sufficient number of aspects to demonstrate the enormous range of applications, techniques and principles involved.

Electronics is a young, vigorous and demanding subject. Surprisingly, it was being suggested in some quarters ten years ago that as a topic it had come of age so that while steady advances might be expected no further revolutions were likely and for major changes one should begin to look to the biological sciences. That prediction seems to have been a little premature for the rate of progress seems to be accelerating rather than the reverse. For example, in the device field in 1965 it was possible to produce a few integrated logic circuits on a comparatively large slice of silicon, say 3 mm × 3 mm. By 1970 this had been improved by an order of magnitude. Today we are in the realm of large-scale integration where several thousand logic circuits (not just circuit elements) are available on a single chip, at a cost not greatly above that of the early primitive chips. This development has already produced the pocket programmable computer, the wristwatch calculator and initiated cheap microprocessors, the impact of which is only just beginning to be felt.

Waiting in the wings, as it were, is the next stage of v.l.s.i. (i.e. very-large-scale integration)—a development which is inevitable but which poses many problems including financial and sociological ones. V.l.s.i. is capable of an appreciably greater density of components, perhaps as many as 20 000/mm^2, with an even further cost reduction from the £3 per function of yesterday and the 1p per function of today, to something even lower. The number of functions performed on a single chip doubles each year and accompanying the higher component density will come higher performance and greater circuit complexity.

The availability of integrated circuits of a greater degree of sophistication has considerably stimulated and enlarged the whole electronics industry out of all proportion to the value of the product and affects every aspect of the profession. The financial problems arise from the enormous investment necessary to set up the required manufacturing plant, investment so large that in most cases it can only be undertaken on a national or perhaps a European scale. Yet despite the difficult decisions to be taken concerning the various techniques, circuit types, method of financing and organization, the question is basically a straightforward one—should the United Kingdom embark on v.l.s.i. and maintain a viable electronics industry or should it opt out and simply purchase its components from overseas suppliers? The question has only to be posed in this form for the answer to be immediately apparent. Not whether but how?

Another major field which may suddenly blossom and have a major impact is that of optical electronics. Hitherto much has been promised but little produced in the way of practical equipments. What has been lacking is a suitable propagating path, the equivalent of a copper wire to an electric current. However, starting from a wild research idea only twelve years ago we now have light 'conductors', i.e. optical fibres, smaller and more flexible than coaxial cables and more transparent than the Earth's atmosphere on an ideal day. Already optical fibre systems are being installed experimentally in telephone and power system networks and an entire community in a new town in Japan is being interconnected with optical fibres. Thus the bandwidth available to the individual home, on an interactive basis, enables data, facsimile and video communications to be carried out. Here is a pilot project of major significance involving both technological engineering and social engineering.

One could continue in this vein at length and discuss the major impacts which might be made in electronics and on society in the future, for example in pattern recognition, digital techniques, interactive computing, distributed computers, communications, but above all by the enormous increase in information processing power, in progressively smaller size, and at lower cost per function, which will be brought about by v.l.s.i.

Far from electronics being played out as a subject its impact is only just beginning and the future holds far more exciting and socially challenging, as well as technologically difficult, developments than any we have seen in the past.

THE UNIVERSITIES

Now what part do the Universities play in all this? First and foremost, naturally, they play an educational role which is reasonably straightforward and perfectly understandable in the case of non-professional faculties such as the arts, humanities and even science. But the task of the engineering educator, and the same applies in other professional subjects such as law and medicine, is far more complex. This is because we have to introduce an element of professional training, in our case an introduction to electronic technology, and to current practice and design. Even though many of the techniques taught will rapidly become obsolete this part of undergraduate training is essential in order to emphasize the relevance of academic studies to the industrial world and to give to the student as good an idea as possible of what engineering is really all about.

Of equally vital importance is the need to develop the capacity of the student to learn by his own resources and above all to be adaptable to new topics and situations. As I have tried to demonstrate, and as I do not need to stress with my present audience, electronic techniques are advancing at a rate which is little short of alarming. Our graduates are in a field in which the basic technologies are likely to change several times during their career and it is essential that the educational base from which they operate should be secure yet flexible. Thus in addition to education in the general sense of the word they must acquire a fundamental training which will stand the rigours of time and enable them to face new situations throughout their working lives.

