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Acharya Prafulla Chandra Ray Memorial Lecture

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Background of
Acharya Prafulla Chandra Ray Memorial Lecture

Acharya Prafulla Chandra Ray was born on August 2, 1861 in a village in the District of Jessore (now in Bangladesh). After studying for two years at Metropolitan College, Calcutta, he received a scholarship from the University of Edinburgh where he obtained a B Sc degree in 1885 and two years later, a D Sc degree for his research in inorganic chemistry. In 1889, he got a special appointment as a Lecturer at Presidency College, Calcutta and became Professor of Chemistry soon.

Sir Andrew Pedlar, the then Principal of Presidency College and himself a Chemist encouraged Ray to pursue research and with Pedlar's help, Ray raised funds to equip a reasonably good chemistry research laboratory and began a search for some of the missing elements in the periodic table. He managed to precipitate mercurous nitrite, a compound that had been regarded as unstable in crystalline form. For several years thereafter, he and his students carried out a systematic exploration of the properties of mercury salts and a range of nitrite compounds. His findings of an enquiry into the adulteration of oil and ghee were published in 1894 in the Journal of Asiatic Society and the publication was highly acclaimed.

He remained with Presidency College until 1916 when Sir Asutosh Mukherjee summoned him to the University College of Science, Calcutta. There, he continued his teaching and research for next two decades long after he became eligible to retire. His students included Dr Meghanad Saha, Dr P C Mahalanobis and Prof S N Bose.

Ray's first volume of History of Hindu Chemistry was published in 1902 and the second, in 1908. He was known as the Father of Indian Chemistry. He was knighted in 1919.

Ray was instrumental in laying foundation of chemical and allied industries in India. He motivated to start the Bengal Chemical and Pharmaceutical Works Ltd in 1901. The Bengal Pottery Works, the Calcutta Soap Works, the Bengal Enamel Works and the Bengal Canning and Condiment Works are his creations. These industries, during the next few decades, provided hundreds of technical managers to the industrial establishments all over India. The Jadavpur Technical Institute established in 1921 (developed now into Jadavpur University) had Acharya Ray as its founder President. He formed the Indian Chemical Manufacturers' Association (ICMA) in 1938.

Intellectual regeneration, industrial development, economic freedom, social reforms and political advancement of the country — all made equally strong appeal to him, as did his teaching and research. Having abandoned western dress and manners on his return to India in 1889, he actively promoted the ideals of traditional Indian culture. He played a significant role in independence movement and motivated his colleagues and students for greater participation in it. He donated all his earnings to students, workers, laboratories and scientific organizations. He expired in Calcutta on June 16, 1944 at the age of 83.

In memory of his dedicated service, The Institution of Engineers (India) instituted an Annual Memorial Lecture in his name during the National Convention of Chemical Engineers.

Acharya Prafulla Chandra Ray Memorial Lecture
presented during **National Conventions** of **Chemical Engineers**

Impact of Globalisation on Chemical Industry an Overview

Dr S L Mukherjee

Infar India Limited, 7 Wood Street Calcutla

According to a study conducted by University of Michigan in 1994, only two countries (India & China) have the opportunity of joining the elite group of globalised economy by the veer 2005. The new economic policy of India is aimed at stimulating competition, enlarging the use of private sector and increasing participation in global trade. India to-day has, in fact, evolved a market friendly economic/business environment to attract investment from both, within and outside the country.

The 6-7% GDP growth indicates two very significant factors viz. the resilience of economy and the economy is gradually becoming isolated from vagaries of politics witnessed during some periods. It is evident that economy is gaining its own momentum.

The Indian Chemical Industry in all sectors, is playing its role admirably in conformity with demand of market based economy. The industry has grown from strength to strength in all sectors during last six decades.

The chemical industry is associated with all basic needs of the society such as food, clothing, shelter and health. The chemical Industry in India, like its counterparts all over the world, has a multi-dimensional character and forms an integral part of the national economy. The industry to-day exhibits a vitality achieved through a gradual process of consolidation during past decades in terms of product mix, installed capacity and turnover.

The liberalised economic scenario as well as competition with multinationals in both domestic and foreign market reiterate the necessity of planned R&D activity for technology development.

