MODERN TECHNOLOGY TRENDS : SOCIO-ECONOMIC IMPLICATIONS FOR INDUSTRY AND MANAGEMENT

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Professor N.P. Gandhi
(1886-1960)

The Professor N P Gandhi Memorial Lectures were instituted by the Indian Institute of Metals in 1961 in grateful recognition of the pioneering contributions made by Professor Gandhi to metallurgical education in India. These lectures are being organised jointly by the Indian Institute of Metals and the BHUMET Golden Jubilee Trust since 1980.

MODERN TECHNOLOGY TRENDS : Socio-Economic Implications for Industry and Management

It is a great honour to have been invited to delivèr this memorial lecture and to pay homage to the late Professor N.P. Gandhi for his outstanding contribution to the growth of metallurgical education in the country. Professor Gandhi was a unique personality of his time, with a rare blend of science and culture, patriotism, vision and dynamism. A distinguished scholar, genuinue sportsman and a dedicated teacher, he embodied in himself some of the noblest qualities of his profession. An ardent nationalist, Professor Gandhi was inspired by Mahatma Gandhi's ideals and it was at his instance that he joined Pandit Madan Mohan Malaviya at the Banaras Hindu University. Justifiably, Professor Gandhi is regarded as the Father of Metallurgical Education in India. It was he who pioneered the establishment of the Departments of Geology, Mining and Metallurgy at BHU. All his students remember him with deep affection and reverence as a great teacher, philosopher and guide; and for his sense of sportsmanship and fair play.

Professor Gandhi had wide and varied interests and he was quite alert to the technological developments taking place in the world. Had he been in our midst today, he would have been excited by the challenges posed by the new technological advances that are transforming the socio-economic structure, the growing awareness and concern about environmental degradation and abuse, and the new perception about the crucial need for energy efficiency and optimization. I have, therefore, chosen 'Modern technology trends : Socio-economic implications for industry and management' as the topic of this memorial lecture.

Changing perspectives of metallurgy

In the context of the rapidly changing perspectives in technology and engineering, metallurgists are being called upon to cater to the increasingly exacting demands for newer metals and materials for complex and sophisticated uses. In fact, in keeping with this trend, the discipline of metallurgy itself has undergone a transformation and blossomed into the discipline of 'materials science' involving an interdisciplinary and integrated approach to the study and applications of all engineering materials including metals. I was invited last year to the Centenary Celebrations of the Department of Metallurgy at M.I.T. (Cambridge, USA). It was saddening for me to see that the old Department of Metallurgy had disappeared — it was no more in existence as such. At the same time, I was elated to see it reborn as the Department of Materials Science and Engineering, promising a new era of exciting changes in the modern space- and computer-oriented world.

What is even more crucial, the metallurgists or materials scientists of today — and tomorrow — will be increasingly required to shoulder managerial responsibilities not only to manage materials and machines, but also men and industrial complexes, and now, even the entire biosphere. In the continuing search for higher productivity, improved production efficiency and reduction in costs, newer techniques and tools of management are being evolved, and the existing ones are being honed. The entire management concept and practices have been revolutionised by computer-based information systems, computerised process and production control, and fully automated manufacturing systems.

1. Frontier Technologies and Advanced Materials

The rising demand for special engineering materials by aerospace, nuclear power, electronics, computer, telecommunications, defence and other industries led to the investigation and development of new classes of advanced materials in recent years. These include special purpose steels and alloys of metals, polymer matrix composites, ceramic materials, materials for space propulsion and power systems, smart materials which adjust their properties to changing environment, and a number of other new materials for use in automobiles, turbine engines etc.

Developments in metals

Steel is still the most widely used material in a large variety of applications, both simple and sophisticated. Others are metals like aluminium, titanium etc. It will, therefore, be relevent to review briefly the recent developments in steel and other metals, before we turn to other materials.

The current thrust in steel is on process improvements to enhance product quality and to reduce costs, energy optimization and environmental control. These have been sought to be achieved through improved melting and degassing techniques, continuous casting, controlled rolling, thermo-mechanical processing etc. Improved vacuum melting and vacuum degassing practices have enabled the production of clean steels with reduced carbon contents, enhanced toughness, ductility and weldability. Ultra-low carbon, interstitial free steels with microalloy additions of niobium and titanium have been developed which have improved strength and formability. Continuous casting has come of age and now the emphasis is on near-net-shape continuous casting of strip, rod and thin slabs, and direct rolling. In the coating field, coating steel with zinc-nickel and zinc-iron alloys is finding use because of their superior corrosion performance. A new heat- and corrosion-resistant aluminised (type 409) stainless steel is being produced for automotive applications.