Another difficult task facing the engineering educator is to develop in the student a critical and inventive approach to the solution of engineering problems. This is a crucial factor because at its highest level engineering is a process of invention and innovation. Basically, pure science is concerned with analysis, the breaking down of the complex processes of nature into their simplest elements, whereas engineering is a synthesis of a wide range of complex facts and factors, some incompletely understood, into a greater structure which we hope is of benefit to mankind.

After I had written this address I discovered that Saint Thomas Aquinas[5] was of much the same opinion when, in the thirteenth century, he wrote 'Practical sciences proceed by building up; theoretical sciences by resolving into components'. I really despair of ever being able to say anything new on education!

Synthesis alone, while essential, is not enough, becoming dry and lifeless unless allied to creativity. We must therefore somehow train our students continually to question existing theories and established precedent, so that an inventor has been described as 'a fellow who does not take his education seriously'. For example, if Marconi had not ignored all the advice and theories of the leading experts of his day, he would not have attempted the classic experiment which demonstrated the feasibility of long-distance radio communication. It is interesting, but perhaps not very helpful, to observe that if the Science Research Council had existed at that time, Marconi's application for a research grant would probably have been rejected out of hand.

In summary, then, four of the requirements of an engineering undergraduate course, and there are others which I could go into if there were time, are to provide a sound knowledge of the scientific principles underlying a chosen field of technology, to provide some knowledge of current practice, to develop the student's ability to learn by his own resources, and to develop a critical and inventive approach to the solution of engineering problems.

The product of the university is required to be a mature young person capable, after training and appropriate experience, of becoming a high-grade professional engineer with all that the latter term implies. Some of the processing we have to apply I have just described. The material on which we have to operate consists, ideally, of bright and enthusiastic young people of quite good ability in mathematics and physics (many university engineering departments have entrants with high A-level qualifications), having a fair understanding of basic physical science but little idea of the relevance of their school studies to the outside world nor even of how, or why, such knowledge is to be applied. The transformation required is thus a very major one and the time available for the universities to perform their processing function is ridiculously short, namely three years each of thirty working weeks of 4½ days (or something equivalent to this on a thin sandwich course), making a total of 400 days. Rather a formidable task.

In the circumstances, given the task and the dwindling facilities available, I believe the universities do a remarkably good job with a productivity which is unmatched in almost any other country in terms of the quality of the product and the time available. Judging by a recent report in *The Times*, the Shadow Minister of Education[6] is of the same view.

There are, of course, many criticisms made of the universities, often by people who have never visited one or who made no great success at their own studies, much of it unfounded and based on ignorance of the functions and performance of engineering departments. It is as fallacious to consider oneself an expert on education just because one went to school, as it is to claim to be a surgeon on the grounds that one's appendix has been removed. If, as in the usual fairy tale, I had three wishes, the first would be that no one should make public comments on universities without having spent several days, within the preceding five years, at a university studying the real, rather than the imagined, situation.

Despite the excellent work which, I believe, university engineering departments are doing, there is no room for complacency. Within the time span of a present-day degree course not all the desirable aspects of the subject can be covered. Furthermore there is hardly any opportunity of dealing adequately with the broader aspects of professional engineering such as accountancy, industrial organization, social responsibility, and so on. Indeed the increasing variety of background of our entrants, which will be further accentuated if the new sixth-form examination and syllabus proposals are approved, will cause even greater difficulty in maintaining, let alone improving, the present quality of our graduates. In an increasingly competitive world a much higher degree of professionalism is required and engineering educators have long been of the opinion that three years are simply no longer adequate if this country is to try to regain something of its former stature among industrial nations.

