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SPECIAL REPORT

The instrumentation imperative

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A sound instrumentation base is absolutely necessary for healthy and competitive science. What ails the instrumentation industry in India? Analyses, suggestions for a solution, and a review of a recent publication on physics instrumentation in India.

Science often progresses by leaps and bounds when new tools of investigation become available. Cyclotrons, electron microscopes, mass spectrometers, polarography and ultracentrifuges are examples from the first half of the century of the development of a new technique or instrument spawning substantial new knowledge. Chromatography, computerized axial tomography (CAT), atomic absorption spectrometers, bubble chambers and superconducting quantum interference devices (SQUIDS) are new-generation techniques and instruments that have opened up new vistas in science and technology. In a different direction, one may cite digital-display and automatic-control equipment, which have made R&D and industrial work less taxing and more accurate. So many are such examples that it is only stating the obvious to reiterate the symbiotic relationship among scientific ideas, scientific instruments and R&D activity.

In any discussion regarding the future of Indian science and technology, it is pertinent to look at this one link in the chain, namely scientific instruments, in some detail. It will not help very much to recall fondly the glorious tradition of Indian science and technology in ancient or medieval times. Indeed, the achievements of J.C. Bose, who made world-class scientific instruments for the first time in India nearly a century ago, only drive home the yawning gap between the promise of potential and actual achievement today. This weak link has been noticed before. For example, more than a decade ago, the Scientific Advisory Committee to the Cabinet (SACC), Government of India, heard a report by S. Ramaseshan. About five years ago, the Scientific Advisory Committee to the Prime Minister (SAC-PM) heard an equally fervent plea by G. Venkataraman [see the following article by G. Venkataraman]. Many others have spoken at public forums and have written in the public media. Scholarly articles have been written in professional journals. The Department of Science and Technology (DST), the Department of Electronics (DoE) and other agencies have committees on instrumentation working for them. Instrument manufacturers and instrument societies have organized symposia on the sad state of the instrumentation scene.

Where does the blame lie?

Many reasons have been adduced for this plight, some direct and some indirect. One group of persons characteristically throws the blame on the government. Our industrial labour laws and factory licencing policies have made it advantageous to be a company agent or a representative rather than be a manufacturer of instruments. The producer is penalized by the labour laws and taxation policies, but the middle-man is not affected. The government imposes heavy customs duties on the import of components and materials while the duty on finished equipment is much less, making it cheaper to buy whole equipment rather than build them. The Open General Licence has allowed the better-funded institutions to freely import instruments, killing whatever was left of the precision-instruments industry.

There are others who point the finger at the present dismal position of the Indian scientist as regards quality and innovativeness. No doubt the quantity of Indian science and technology, the number of laboratories, the number of persons employed, and so on have increased manifold in the past four decades. But have we produced in the post-Independence era a number of persons like C.V. Raman, K.S. Krishnan, S.N. Bose, B. Sahni, S. Ramanujan or J.C. Bose, who, in the pre-War era, had world stature as scientists? Have we contributed any innovative measurement or technique, like J.C. Bose's crescograph or K.S. Krishnan's magnetic anisotropy experiments? Have we written textbooks that are applauded all over the world, like the books of Saha and Srivastava or Bhatnagar and Mathur? Without the cutting edge of world-level competition, we have not made any significant instrument or instrumentation principle, like, say, a scanning tunnelling microscope or a radioimmunoassay, to cite two Nobel Prize-winning innovations. Poor science has gone hand in hand with poor instruments.

Yet others flog the hapless manufacturers. They are accused as villains who worry only about profits. It is conveniently forgotten that the entire nation pays heavily when a public-sector company is making loss. They are accused of taking the easy option of making, say, plastic buckets and selling them rather than undertaking professionally challenging jobs of, say, high-tensile bolts. Indian manufacturers have poor maintenance and service cells as well as inadequate documentation of their products. Agents of foreign companies are said to corrupt scientists by offering foreign visits in the guise of training when equipment is imported; they are sometimes accused of other deeds of corruption, bribery and winding-up charges.

All these statements have grains of truth. Yet we must take an objective, dispassionate view. The complaints and the criticisms are about one segment of the instrumentation industry, namely the precision, state-of-the-art, high-technology scientific instruments, often serving research needs. If one looks at lower-cost, high-sales-volume products like, say, industrial Bourdon-type pressure gauges, process control instruments, or equipment needed in school and college laboratories, the situation is indeed changing rapidly. Because of the large sales turnover, instrument manufacturers are coming forward to produce, say, reasonably good-quality pH meters or oscilloscopes. They may not be of high accuracy or may not use the latest possible techniques, but are good enough to satisfy one class of users. People may still complain that, say, the geometry instrument boxes used in the tenth standard class are not as good as the ones available in Germany or the USA. There is, however, no denying the fact that inexpensive, general-utility instruments of various types are available today.