Other developments include the increased use of stainless steels in structural, architectural and automotive applications; and the development of duplex stainless steels in the USA, which combine the characteristics of austenitic and ferritic grades. These duplex stainless steels are used more and more in severe corrosion environments in chemical industries, power generation etc.

In superalloys, significant advances have been made in the realm of processing techniques which include directional solidification, single-crystal solidification, and powder making methods such as rapid solidification and mechanical alloying. To improve the melting practices, electron beam and plasma refining are being increasingly employed.

Some of the developments in special alloys include rapidly solidified alloys for aerospace applications; and new alloys for sulphidizing environments encountered in petrochemical, petroleum refining, thermal power generation, chemical and process industries etc. In the search for high temperature materials with high melting points and hot strength, low density and good resistance to oxidation, *intermetallics* of iron, nickel, titanium and beryllium are being investigated.

Titanium alloys have been contributing to the improved performance of gas turbine engines for the past few decades, because of their light weight, high strength and ability to withstand moderately high temperatures. Investigations are under way to extend the useful temperature range of titanium-aluminium alloys, which would increase the thrust to weight ratio of aircraft engines and enable replacement of heavier nickel-base alloys with titanium alloys.

The development of aluminium-lithium alloys for aerospace applications in recent years constitutes a major technical advance in aluminium. These alloys with lithium content of 2% to 3% have densities lower than the traditional alloys and have moderate to high strengths. The increasing demand for improved airframe materials for the next generation subsonic planes has spurred further research and development in aluminium-lithium alloys.

The other two major areas of development in aluminium alloys are rapid solidification technology combined with mechanical alloying through the powder metallurgy route; and metal-matrix composites for aerospace applications.

Advanced polymer composites

It is now common knowledge that the development of polymers has resulted in the replacement of metals in many areas in the automobile, aircraft, household appliance, packaging and other industries. The share of polymer composites in replacing metals in traditional transport and military hardware is expected to have an explosive growth in the coming decade. Today, about 78 per cent of the airframe weight in a modern subsonic plane is accounted for by aluminium alloys. With the development of aluminium-lithium alloys, this percentage is expected to drop to around 54 per cent. The increased use of polymer composites in airframe is expected to further reduce the share of conventional aluminium alloys to about 11 per cent by the turn of the decade.

Advanced composites are meeting the increasingly tougher performance requirements of the new generation of military aircraft in the USA, UK etc. Ultimately, the share of composite construction in these advanced aircraft may rise to 50 per cent. The combined advantages of weight reduction and use of new design concepts will extend the application of composites in commercial aircraft.

Plastics and composites are expected to grow into a $ 350 billion industry by the turn of the century in the USA alone. Areas of significant new development activity that will have priority in the coming years include polymer matrix composites, recycleable/bio-degradable plastics, materials for large sheet forming and improved high temperature polymers. The major deterrent holding back the use of polymer composites in commercial applications so far has been the high cost. Process engineering for composite materials is also expected to take a leap forward in the coming decades with probable lowering of costs.

Composites for high temperature applications

The giant automobile manufacturers and aircraft industries are fully gearing themselves up for eventual switch-over to composites, replacing traditional materials. Liquid crystal polymers (LCPs) which have the capability of retaining their strength, properties and dimensional stability at higher temperatures (250°C) are being developed for these applications in a big way. The current prices of LCP materials are much higher than the other competing polymer polyphenyle sulfides (PPS) and therefore, their use is at present limited to high value, high-tech applications like military communications and other hardware. New formulations such as DuPont's HX-2000 'amorphous' LCPs, are expected to be developed for commercial applications in the near future. Worldwide sales of 9 million kg of LCPs have been projected by mid-1990s, which represents a 20 per cent annual growth rate, nearly double the overall growth of engineering resins. PPS/metal camshafts are already replacing conventional steel camshafts within the conventional heat engines, automobiles etc. The growth of LCPs may lead to replacement in the future of many conventional materials in engineering industries.

Advanced ceramic materials

Continued research and development work indicates that ceramics may also replace conventional engineering materials in certain high performance applications such as in advanced heat engines, heat exchangers as well as many other engineering components. Benefits that can be achieved by using cermets include higher operating temperature capability, lower weight-inertia (in heat engines), lower friction losses, smaller engines for a selected power level, lower heat emission to the environment, significant impact on system costs (initial as well as life cycle), good wear- and corrosion-resistance (unique chemical stability).

Generally, ceramic parts and ceramic coated parts are expected to be incorporated gradually into high-heat areas of motor vehicle engines during the early 1990s. This may open up market possibilities for ceramic engine components like turbocharger rotor, rocker arm/cam follower, valve and piston components.