Fortunately this view is beginning to gain credence and the University Grants Committee has recently set up four-year degree courses, orientated towards manufacturing engineering, at a few universities. This is a start and one hopes that four-year degree courses will become available for all professional engineers. High-quality engineers are required not only on the factory floor but also in design, sales, development, management and research. There is no point in having excellent production facilities for inferior or poorly-conceived equipment. The provision of more-highly-trained production engineers is therefore unlikely to have more than a marginal effect on the quality of our engineering products, since quality is something which has to be built into a component or system in the early design stage and cannot be simply tacked on as an afterthought in the production line.

One might go further and say that by giving embryo production engineers a four-year undergraduate training it does not necessarily follow that they will take up a *career* in production engineering. Why is it that the best graduates are not queuing up for jobs in this field already? The answer, I fear, may not be entirely unrelated to working conditions, the intellectual challenge and the rewards provided by industry. For example, recent surveys have shown that the salaries of professional engineers in manufacturing industry are not only low compared with those in other professions and in nationalized industries, public corporations, local government and the civil service, but they are steadily falling further behind. Young people in schools choosing careers, and graduating students, are well aware of the situation and the best production engineers in the world cannot improve industrial productivity unless they can be attracted into that sphere of activity.

Because engineering innovation, design, development and production are highly interrelated activities, I believe that four-year degree courses should eventually become the norm for all engineering students. This raises the question of which subjects should be covered in the extra year. Generally speaking most existing three-year courses probably are successful in providing an adequate basic education in engineering and applied science. However some of the additional time is increasingly needed to provide a sound basis for these engineering studies because of the diversity of A-level syllabuses and subjects. As I have already mentioned, this will be even more necessary if the change from A levels to N and F levels finally comes about. In principle, however, the need to strengthen the professional element in degree programmes has long been recognized. Thus while a certain amount of additional engineering science may have to be included, the main emphasis should be in such topics as business studies, accounting (if we are to compete at Board level with accountants on their own terms), industrial organization and law. The new courses should emphasize integrated studies in professional engineering, including both social as well as the technological aspects, preferably through individual and group projects having as much industrial contact as possible. Project work is valuable not only because it excites and motivates the student but also because it offers him the opportunities to develop organizational and communication skills.

While engineering degree courses should be broadened by introducing professional subjects the technological base itself must be soundly laid and within a particular discipline. It was once thought that there is a subject called 'engineering' and that it must be taught to all first-year, and sometimes second-year engineers. This form of 'engineering' comprised a range of subjects drawn so widely and diffusely as to provide little real knowledge and no intellectual training. The same dangers lie in any scheme aimed at producing a general engineer. If a university training means anything, it involves training in depth in a particular field so as to produce a sharpening and a stretching of the mind. People educated properly in this way should be able to tackle completely new problems, including a transfer to other disciplines, such as management, after proper training, otherwise the universities have failed.

The argument has been put much more eloquently by Lord Ashby in a book[7] which ought to be compulsory reading for all new engineering teachers. He said, paraphrasing slightly, that 'the essence of technological humanism is the habit of apprehending a technology in its completeness and this is what we should expect education in higher technology to achieve. I believe it could be achieved by making specialist studies the *core*, around which are grouped liberal studies [and here I would add professional studies]. But they must be relevant; the path to culture [professionalism] should be *through* a man's specialism, not *by-passing* it. ... A student who can weave his technology into the fabric of society may be said to have a liberal education; a student who *cannot* weave his technology into the fabric of society cannot claim even to be a good technologist.'

My sincere hope therefore is that the new UGC four-year courses will not set out to produce engineering managers having a smattering of technology but good technologists capable of developing into first-rate managers.

The need for university collaboration with industry is strong, but let it not be thought that this collaboration does not already exist. Firstly, a large fraction of engineering staff in universities have industrial experience. To take one example, a recent survey shows that each member of the engineering staff at Southampton has spent, on average, 5 years in industry and 3 years in government establishments. Added to that is the fact that 80% of the staff are engaged, from time to time, as consultants to outside bodies and in addition we have seven industrial units which are self-supporting and have no direct subsidy from the University. They take on work ranging from consulting to prototype equipment production.