Hi-tech instruments

If one goes on to the availability of sophisticated scientific instruments for R&D laboratories, there is clearly a near-vacuum in the Indian scene. Even if this is only one segment of the broad range of instruments in use, two factors tend to highlight this sector. The users, namely R&D personnel in the comparatively better-funded R&D institutions, are more vocal in their demands, more visible in the public gaze, and are often the persons controlling the S&T efforts in the country. It is also possible that they have also to defend their performance, or non-performance, in the light of their getting large shares of the S&T funding. Twenty years ago, they could offer a convenient excuse, namely the inability to import world-class equipment said to be essential for the R&D work. Today, perhaps, other reasons have to be offered. Irrespective of this factor, there is a more fundamental second factor which should be considered. Ther is a need for continuous updating or evolutionary growth in almost every activity. To survive, one should move from bicycles to automobiles to aircraft in the transport sector. In a similar way one must move to greater accuracy, resolution, speed and range of instruments, almost like the Olympic goal of 'faster, higher, stronger'. One must change to newer materials, wood to metal to plastics, in response to new demands. Inevitably in the present-day context, this task is in the realm of high technology. One must at least keep pace with trends elsewhere even if it is a pipe-dream for us to hope to set new trends. Lagging behind is an invitation to obsolescence and disaster.

It would not be correct to say that suggestions for such modernisations or actual work in such tasks have been absent. After all for over a decade various persons and committees have been drawing attention to this problem. In various laboratories scientists and engineers have made working models of contemporary scientific instruments, whether they be tiny scanning tunnelling microscopes or large X-ray diffractometers. Prototypes of scanning tunnelling microsopes, Stirling-cycle liquid-air plants, 4-MeV linear accelerator (LINAC)-based X-ray machines for treatment of cancer, UV/VIS spectrophotometers, and so on have been made, most of the time with large-scale funding from the instrumentation committees of various government departments. Defence and nuclear energy laboratories have developed a whole range of components, gadgets, equipment, materials, devices, sensors and so on that belong in frontline contemporary work. Alas, most of them do not reach needy users in the rest of the country. By contrast, in the USA, the UK, Germany and other countries, when a useful new item is made in the laboratory, it rapidly progresses to manufacture and becomes available to restricted or general user communities. One also notices that a very large percentage of the well-known manufacturing companies have grown to their present position of size and eminence from relatively small beginnings some years ago. There are only rare cases of companies that started as large organizations. Most of the companies have a constant exchange of fresh ideas and inputs with R&D and university laboratories, even when they have their own R&D laboratories.

Herein lies one of the problems of the sophisticated scientific instruments industry in the country: *we have not developed the mechanism to move items from laboratory cloisters to manufacturing factories.* In this mechanism there are four identifiable partners: the laboratory workers, the manufacturer, the product-development group interfacing the two, and the government, which controls and oversees the whole scene in the present administrative set-up of the country. The partners must function in a coherent manner if the task is to succeed.

Steps towards a solution

Nurturing a culture

It may appear at first sight that nothing need be done on the side of the laboratory workers, who generally stop with giving an idea or making a first laboratory model of an instrument. Unfortunately the present value system in the scientific community is driving such experimenter-scientists to extinction. In many laboratories in the advanced countries, the investigator builds or assembles apparatus from readily available subunits. In this process new modes of use or new accessories or even new ideas are generated to make a better product. Some of these products, if needed by other investigators, are then manufactured. This culture of instrumentation is taken as a part and parcel of scientific work, subject to the same reward system for good work. In India, for various historical reasons, the most important of which was the lack of import facilities, such a culture of indigenous fabrication was present till the mid-seventies. The item fabricated in the laboratory was probably inferior to the then world standards of performance, yet so much interesting and first-class investigations came out. Indeed, quite a few of the distinguished scientists of today who are over fifty have been through this experience. Unfortunately, with the new wave of Open General Licence policy of easy import and the associated covert benefits of dealing with selling agents of foreign manufacturers, this culture of instrumentation has all but disappeared. It has a precarious existence in a few atomic energy, defence and space department institutions, where foreign-equipment suppliers are not allowed to sell items directly. If ever a nail in the coffin were needed, this has been provided by the availability of computing equipment, whereby persons can sit in air-conditioned rooms without sweating or soiling their hands. Good theory is as hard as good experiments; but the soft option of second-class calculations and computer simulations has lured persons away from hardware-based work. The novelty of the computing equipment and their physical environment have produced the unfortunate value system that hardware-based experiments are inferior investigations. That this conclusion is not pure imagination but is based on facts can be verified easily by counting the awards and appointments announced in various branches of science and technology where hardware experimenters have to compete with others. A change in value system must come immediately among leaders and managers of science and engineering R&D in the country, with the recognition that hardware experiments are generally much harder and have less tangible outputs or results. Indeed, such a change is perhaps necessary for the general health and progress of science and technology in the country. If this does not happen in the near future, the hardware experimenters may have to be put in the list of endangered species requiring special environmental laws of protection.