Smart materials

Smart materials are being talked about and developed in various research laboratories. These materials adjust their physical properties to meet changing conditions. For example, when external stress builds up on these materials, the materials develop adequate resistance to adapt themselves to the changed environment. These materials are being produced by using electro-rheological (ER) fluids which thicken in micro seconds when exposed to weak electrical fields. The ER fluids when synthesised with composite materials and processed, lead to the development of smart materials. Materials scientists believe that they will soon be able to develop materials which can respond immediately and continually to changes in vibration. Since these materials respond to external stimuli, they may find applications in aerospace, defence and other engineering industries.

Advanced materials for space systems

Space stations are now a reality and in the near future, human civilization will set up space workshops, research laboratories, observation stations etc to explore the universe further and to sustain the growing needs of our civilisation. To meet these objectives, the special materials processing techniques required for space propulsion and space systems are under development.

The next generation propulsion for space vehicles will increasingly involve liquid hydrogen/oxygen or hydrocarbon/oxygen systems. The advanced space shuttle's main engine which will be using these propulsion fuels, will need high strength, high conductivity combustion liners fabricated of composite materials such as tungsten fibre reinforced copper composites, rapidly solidified copper for replacement of current lower strength copper nozzle alloys and others. High thermal conductivity and thermal fatigue resistance are key issues that need to be satisfactorily solved by new materials and supporting structural analysis, composite ply architecture and improved processing techniques. Another area would be the development of suitable metal-matrix composites for turbo-pump blades to be used in advanced liquid fuel engines. Development in the field of tungsten fibre-reinforced superalloys (TFRS) holds a future promise, as it may offer a better higher temperature service capability compared to even advanced single crystal superalloys.

Space power system is crucial for the success of the space exploration programme. So far, the workhorse for power generators for satellites, probes and orbiting platforms had been silicon solar cells. Today, gallium-arsenic (GaAs) and indium-phosphorus (InP) compounds are being optimized for future photovoltaic systems, because of their higner power generation capabilities and greater stability in the radiation environment of space.

Dynamic systems are also being developed to provide higher power levels required for space stations. A solar dynamic (Braton) system operating around 1025°C and a thermal energy storage system based on the enthalpy of transformation associated with a solid to liquid change, are under development and will enable the provision of electric power levels in the 100 kW range for space stations. The technological feasibility of space nuclear power is also being investigated in the USA under a NASA/DOE/DOD programme.

Materials factory in space

The establishment of a space station with assured supply of high levels of electrical power will enable investigations on high purity materials and their processing in the low/zero gravity, near vacuum environment of space. Current investigations on earth under simulated condition of this environment,will eventually prepare the way. The products that can be manufactured in space are fascinating: perfect crystals for the electronic industry; ultra-pure glass for laser transmission; defect-free, long-life metals for use in the turbine industry; and immiscible materials fused together to produce new materials such as steel-and-glass composites.

2. Microelectronics and Information Technology

The applications of advanced materials have been possible to a large extent due to the spectacular developments in microelectronics, computer technologies and telecommunications as well as the current technological transformation towards an 'information society'. The integration of the three, accelerated by the development of integrated silicon circuits, has made possible rapid progress of 'telematics'. Information is now regarded as a resource, in the same way as energy is, and has become an essential input for a wide range of mechanical and intellectual activities. Its wide and easier availability, exceptional reliability and the large cost reductions it promises are its other attributes. In fact, the electronic industry is now recognised as essential for future industrial growth. To quote the OECD Interfutures Project Report (1979), "the electronics complex during the next quarter of a century will be the main pole around which productive structures of the advanced industrial societies will be reorganised". This is indeed happening as witnessed by the increasing amount of control and automation of production processes and service sectors.

It would be interesting to review briefly the development and diffusion of the microelectronic industry in the industrially advanced countries. Three distinct spheres of activities — design, manufacture and coordination — can be discerned in the production activity. The suppliers of these technologies are targeting to integrate production across each of the three spheres to give computer aided design/computer aided manufacture (CAD/CAM) and other types of computer integrated production systems. Computer integrated manufacturing (CIM) represents the ultimate logic of incorporating microelectronics into individual or a group of machines — the eventual goal for the supplier industries.

With the convergence of telecommunications and computer technologies, the world is fast moving towards satellite network, optical fibres, video conferencing, facsimile and computer data transmission over long distances. Telecommunication networks now provide a whole range of services capable of pushing voice, data and pictures across telephone lines. Optical fibres are now being increasingly used in advanced countries and it is interesting to note that India is the first developing country to indigenously develop these for use in communications.