Furthermore the support provided to departments through the University Grants Committee is now barely adequate to ensure a proper level of teaching activity and for the bulk of our research we have to seek funds elsewhere. Last year my Faculty of Engineering attracted as much money from outside sources as the amount it received via the UGC; namely some £1·6M of which 65% came from industry or industrial type sources. It is nonsense to say that universities, or at least their engineering faculties, are ivory towers having no interest or contact with the 'real' world. I would go so far as to suggest that the comments of universities on industry may be more soundly based than those of industry on universities, but having said that let me stress that the emphasis should be *not* on criticism, other than of the constructive kind, but on co-operation and partnership where, given the existing constraints on both sides, the situation is reasonably good but needs continual nurturing.

While I am in this somewhat aggressive frame of mind perhaps I might be allowed one further comment. It is frequently stated in the media, and believed by many politicians, that contacts with industry are stronger in the polytechnics and technological universities than in the 'traditional' engineering schools. I hope the situation I have just described will show that such statements are not necessarily true. Similar remarks are made about sandwich courses, but here again about 40% of the electronics students at Southampton are on thick-sandwich schemes, spending a year in industry before starting their academic studies and returning to their firms in the 'vacations'. This does not happen by accident and requires much negotiation by the teaching staff together with visits to the students during their industrial periods. Seldom are 'traditional' universities given much credit for this kind of initiative.

Many of the misconceptions which arise concerning the functions and performance of engineering departments arise because the statistics for engineering are frequently lumped in with those of science to produce a very misleading picture. The situation is probably not helped by the fact that many of our 'scientific' administrators are pure scientists and not engineers.

The second of my three wishes would be that in any assessment of universities the performance of engineering should be considered separately from those of science, arts and other faculties.

The number of science students in the country greatly exceeds the number of engineering students and maybe this situation should be reversed. The Japanese industrialists with whom I talked were greatly surprised at the situation in the UK since in their country there are twice as many engineering as science students. In the latest UGC publication[8], 'Statistics of Education' (published in 1974 and admittedly now out-of-date), the proportion of engineering undergraduates in this country is stated to be 16% compared with 25% studying science —surely there should be a major redress of these figures. As Sir Ieuan Maddock has pointed out,[9] in terms of its population this country has an outstanding record in the acquisition of Nobel Prizes but what we really need at present, and have needed for a long time, is a better overall industrial performance. Arguably more, but without doubt higher calibre, graduate engineers are urgently needed, and who says we cannot afford it? One day's loss of the British Steel Corporation would finance four-year degree programmes for many years to come. Conversely, by reducing the intake to engineering departments by 25%, then four-year courses could be operated with only a small additional cost while the lower quality tail of weaker students could be removed.

So far I have concentrated mainly on teaching activities but these are only one aspect, albeit an important one, of the function of universities and the one which receives most attention. Even so undergraduates form only a part of the teaching load and in addition there are M.Sc. and research students who are in residence for the whole of the year and comprise, in our case, about one-third of the undergraduate load. Furthermore, while the undergraduates are enjoying their vacation (and what a misnomer *that* is as far as university staffs are concerned —it is popularly thought that *out* of undergraduate term time the universities close down, as is the case with schools and technical colleges, but this is far from the truth.) As I say, while the undergraduates are on vacation when they are, or should be, engaged in private study and undertaking vacation training, the universities are holding conferences and running post-experience courses which are increasingly necessary.

Quoting examples from my own University and Department might savour of slightly bad taste and if so I apologize, but the local situation is certainly the one that I know best. Furthermore universities are normally reticent in stating their own cases so perhaps I should redress the balance somewhat.

Universities also make a valuable contribution to the life of the nation through research, not only in terms of scholarship and the training it provides, but equally importantly in producing a reservoir of skills, as well as producing new processes and results. In recent years considerable changes have taken place. It used to be thought that too much money was being spent on fundamental (in some peoples' minds this means frivolous) investigations and while this was rarely true of engineering schools it is certainly not the case today. The point has already been made that money from UGC sources is very scarce and research money has to be attracted from outside bodies so that the pressures to look only at short-term practical problems is intense. The situation is exacerbated by the severe cutting back of the normal research studentships by Science Research Council in favour of CASE awards, which have to be carried out in collaboration with industry, and while this is no bad thing in itself, such schemes can only be based on existing expertise and are unlikely to generate new skills for the future.

