Emerging technology challenges in the post-liberalization era

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Technology is a crucial instrument, even a weapon, to compete internationally in a truly free market. Technology can also constitute an expensive equity and ability to make advances become sharper. It is now widely recognized, even by economists, that at least 50% of economic growth could be attributed to technological improvement. The emerging scenarios will call for cleaner and safer technologies which are benign on capital cost and which consume relatively less energy. In chemical industry we would be looking for 'zero discharge' total recycle processes as we would be called upon to explain the ultimate fate of everything that arrives in a plant. The plants would be required to be super safe and the risk element will have to approach vanishing levels. The example of nuclear power industry may be cited where robust and rogue-proof technology has to be adopted. The availability of highly sophisticated instruments enables users to track impurities at even ppb and sometimes parts per trillion level.

We in India will face yet another challenge of getting much more out of our existing assets in thermal power stations, transport sector, fertilizer plants, small chemical plants which pollute, etc. Here also we would need a cutting edge of science.

In order to be a technological power the base of scientists and engineers has to be extraordinarily strong. While we are somewhat justified in boasting about our technological manpower we must not overlook the mediocre quality of people who are going to basic sciences and many bright engineers who gravitate towards 'management' degrees. We must ensure that high quality students go for Chemistry, Physics and Biology. A new disturbing feature is the emergence, on a grand scale and with an explosive growth, of a large number of colleges of engineering. In the very near future the total number of graduates from such colleges will probably be 3 times those from 'recognized' institutions of which we are justifiably proud. The quality of teachers, which definitely influences the calibre of graduates in engineering and technology, will take a terrible beating as such a number of teachers that are required (more than 25000) are just not visible and working with retired teachers *en masse*, or fresh graduates in engineering who read the same books as the students is retrograde. We will have to correct this most undesirable development in our hurry to privatize engineering education. The A.I.C.T.E. act has hardly been of any tangible help.

I should like to take some examples from the chemical industry (CI), with which I have some familiarity, to bring out some of the emerging challenges.

Cleaner and safer technology

The importing countries will demand a technical audit of the plant and the prowess of accurate material balances will be brought home. Thus I foresee a number of chemical plants making dyestuff intermediates, drug intermediates, agrochemicals, etc., facing a bleak future unless they become contemporary in every respect. I do see a bright future for technology and technologist-driven chemical companies based on meritocracy. The existing centers do provide a basis to improve upon substantially in a short period.

We need process innovations through selectivity engineering, to make processes neat and carry out sophisticated optimization for multi-step processes. The history of the CI is replete with such examples and the case of ethylene oxide/propylene oxide *via* chlorohydrin, which generates a lot of waste and unwanted by-products by neat oxidation processes, replacement of nitric acid based oxidation of *p*-xylene to terephthalic acid by air oxidation process, total recycle process for urea, etc., may be cited.

The need for intrinsically safe processes is acute as was brought home to us through the most unfortunate Bhopal disaster. It is interesting to record that we in India did have for a wheat weedicide—Isoproturon, a nonphosgene technology and India is an important world player in this product. This brings out how technology provides an edge to compete internationally. The use of hazardous chemicals will rapidly eclipse both through the technological changes in the processes as well as replacement of products which cannot be made by safer chemicals. We can foresee replacement of hydrocyanic acid and phosgene-based processes and hete products such as urethanes, polyamides, etc. are industrially very important. Ethylene carbonate and propylene carbonate can be conveniently made from ethylene oxide and

propylene oxide, respectively, and these can be ester exchanged with methanol, phenol etc. to give the corresponding carbonates, which are important precursors for the products named above. The restrictions on hazardous chemicals will call for on-site, on-demand generation, calling for new technology.

We will have to adopt sophisticated optimization methods for multi-step processes and the desirability of adopting continuous plants for smaller scale operation will have to be assessed.

Function oriented chemical industry

The CI has not been accustomed to a function orientation as the main output has been of high purity/quality chemicals, polymers, fibers etc. In parallel with the mechanical and electronics industry it will become necessary to provide 'functions'. Thus, take the example of even water treatment in power stations and the CI, where a total package which removes dissolved solids to ppb levels, provides corrosion resistance, inhibits fouling etc. will be required.

Pharmaceuticals and agrochemicals

Our growth, so far, has been almost totally on products discovered elsewhere in the world. While we can take justifiable pride in our growth and the availability of drugs at attractive prices, this is just not enough. We will have to face the realities of the intellectual property rights and keep in mind the cost of developing a new drug or agrochemical which is around $200 million. We should continue to come out aggressively with innovative, clean and safe processes for drugs and drug intermediates for products which are off-or will come off-the patents. We can make spectacular progress in this sector to boost our morale and to catapult us into the 'discovery' route. We can also make a notable contribution in coming out with chiral compounds.