Microelectronics technology has led to a veritable information explosion. Information and knowledge which were formerly services, have now been transformed into a primary growth industry. Today, a nation's information and knowledge resources have become the hallmark of its international standing and strength.

Computers and 'Artificial Intelligence' (AI)

The phenomenal capability of the computer is the combination of speed and complexity. Miniaturization has led to the development of super computers enabling multiple and parallel processing and resulting in substantial reduction in costs along with increased reliability.

Artificial Intelligence is an effort to imitate the functioning of the human mind using computers. The subject of AI research has been mainly on the task that normally requires human intelligence and uses symbolic reasoning and inference method of problem solving. AI broadly comprises Expert Systems, Natural Language Processing, Vision/Pattern Recognition Systems, Voice Recognition Systems and Robotics.

Expert Systems technology is considered as a down-to-earth implementation of the Artificial Intelligence System. It uses knowledge and reasoning techniques to solve problems in the same way as human experts do. It is its ability to store the connection between the facts, rather than just the facts themselves, that gives it an appearance of human-like understanding of real life situations. AI Systems are now emerging from research laboratories into the commercial world. Companies in the USA and Japan have already invested billions of dollars in 'government-industry' co-operative effort to produce special computers for AI Systems.

In a radical departure from traditional computing, scientists have been working on a vastly different approach, namely neural net technology which imitates brain's complex network of neurons. Research in this field could lead to a new generation of machines 1000 times faster than today's computers and capable of interpreting speech, vision and data in ways far beyond the capability of present machines. They will also possess self-learning capabilities. Neural net technology, however, is still in its infancy.

Microtechnology

It would be relevant here to mention the breath-taking developments in the emerging field of microtechnology (or micromechanics or micro-machining) which is poised for a rapid breakthrough. Scientists and engineers foresee an exciting future for this field. Researchers at the University of California in Berkeley (USA) have developed the first electrically powered micromotor, an outstanding achievement in miniaturization. Its eight-arm rotor is about 0.005 cm and the entire motor is 0.007 cm across. It is so tiny — only about two-thirds the width of human hair — that it will easily pass through the eye of a needle and its shape can only be seen under a microscope. The micromotor is driven by electrostatic forces between the motor elements, and not by magnetic field used in most conventional motors.

When perfected, micromotors and micro-machines promise revolutionary and explosive growth in hitherto impossible fields, from robotics, nuclear energy to medical examination and intervention. Scientists are visualising that it will then be possible to send micro-robots through the body — thousands of them from one injection — cleaning out deposits, scouring tubes, sensing cancer cells by their defective genetic code and then pureeing them. The robots will be of bio-degradable types and will eventually be purged out of the human body. Neurosurgeons are already talking in terms of remote controlled brain surgery. Similar applications are being envisaged in the field of nuclear engineering, robotics, power plants, space technology, computer appliances and a host of others.

The factory of tomorrow

The impact of microelectronics and computers is being already felt in many a manufacturing industry. The concept of the factory of the future as viewed by managers, designers and engineers, is one that will be computer-driven, not human-driven. This concept visualises that the computers will supplement and enhance human thought processes and expand an individual's potential in a more creative work environment. Computer-aided design (CAD) and engineering (CAE) and the automated warehouse are the various components of the computer integrated manufacturing (CIM) system. Its miniature version, flexible manufacturing system (FMS) is already in extensive use in several industrialised countries. At the other end of the spectrum are robots which perform a wide variety of functions formerly carried out by human beings.

3. Environment and Technological Change

Industrial calamities and natural disasters in recent years have served to awaken global awareness about environmental pollution and its effects on our fragile biosphere. Governments and politicians, conservationists and environmental action groups are increasingly expressing their concern about environmental degradation. Also, there is alarm about the 'green house effect' changing the world climate, melting polar ice and submerging coastal areas due to the rising ocean level; oil spills and rubbish dumped into the sea endangering acquatic life and the beaches; acid rain further destroying the diminishing oxygenating forest; degradation of land and soil erosion resulting from bad agricultural practices and excessive use of pesticides and fertilisers; deforestation and destruction of the tropical forests with their rich 'biodiversity' and ecosystems; and about the quality of life of the masses living in modern megacities and urban sprawls created by industrialisation. The environmental side-effects have increased with industrial growth and some of the damage done to the environment appears to be irreversible.

Materials scientists are making valuable contribution towards correcting the environmental imbalances that have resulted from years of neglect. By virtue of their professional training and experience, materials scientists are increasingly called upon to devise workable solutions to contain environmental damage and to mitigate its adverse effects, namely designing and engineering pollution-safe industrial plants and complexes; exploiting natural resources without environmental degradation; conserving unreplenishable resources of naturally occurring materials and optimizing energy use; developing alternative non-polluting and renewable sources of energy as substitutes to pollution generating fossil fuels; and developing new materials and products which are environmentally less harmful to the flora and fauna, the farm land and forests, air and water.