Universities should not expend all their research energies on tackling the industrial problems of today but should be, at least partially, engaged in longer term work, generating the ideas that will be required by industry *tomorrow*, *and* producing innovation. Long-term research is no longer being done on any scale in industry or government research establishments and if not encouraged in universities it will not be done at all in this country. For a limited time we can survive on existing knowledge, on our fat as it were, but when that is exhausted the situation will be serious and possibly irremediable. Perhaps too much fundamental research has been supported in the past, particularly in the 'big' sciences, but the pendulum has now swung too far in the reverse direction and long-term engineering research is in danger, with possibly serious repercussions. It is the classic situation where governments and government agencies have not so much responded *too late* but have responded *too much*. The proverb about not throwing out the baby with the bath water is very pertinent here.

The comment is frequently heard that university research is a narrow specialist activity in which more and more is learned about less and less, so that after three pedantic postgraduate years at university, the Ph.D. graduate is completely useless to industry. For the reasons already given I would again like to take a personal example. My research group is concerned with optical fibre communications. We fabricate optical fibres and therefore need to know a lot about a certain type of glass technology, about materials processing at extremely high purity levels (better than 1 part impurity in 10^8), and about the optical absorptive and dispersive properties of glasses. None of the group has any formal training in any of these aspects but are simply high-quality electronic and electrical power engineers, together with two mathematicians and one mechanical engineer. We need to have a very detailed knowledge of electromagnetic wave propagation in fibres; of sophisticated mathematical techniques; of microprocessors for control of fabrication and instrumentation; plastic coating and fibre strength measurements; some knowledge of cabling processes; detailed experience with lasers, light-emitting diodes, detectors, modulation techniques; design of joints, connectors and couplers; optical fibre system design; high-temperature furnace design; some aspects of optical system design. A particular research student needs to be expert in about half the topics mentioned and be familiar with the others. Not, I would have thought, a narrowing experience but one likely to produce versatile and adaptable engineers. All our Ph.D. graduates, by the way, have taken up posts in industry.

Lest it be thought that the research itself may not be of any great practical use the following points can be made:

Plans of the fibre-drawing equipment and furnace we designed and constructed have been sold to industrial firms in this country and abroad, including North America (from which the contractor supporting our research pocketed the proceeds!).

We have developed new materials and fabrication techniques for fibres (from which NRDC is earning money through licensing agreements).

Japanese manufacturers have copied our process and materials to produce the lowest loss (0·5 dB/km) fibres ever reported.

We have held several world records for low fibre attenuation and still hold those for liquid-core fibres and high numerical aperture fibres.

We hold the world record for bandwidth.

The first public demonstration, in January 1973, of a live colour television broadcast was given by the BBC over a 1·25 km fibre link using our fibre and system.

We have invented four new techniques for characterizing multimode graded-index and single-mode fibres.

We proposed and subsequently proved, that greatly increased bandwidths are obtained by operation at a wavelength of 1·25 μm—a proposal that has been taken up by the UK Post Office, and many industrial laboratories and manufacturers all over the world.

We have supplied experimental lengths of fibre to many industrial concerns all over Europe.

There are other claims that could be made but perhaps I have already over-stepped the bounds of modesty. The only point of my argument is that engineering departments of universities do, through their research and development work, make very direct and practical contributions to industry. The example quoted is solely illustrative and could be matched by other groups in my own and most other universities. Most of the academics present in the audience could all make similar, indeed more impressive, statements.

THE INSTITUTIONS

In this discourse on engineering in the universities a number of aspects have been stressed. For example, the wide spectrum of electronics, both in its applications and its fundamentals; the speed of advance of electronic technology and its increasing social impact; the need for a sound and flexible intellectual education for our future professional engineers. There is also need for a smooth, non-reflective and well-matched interface between educational establishments and industry, since universities are no more able to produce trained professional engineers than industry is able to give them a sound fundamental academic training. All of these factors are relevant to the functions of institutions, especially those of the IERE.