With the intellectual power that we do definitely possess I see no reason why we cannot come out with new drugs and agrochemicals, even though their major outlet may be elsewhere in the world. In this context I see a definite need to come out with better processes for antimalarials and enteric fevers; there is a dire need to come out with better drugs. Even in the area of tuberculosis we need better and more efficacious drugs which can possibly work in a shorter period. In veterinary drugs our record is very poor; our milk is very expensive even though we have the dubious distinction of having largest number of cattle—around 350 million in the world. In pesticides we need to develop safer nematocides and rodenticides; our rat population is frightening.

Advanced materials

Polymer alloys and blends are occupying a pivotal position in providing stronger and cheaper materials. We will witness important breakthroughs through clever manipulation of polymer physics and polymer technology. Performance plastics will supplant metals across the board in majority of applications. We should carefully select our thrust areas and this could well be in the area of copolymers of propylene, involving those which lead to thermoplastic elastomers where metallocene catalysts with uv stabilizer and antioxidants are integrally involved during polymerization. Further copolymerization of alphaolefins, styrene, etc., with carbon monoxide to give nylon-like materials should be undertaken.

Engineering plastics like polycarbonates should be made *via* a process which bypasses the use of phosgene. This strategy should also apply to urethanes.

We should combine our strength in structural engineering with polymers and come out with structures which will allow replacement of steel. We also need to make a decisive impact on our railways which provide the national lifeline network.

Catalysts

Industrial catalysis is truly the corner-stone of today's chemical industry. We have made an impact in this area but we should aim much higher. We should further strengthen our base in zeolites and pillared clays. It is important to work in the area of direct utilization of ethane and propane for products which are based on ethylene and propylene, respectively. Activation of alkanes, particularly C_5's which are no longer welcome in gasoline, should receive attention. For instance it may be possible to coax C_5 alkanes to react with formaldehyde to give alcohols in the presence of peroxides as catalysts. The use of alkanes or aryl alkane hydroperoxides should be exploited to provide peroxide oxygen, which otherwise comes from expensive hydrogen peroxide—an epitome of 'Mr Clean'. The technology for vapour phase and liquid phase oxidation should receive attention to acquire a prominent slot in global competition.

Fertilizers

Populous countries like India, China, Nigeria, Indonesia, etc. will have to necessarily depend on nitrogenous fertilizers for a long time to come. It is of utmost importance for India to acquire a special status in this sector in view of our persistent need for a protracted period of coming two decades. We must develop new technologies for ammonia and urea and also develop

functional slow release urea at acceptable costs. The acidulation of phosphate rock with nitric acid should be yet another thrust area.

Engineering services and software packages

We should make a determined effort and provide composite, quick-action, reliable engineering services across the board. The scope is much more than we are inclined to believe as India can muster, at the drop of a hat, 100 engineers of any kind. We should remove irritants due to bureaucracy. We have made an impact in selling software, but the scope is far too great. Here capital cost can be minimal in relation to pay-outs and long-term contracts can be undertaken.

Nuclear and space programmes

The spin-offs of entirely civilian technologies are really impressive but we have yet to cash on our capabilities. The use of radioisotopes over a wide spectrum, food irradiation, nuclear medicine, etc. are only few examples. Satellite-based surveys can be conducted and interpreted for many poorly explored areas of the globe.

Concluding remarks

We as a nation will have to innovate to survive and chance favours only the best-prepared minds. To trigger innovation we have to radically change our methods and, per force, elitist policies, based entirely on quality of mind, will have to be fostered. We need to remind ourselves that genius prefers homogeneity of individuals rather than heterogeneity of groups. It is also a recognized fact that small firms have much greater propensity to innovate.

We will have to become quality-conscious on a consistent and long-term basis. Productivity ought to be much higher. We must get out of our delinquency and eject ourselves out from vicious circles to virtuous circles.

The time for scientists and technologists to play a pivotal role in ensuring the economic and social well-being of the nation has never before been so urgent. There is no viable alternative to 'technology push' based growth. We are desperately in need to *engineer* financial success. We must rid ourselves of the phobia of legislation and control and provide truly promotional activities. We ought to launch technology as an endless marathon and declare emphatically the support for technology as a potent instrument for rapid growth. We must usher the era of 'Knowledge Engineering'.

Vision is created by gifted researchers and not by Managers and Managing Directors or Committees which only purport to 'manage' but do not lead.

The role of technology in industrial competitiveness in post-liberalization economy — some issues and challenges for India

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The role of technology

A brief glance at human history will reveal that technology has been continuously put to use by man in bringing about changes in his environment, his life style, his perceptions. While this process was a gradual and continual one, through technological upgradation and modernization, we are also confronted with phases in human history when major technological breakthroughs were achieved to overcome threats and challenges. The application and management of such technologies brought about step-changes in human civilization. Eons ago, primitive man was only a food gatherer. When he managed for the first time to shape a crude implement out of stone, he had harnessed and put to use a major technology (literally a cutting-edge technology) which helped him to meet competition and upgrade himself into a hunter. Similar technologies such as the fire, the wheel, agriculture, the discovery and application of metals, etc., helped him to overcome environmental challenges including survival problems and provided qualitative, quantitative as also directional changes in civilization. At the same time, primitive tribes and nations beset with technological