Creating competition

When it comes to manufacturers, one must recognize immediately that a company must naturally make profit if it is to survive and grow. Here, again, unfortunate value systems have developed. Almost all the laboratories are government-subsidized. In the guise of academic freedom, the government subsidy has in many cases become a one-way dole without a reciprocal commitment and has killed the competitive element so crucial to success in any walk of life. If scientists and engineers make remarks on scientific instrument manufacture, they run the risk of an unconscious attitude of permanent government subsidy. Government support, especially at the early stages and in various labour and taxation policies, is definitely needed, but if the competitive element and the drive towards favourable cost–benefit ratio are not maintained the company will surely become a white elephant draining the nation's resources, as is indeed happening in many public-sector concerns. No one will willingly buy a scientific instrument unless it is competitive by way of price and initial maintenance costs. The best test of competitiveness is exportability or overall cost-effectiveness by way of effective servicing and maintenance in India. While many instrument manufacturers will fail by this yardstick, a few companies come out successful in the slightly less sophisticated level of instruments.

Policy changes

Before discussing the interfacing of universities or R&D organizations with instrument manufacturers, it may be advantageous to discuss whether any government policies should be restructured. It would obviously not be proper here to discuss the question of public sector versus private sector, which is to be determined by the greater political wisdom of the country. The taxation and labour laws, however, do suffer from one hangover of British rule, and require reconsideration. The British government wanted the colonies to be subservient to England, and that the fruits of industrialization should remain primarily in their hands. So it did not want the colonies to start manufacture but wanted items to be traded from England. Even raw materials and components were not to be freely imported by the colonies, lest the colonies convert the raw materials and components into finished products competing with those made in England. Therefore the customs duty on raw materials, components and consumables was made higher than the duty on complete equipment. Secondly, the commercial taxation and labour laws were so framed as to encourage middleman-trading activities and to discourage industrial, manufacturing activities. These two policies are unfortunately followed even now by India, although a developing country that wants to industrialize and produce more goods must have the exactly opposite philosophy. This is an urgent task if progress has to be made rapidly.

There is a second change of policy required, which can be done somewhat easily. At present most R&D laboratories can get customs-duty exemption for import of scientific equipment. If a manufacturing company imports the subunits and makes some equipment then the company has to pay the full customs duty on the imported components. Thus the same equipment assembled in India becomes more expensive. This situation is especially serious when a new product is introduced, during which stage the import component is high and indigenization is incomplete. Thus the foreign vendor is at an advantage in having no customs duty while the Indian manufacturer has paid customs duty on the subunits. The scheme of customs-duty exemption on scientific equipment applied to R&D laboratories should include exemption of duty on the subunits/components/materials used by an Indian manufacturer suppplying the same scientific equipment. Alternatively, the whole scheme of customs-duty exemption can be scrapped, charging the same duty to the R&D laboratories and the manufacturer, and assisting the laboratories with extra grants, which anyway go back to the government through the channel of customs duties.

These steps, important though they be, are indirect supportive measures. To make visible progress in a reasonably short time and to get enough self-confidence to move with vigour, more active measures are needed. One such measure is the creation and development of an interface between laboratories and manufacturers. This could be a crash programme for a five-year period, after which the system will reach a new self-sustaining equilibrium. In the absence of such an interface, the laboratory researcher is content with doing his or her work and has no motivation to crusade for the manufacture of an instrument developed in the laboratory. The manufacturer can anyway make profit through the existing channels or through turnkey projects imported from abroad and so has no motivation to embark on a risky venture of trusting a half-baked laboratory fabrication as a model for manufacture.

What can be the motivating force? Unfortunately wrong decisions have been made in this context, as pointed out in perceptive analyses of the recent Indian scene by several sociologists. The decision-makers are in the age group of the over-fifty. They had the good fortune of having, in their childhood, persons like Mahatma Gandhi or Pandit Nehru or Sardar Patel as their heroes or models. These persons had visibly sacrificed everything for their country. Unconsciously the decision-makers are making the mistake of assuming patriotism to be a dominant driving force in the India of today. As the sociologists point out, the urge to become an independent nation, which motivated the entire country to hard work and struggle, has ceased to be a source of motivation for young people. These young people have no models or heroes who have sacrificed for the country. The only driving force readily available in peacetime is economic motivation, namely cash, which can be converted to amenities/living conditions. It is unrealistic to expect large numbers of people to work with an idealistic vision of a great country, but getting large numbers of people to work for extra money is certainly feasible.