The range of electronic techniques requires a wide variety of skills from materials science, mathematics and software, to large-system design and installation, and to production. More and more computer-controlled processes are emerging and the production engineer must work hand in hand with the software or systems engineer and is increasingly dependent on him. Thus institutions, and CEI, must be flexible and forward-looking in approach so that in maintaining high professional standards they must avoid rigidity and be prepared for new disciplines to emerge and be recognized with, where appropriate, the emergence of new institutions.

I have illustrated the rapid advances being made in electronics by saying that 11 years ago there was no such subject as optical fibre communications while today optical fibre cables are being produced and experimental optical systems are already being installed in telephone networks, electrical power systems, ships and aircraft. There are many other similar examples so that continuing education is vital if we are all to keep abreast of our subject. The universities are already involved, not as heavily as they would be if adequate additional resources were made available, but the institutions also have an important role to play, as indeed they are already playing, through their journals and by organizing conferences, lectures, summer schools and the like. The post-experience training aspect of this work could well be strengthened, with the institutions taking an active role in co-ordinating the requirements of industry with the training facilities available.

Individual institutions are much more likely than CEI to be able to recognize, and evaluate correctly, new developments and for these and other reasons, such as the fact that their charters require them to do so, they must retain and foster their learned society role, with CEI acting as a co-ordinating body and concentrating on the well-being and status of the engineering profession as a whole. Qualifications and qualifying procedures must remain specific, both for educational reasons, as I have argued above, and because an employer is less concerned with whether he is employing a chartered engineer than whether the person is a chartered *electronic and radio* engineer, chartered *electrical* engineer, chartered *mechanical* engineer and so on. CEI has a difficult enough task in enhancing the status of the engineering profession and representing us in dialogue with government, industry, education and elsewhere, without attempting learned society activities which are dealt with so much more effectively by its constituent members. The fact that the Government has deemed it necessary to set up a Committee of Inquiry would appear to indicate we have not yet, over the past twelve years or so, through CEI done an outstandingly good job of raising the image of the profession in the public eye.

The same form of argument can be applied to the qualifying role which has traditionally been the function of individual institutions, where a man is judged by his peers and not by a committee. A committee is, after all, a cul-de-sac down which ideas and initiatives are gently lured and then quietly strangled.

CONCLUSIONS

My conclusion is that there must be strongly increased interaction and dialogue between establishments of higher education, industry and the institutions. If that dialogue produces effective action then the interface with government is a smooth one. If, as engineers from all sectors, we fail to put our house in order, to the satisfaction of the world at large, then we must not be surprised at government intervention; but perhaps this should not surprise us anyway! I have stressed the contribution of the universities and made the point that their relations with industry are far closer than is generally thought. Polytechnics also have a strong contribution to make, but I have not taken up cudgels on their behalf, partly because I do not feel qualified by experience to do so, but also because I feel they are given adequate and fair coverage by the media. Universities, on the other hand, receive less than justice on many occasions and seem reluctant to state their case forcibly.

I have touched, more lightly than some of my colleagues would have liked, on the delicate and fine balance to be struck between CEI and the institutions, and suggested that learned society and qualifying activities remain largely with the latter. CEI itself has sufficient strategy to deal with without becoming involved in tactics!

Finally, however successfully the problems I have outlined are solved, however inspired are the responses of universities, polytechnics, institutions, and CEI, the ultimate remedy for improving the status and performance of the profession must lie largely with industry and government. Industry alone has the power to convince young people that it can provide challenging, interesting and financially rewarding occupations. Government has the responsibility fot changing social attitudes to industry, and to the concept of professionalism and excellence, and for allowing industry to provide adequate financial incentives.

The third of my three wishes would be for all the various bodies concerned to collaborate successfully so as to produce good professional engineers, and thereby a healthy and influential profession, capable of leading this country back to a state of industrial excellence and national prosperity.

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