Sustainable growth and 'Green GNP'

Poorer developing countries are doubly threatened by the environmental degradation taking place. Their current subsistence economies and livelihood are often dependent on exploiting the environment. Their schemes for industrialisation become prohibitively expensive, if they were to incorporate all the new suggestions for environmental control out of their own resources, in effect to protect the whole earth's remaining ecosystem. While the need for environmental protection and improvement is thus even more crucial in the case of developing countries, their governments are faced with the dilemma of safeguarding the environment and at the same time ensuring economic growth and better living standards for the people.

Though the earlier limits to growth and environmental disaster scenarios by the Club of Rome and other futurologists have been proved wrong, the elements that are progressively damaging the environment are still there. The recent Brundtland Commission Report 'Our Common Future' is more realistic and defines the environmental protection concept as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". There is no gainsaying that environment has become a live issue which governments and politicians can ignore only at their peril.

With the new awareness of environmental protection, not only greater attention is being paid to it in the design and engineering of modern industrial plants, but also to its impact on the national economy. In fact, the very concept of national statistics is changing. Efforts are now under way in a number of countries like France, Germany and Norway to incorporate environmental costs and benefits in the gross national product (GNP) and to produce alternatively a 'green GNP'. The conventional GNP measures in monetary terms the total goods and services of a country during a year. The new 'green GNP' seeks to incorporate also the monetary value of existing natural resources and the cost of using or misusing the environment to adequately reflect the economic reality in an era of acid rain, dying forests and greenhouse effect.

The greenhouse effect

Since the beginning of the industrial revolution, large amounts of carbon dioxide, carbon monoxide, nitrous oxide, methane and chlorofluorocarbons (CFCs) have been steadily building up in the earth's atmosphere. These gases let in the sun's rays, but trap in resulting heat to act like a greenhouse. Though hard evidence of global warming is not available, the greenhouse effect has to be taken seriously. The destruction of the ozone layer had been prophesied for years, but it is only very recently that it has been established.

Several countries have already taken preliminary steps that would help postpone the greenhouse effect, such as phasing out CFCs; conserving energy and building highly fuel-efficient cars; preserving tropical forests and stimulating development of smokeless forms of energy generation. Needless to say, global warming can be slowed down by reducing the combustion of carbon-rich fossil fuels. A meeting of scientists, conservationists and politicians in Toronto last year called for a 20 per cent cut in the emission of carbon dioxide by 2005 and 50 per cent by 2025. Interestingly, a computer developed scenario of how the world might stop or stabilize warming by 2060, prepared by the World Resources Institute, USA, indicates that energy conservation is by far the most fruitful and cost-effective way to slow down global warming.

After the two oil shocks, there has been some conscious effort all round towards energy efficiency and optimization. This switch over to greater energy efficiency could be speeded up by setting minimum energy efficiency standards for industrial machinery, automobiles, domestic equipment etc. Materials scientists can make valuable contribution in bringing about this change. Many alternative sources have been suggested to stop 'the complex web of environmental problems' arising from the use of fossil fuels. Recent breakthroughs in solar energy technology seem to suggest that low-polluting and renewable solar-generated hydrogen gas may be one of the few long-term options that can meet the world's energy needs without contributing to the greenhouse effect.

Population explosion

An area which will increasingly have impact on industrialisation is the need for lesser number of people with a higher level of education, for both production and services. The earth will not be able to support 6 billion people by the end of the century as forecast by the United Nations, at even the standard of living enjoyed today in middle income developing countries such as Mexico and Malaysia, leave alone the higher standards to which the rich western countries are accustomed. Providing even the basic needs and amenities to such a large population will tax the resources of even the rich countries to the maximum and in this respect, the poorer countries will be worst hit. This realisation emphasises the need for well considered population and education policies and their effective implementation urgently, particularly in the rapidly developing countries.

International cooperation and the Planet Protection Fund

Internationally, various schemes have been suggested for assisting developing countries to implement environment programmes, such as buying up third world debt and swapping it for environment conservation schemes in debtor countries. Some of these 'debt for nature' bargains have been concluded with countries like Costa Rica, Ecuador, Madagascar and the Philippines, mostly by voluntary organisations interested in saving the biodiversity of tropical forests and their ecosystems. Some developing countries, however, regard such schemes as 'environmental colonialism'.