Bridging lab and industry

A product-development group bridging the laboratory model and the production model of an item is a key element that is largely missing in instrumentation activity in the country. In chemical engineering, the need for scaling up production from laboratory-size activity to pilot-plant production and finally to manufacture scale is clearly recognized and there are persons who are actively engaged in this task. In fact, the relative success of the chemical industry in India owes a large debt to this group of people. Laboratory-scale activity in instrument development is often the realization of a goal with available resources and without worries about the problems of manufacture, reproducibility, serviceability, ease of operation, reliability, long-term stability and, above all, cost. Development-oriented personnel do exist in small numbers in a few national laboratories and in a few instrument manufacturing organizations, but are largely absent in the university sector. It is true that they have not achieved conspicuous success. A major reason for this is the lack of 'moving with the product' on a conveyer belt, to use a phrase common in production engineering. Work on a production shop-floor is efficient when the item being produced is moved on a conveyer belt, with each worker adding his or her part to the item, a method made popular by Henry Ford in his automobile factory. If a researcher who develops a new equipment moves to the product-development area, all the background information,—knowledge of the 'whys', the 'dos and don'ts' and the 'hows'—can be passed on easily, much better than when these can be documented. In a similar way, if a product-development engineer moves with the equipment to the manufacturing phase., the information transfer takes place effectively. We have no method of inducing this movement of people which can catalyse instrument development. In fact, all the present procedures of leave rules, travel rules, daily allowances and other reimbursement of expenses are uniformly against such movement. Why should a researcher move from what is regarded as a more rewarding research work to what is regarded as less rewarding development work by the research community? The only inducement to move is a financial one and can be readily implemented. Many universities, laboratories and organizations will, without murmur, pay air travel and daily out-of-station living expenses at up to Rs. 1500 per day for a technician to come and install new equipment or repair equipment. Yet these same authorities are shocked if a suggestion is made that they pay their own staff at this generous rate when the latter move out for instrument development/manufacture activity. The pat reply that it is not sanctioned under any rule is also given. Therefore we must have a formal scheme under which a person moving from a university/research laboratory to a product-development organization or a person moving from a development organization to a manufacturing factory is paid very generous travel and living-expenses allowances. Then a few persons will move, and usher in manufacture of good scientific instruments, at least for financial rewards if not out of patriotism. Such a scheme can be introduced and monitored by the existing channels of instrument development committees of agencies like DST, DoE, CSIR, etc. This, by providing a priceless resource, namely persons with a mission, will provide a big impetus to the indigenous development and production of high-quality scientific instruments. It is certainly worth trying as a priority programme initially for a five-year period.

Carving a market

All these steps, while promising to motivate, do not answer one question of the manufacturer. Normally, the specialized scientific instruments have a limited market of a few pieces in the country, at least in the early stages. Manufacturers are reluctant to set up production facilities for a small number of units, especially since the route of system integration using readily available subunits is not possible in India because the subunits themselves are not available locally. One can argue that, once a good instrument is available in India, a market for it develops rapidly, as has been experienced in many cases. One can also argue that, besides a domestic market, the companies should be able to compete in the market abroad, especially in the developing countries. All the same, manufacturers are reluctant to embark on the production of a small number of units. At the moment the only solution is that the product-development groups in laboratories/organizations themselves should make two or three units for the use of various buyers. They should associate a manufacturer with the work at this stage itself so that the transfer of technology becomes easy at a later stage. This will give users confidence in the product, enabling the market to be developed. A day must come when an Indian instrument is the first of its kind in the world and aims at a world market.

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The instrumentation imbroglio – Some suggestions for a solution

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The health of science in this country is a matter for frequent discussion. While many aspects like funding, proper administrative support, etc. are always analysed threadbare, one item that receives scant attention is the absence of a proper instrumentation base in the country. Perhaps there is a sense of helplessness, considering the deaf ear turned to the numerous suggestions made in the past for improving matters in this respect. What is more dangerous is the complacency that has set in, thanks to the possibility of easy import of instruments. The obvious truth, that our science cannot be strong unless our base in experimental science is strong, and that, in turn, the latter is not feasible without a proper instrumentation base, sems to be slowly slipping from our minds.

The question of what ails our instrumentation has been studied by about half a dozen committees in the past. The present writer was himself a member of an expert group constituted in 1984 by the then Science Advisory Committee to the Cabinet (SACC); S. Ramaseshan was the chairman of the group. Working with great enthusiasm, the group very quickly produced a comprehensive report. However, after a cursory examination by the powers that be, this report soon joined its predecessors in the dusty filing cabinets of Delhi. Three years later, under the promise of a new deal,