This sensitivity apart, the international dimensions of environment in the present context should be clearly understood. Environmental pollution knows no national frontiers and its effects are felt over an entire region. It presents quite new problems which can only be solved with the cooperation of other countries. It is a global issue to be tackled at the global level for initiating appropriate international policies and action so that both the developed and developing countries can have a stake in protecting and improving this planet's environment.

In this context, India's proposal at the recent Belgrade non-aligned summit meeting for the creation of a multimillion-dollar Planet Protection Fund has received worldwide attention. The Fund will have universal membership from both developed and developing countries and will be administered by the United Nations. It is expected that the Fund would evolve conservation-compatible technologies in critical areas and provide 'positive and supportive measures' to assist the developing countries in exploring and implementing environmentally benign policies of development. India's suggestion was also endorsed by the Commonwealth Heads of Government at the summit meeting in October 1989, in Malaysia. The summit, while adopting the Langkawi Declaration of Environment which seeks coordinated global effort to protect the environment, emphasised at the same time the need for growth of the developing countries.

4. Socio-Economic Implications of Technological Change

The socio-economic implications of technological change are far-reaching which will eventually bring about a radical transformation of the industrial society as we know it today. First and foremost is the effect of displacement of employment and the need for extensive training, retraining and redeployment programmes for personnel affected by the introduction of new technology. Then there is the changing organisation structure from the hierarchical to the functional. These pose new challenges to management to manage the transition and to bring about the technological change without undue friction and distress. In the case of developing countries, three major areas which will be most affected by the introduction of new technology, are finding new avenues of employment for people likely to be displaced; resources for investment in new technologies; and quality- and cost-consciousness for the development of international trade.

Tasks and challenges for management

The real challenge for the management will be managing the technological change. Managing knowledge workers for achieving the objectives of the enterprise is a new proposition. What positively motivates is their sense of achievement at work. They respect knowledge and increasingly desire that knowledge would become the basis for their advancement. Therefore, they also feel that the demand on them be made by knowledge, rather than by floor level supervisors. Knowledge work, therefore, has to be organised as a team effort in which the task itself determines who will be in charge, for what and for how long. For this, the organisation structure should be both rigid and flexible, have clear authority and yet be task-oriented.

With the new technology in position, industry can no longer run by linear mechanistic logic; rather it is being masterminded with the help of the new generation computers which grasp and work out the problems at one go. To cope with this kind of reality, management needs to develop a holistic vision: a vision which perceives a business situation as a whole, rather than as a piece-meal analysis of its various parts.

Then, there is the changing organisation structure itself. In the traditional organisation structure of yesteryears, the most important element, time, is missing. In the context of the new technology and the new economy, time has to be factored into the structural design of a corporation, aimed at visualising its business activities at different points of future time and remaining flexible enough to redesign appropriate structures for each time period as required. This will enable the management to readily change the organisation in response to situations developing as a part of its planning process and to make relevant changes in modest, but almost continual increments. Each change is so minute that the overall effect is "one of a structure in constant seamless motion. In contrast, the conventional industrial structures are like still photographs"

The new technology demands that the organisation breaks away from the hierarchical structure of the past, because the new environment created by information technology cuts across the hierarchical chain of command, and enables direct and instantaneous communication between all the entities of an enterprise. The structure of the organisation has to move away from hierarchical mode to one based on network. Problems of decentralisation and centralisation will arise, but the built-in flexibility of the new organisation structure will permit specialisation and integration to coexist and operate simultaneously.

Displacement fears and positive aspects of new technology

Every major technological change is accompanied by a certain amount of displacement of jobs, while creating new employment opportunities. It will be recalled that during the First Industrial Revolution, the cumulative effect of the advent of the steam engine and metallurgical developments led to a profound change in human life and ushered in a new industrial era, despite the dislocation of industry and society in the early years. A similar situation is faced today. The on-going advances in electronics, computer and communications technology are leading to a veritable industrial transformation which is completely different in kind and degree from past innovations.

In the midst of fear of the workforce about losing jobs and near despair among older employees about the feasibility of retraining for new skills, there are positive expectations of some new employment opportunities and improved economy: a higher standard of living, better jobs with upgrading of skills and stronger competitive position in the world markets for industrial products. Yet, it is clear that the factory of the future will use fewer people. Therefore, the transition will not be smooth. To a great extent, fear and resistance to change are the major stumbling blocks. These have to be overcome as humanely as possible.

Training, retraining and redeployment

Training, retraining and redeployment can reduce these problems. Therefore, retraining of workers to accept and use new equipment and techniques, will assume top priority in corporate education programmes. Attempts should be made to redeploy people in other jobs and locations, as a measure of alternative employment. The opportunities presented by the new technology for gainful self-employment can also be exploited by the retrained worker. The educational level required of the workers at the entry point will be higher. There will be a general upgrading of the skill levels, as the workers learn to use computer assists. The jobs will be more interesting, more challenging. Because of the computer assistance, workers will know more about their jobs in the larger context of the company's operations, an important element psychologically, which will prevent alienation and dehumanisation.

Managing the technology change

A good deal can be done by management and government to remove the feeling of insecurity among the workers and prepare them for the technological change. Management should assure the individual worker of his/her job security, and encourage them to learn new skills and become a 'knowledge worker' and to participate more meaningfully in the technological change.

Most of the industrialised countries have tried to tackle the problem of this transition in different ways. In the USA, for instance, the problem was sought to be tackled cooperatively by a group of employees under the auspices of their trade union. In Sweden also, the government handled the matter with the close cooperation of employees and trade unions. In Japan, the strategy adopted is to assure job security, training and retraining, and creating an awareness among employees as to why the new technology is necessary and that it is in the interest of both the workers and the company. The concept of 'life-time employment' is essentially a Japanese phenomenon. However, no one method may be adequate to bring about smooth technological change. As Peter Drucker has put it, "a combination is needed of the Japanese emphasis on continuous training; the German commitment to industry or plant; and the Swedish guarantee of job and income security through mobility" to make possible, politically as well as psychologically, the acceptance of technological change by the workforce.

5. Case for Action by Developing Countries

There are at least three major areas which are profoundly affected by the introduction of new technology in developing countries. These are employment, investment, and international trade. The question of employment is the most tricky one for third world countries. Sooner or later, the new technologies will enter the third world, in a big way. It has already happened in the case of countries like Singapore, South Korea, Taiwan, Brazil etc and their success is likely to be emulated by other newly industrialising countries like India and China. A wide range of views have been expressed on the impact of new technology on employment. There is, however, a general agreement that in the long run, the level of employment will be lower. As a recent ILO study has concluded, this may be in the form of lesser number of people fully employed or part-time employment or shorter working hours. However, as the history of technological development has shown, alternative patterns of work organisation have coexisted in similar cases of diffusion of technology.

Creating new employment opportunities

Herein lies the challenge and opportunity for social choice and action. Since very different forms of work organisation can ensue with the utilisation of the same electronics-based equipment, it is possible for the newly industrialised countries to mitigate the effects of decline in direct employment resulting from the induction of new technology by retraining and redeployment on the one hand and by appropriate modification in the organisation on the other. Further, electronics-based technologies can generate new employment in the electronics industry itself, in information industries like computer hardware and software, telecommunications etc. However, for the benefits of the new technology to trickle down to all levels of the society, the governments of the developing countries should adopt long-term policies and programmes for population control, education and training.

As for indirect employment, unlimited opportunities exist for the application of information technology in almost all areas of business and industry, specially in the service industries. This is particularly important for newly industrialising countries where the service sector is rapidly growing. The adoption of new technologies offers an excellent opportunity for these countries to rapidly upgrade the skills of their labour force and improve its efficiency. This will enable them to compete with industrially advanced countries on better terms.

Investment for new technology

The other two major problem areas that affect the introduction of new technology in developing countries are finding the resources for investment in new technology and inculcation of quality- and cost-consciousness for developing international trade.

As the developing nations are perennially short of financial resources and foreign exchange, setting up new factories with the new technologies may not be a feasible idea in the short run for many. However, the new technology can be inducted in the modernisation programmes of existing industries where the additional savings generated after modernisation will justify the investment. This applies specially to core sector industries like steel where a reduction in the unit cost of production will be reflected in the price of the product. This in turn will lead to a reduction in the overall cost structure of the economy. The net gain to the economy and funds generation will spur further investment in the new technology.

Quality, price and international competitiveness

The success of developing countries in improving their export performance and international competitiveness will depend to a large extent on the expeditious introduction of new technologies in the various industrial sectors and the induction of quality consciousness accompanied by reduction in costs through greater production efficiency. However, this performance can be fostered and maintained only through innovation and the adoption of newer techniques to produce a better quality product with added value; and of course sound and sensible management to optimize the available resources in the constant march towards excellence. In this context, it is interesting to note that India's Eighth Plan Approach Paper has laid special emphasis on technological updating, world class quality of products and services at competitive prices.

The new technology will enable the industries of developing countries to produce quality products at competitive prices. The accent is no longer on simple quality control, but on 'quality assurance' which ensures the customer or client with a high quality product or service. This quality consciousness is gathering momentum in the newly industrialised countries like South Korea, Singapore, India etc. Where this quality consciousness is absent, there is a tendency for production processes and products to continue beyond their 'maturity stage' and natural life, mainly because of the sheltered market and little or no competition. The situation till recently in respect of passenger cars in India is a case in point.

In this context, it would be relevant to mention the 'just-in-time' system of inventory and quality control or 'Kanban' as it is kown in Japan. The system seeks to coordinate and synchronise the arrival of parts and components with the on-going production process. It is designed to ensure quality control of the final product, while eliminating defective or inferior quality components as well as the need to carry unnecessary inventory. This quality production on the assembly line is only possible because of the assured quality and reliability of the parts and components obtained from various outside sources. It is this quality consciousness at all levels that has made Japan a world leader in industry today.

Concluding Remarks

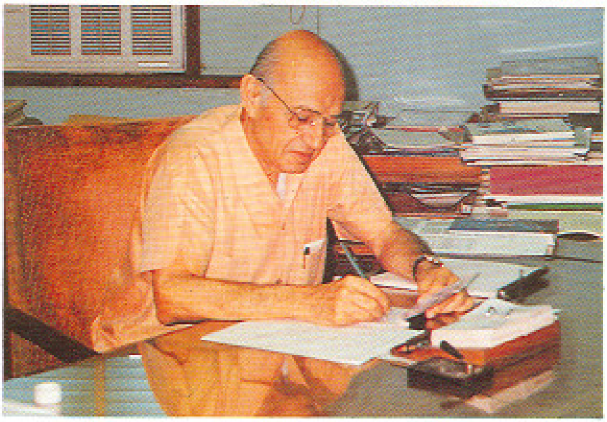
There are certain features of changing technology scenario, namely the development of advanced materials, the burgeoning information technology and the new sophisticated industries, which have speeded up change marking a complete break with the past.

Apart from the factors which I have touched upon, there are a few more which are of special significance to the developing countries.

First, in today's context, the 'life' of a particular 'new technology' tends to be very short, so fast is the pace of change in the advanced industrialised countries. Unless a developing country has the technological infrastructure to keep pace with the changing technology in the chosen area, a situation may arise which will land it in high-cost production and lose in international competitiveness. Second, the concept of 'raw materials' has totally changed in the industrial economy created by the new technology. These technologies do not use the traditional raw materials and natural resources as inputs. Instead, they put to work new technology in an essential manner to produce high-tech raw materials. It is crucial, therefore, that the developing countries acquire and successfully absorb these technologies to achieve a measure of technological independence in this highly competitive and rapdily changing world.

Any change has a price tag attached to it, big changes have big price tags tied to them. The change brought about by the new technology is total and all pervasive; every single segment of the society will have to adjust to it, the sooner the better. The process has already started in the advanced industrialised countries. However, unlike developing countries, these countries are endowed with strong infrastructure, high per capita income, high level of general and technical education, comparatively small populations and a relatively small labour force. All these factors provide a great cushioning effect to the turmoils of change that accompany the new technology in advanced countries.

It is exactly these very factors that are missing in most developing countries, particularly in India. Inducting new technologies into such countries, allowing the economy and the society to adjust to the changes without undue turmoil or dislocations, and bringing about a peaceful transformation of society — these underscore the need for planning and implementation of realistic population, education and training programmes in conjunction with growth-oriented industrial and farm policies.



Dr M.N. Dastur, Chairman and Managing Director of M.N. Dastur and Company, Consulting Engineers, is one of the most distinguished engineers and technologists. He was a past President of the Indian Institute of Metals.

After his graduation in Electrical and Mechanical Engineering from the Banaras Hindu University in 1938, he started his career and worked for six years with Tata Steel at Jamshedpur. He then obtained his doctorate in Metallurgy (Sc.D) from M.I.T. (USA) in 1949, specialising in 'Principles of Steelmaking'. He worked in the USA for the next seven years with consulting firms on the design and construction of steel plants in various parts of the world including USA, Latin America and Europe. On his return to India in 1955, Dr Dastur pioneered steel plant consultancy in India and founded M.N. Dastur and Company.

Dr Dastur has served on a number of Indian Government Missions and Committees, including the Steel Missions to USSR and China. He was member of the National Committee on Science and Technology (1977-80) and the Science Advisory Committee on Science and Technology (1981-83). He is an internationally recognised steel expert and is consultant to UNIDO, Vienna. He is the author of several papers on steel technology and industry.

The Banaras Hindu University conferred on him in 1980 the degree of D.Sc. *honoris causa* for his conspicuous services to the development of self-reliance in steel industry and the advancement of engineering and technology. Dr Dastur was awarded the prestigious JRD Tata Gold Medal by IIM in 1982 and the IIM Platinum Medal in 1987 for his outstanding contribution to the metallurgical profession.

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