There is necessity to reform the structural and functional set-up of R & D activity in industrial sector. There are various facets of reforms to be incorporated in R&D policy of industries. One of the main facet is to foster healthy and mutually beneficial relationship between industry and academy for meaningful and target-oriented R & D activity in developing countries for technology development.

The chemical industry should aim at technology that can hold its own say 5 or 10 years from now, against severe competition from the developed countries. The technology development cannot take place in R & D Labs but needs appropriate engineering inputs in the form of process engineering, equipment know-how and operational considerations to transform a basic process know-how into a viable operating plant.

It may be pointed out that India is more than a market. It is rich in resources that make valuable contributions to business at both national and international levels. The enriched natural resources, low operational cost, skilled scientific manpower and technological & management capabilities acquired throughout last six decades, provides an excellent launching pad for initiating pragmatic R&D programme for technology development.

A high degree of innovation is a must to remain in business. It must be remembered that fundamental characteristic of the modern market is not the price, but innovation and the stakes high the best technology wins, the second best lose.

Fire and Explosion Hazards for Process Industries

Shri C N Mehta

Director (Technical)
GSFC Ltd. Baroda

In last two decades Indian Chemical Industry has emerged with large size plants with unique technologies and having severe operating parameters like high pressure, high temperatures, handling of hazardous, toxic and corrosive materials. Eastern Asia has started making its presence felt in world economics and chemical industry sector. The opening of Indian Economy to Multinationals and challanges posed by globalisation has sounded Indian Industry to face challanges with added dimensions of Process Safety. Health & Environment (SHE). Today with changed legislations, particularly concerning SHE the chemical industries credibility depends on its Accountability. Industry has to achieved the highest standards of SHE. Environment are the vital link of the human life and ecology. Safe and Cleaner Production technoloties are the need of Hour. Chemical Industry whether it is organic or inogranic, has various types of hazards which can lead to fire, explosion followed by fire spread, loss of life and property, ecological imbalance. The hazards, can be grouped as firest degree and second degree hazards. The sources/causes of hazards due to intrisis nature of chemical process, if taken care at the initial stage of project the Domino effect of hazards to the surrounding, loss of property / life, the damage to the environment can be minimised or avoided.

Main components of safety are protection of Health, Safety from operational risk, preservation of Environment. Process Availability, Reliability and Flexibility are the key pillars to industrial growth.

Various methods are available for design in safety and hazards elimination/minimisation. In last two decades, new techniques and models have been developed for safety in process plant design and with introduction of computers these models and techniques have been rigorously tested/simulated. The various techniques available for process design are FMEA (FAILURE MODE AND EFFECT ANALYSIS) FAULT TREE ANALYSIS, HAZOP, HAZAN, Consequence analysis for Chemical Process Quantitative Risk Analysis (CPQRA) etc. The various software and models have been developed which are the gift of space technology and are capable of evaluating the risk and damages caused by fire and explosion resulting because of UVCE (Unconfined Vapour Cloud Explosion) and Flash Fires, Physical Explosion, BLEVE (Boiling Liquid Expanding Vapour Explosion), Fireball, Confined Explosion, Pool Fires and Jet Fires.

The hazards level minimisation and controls which triggers either automatic shift to safe operation or warning for appropriate action for damage minimisation and control are the key aspects to be taken care at the design stage.

Site/Plant layout, size of leakage, possible explosion and control, fire protection, statutory regulations compliances, system for early identification of hazards, change of process route, review of dangerous processes and operation, materials identifications, hazardous installation notification, impurities in chemicals, transportation of raw materials, intermediate and finished products, emissions and effluent review, safety review at every stage of project starting right from the basic engineering step etc. are the important factors, contributing relatively to safe plant design.

The most important is the reactive and proactive commitment of industry in implementing statutory regulations to consider social threats, to recognise public perception, and to understand global trends. It is must to think on cleaner production technologies, efficient utilisation of resources, monitoring the conservation steps for raw materials, energy, water and environment. It is also must to consider hazards reduction at sources instead of end of pipe solution. The Government and Regulatory Authorities can consider provision of incentives for "at source reduction of hazards". The Management should be updated with latest lagislations/norms at international level too and maintain operation standards ahead of for seeable stringent laws and monitor the trends technology.

Responsible care for the safety and commitment to the continuous improvement are the key factors which can win the trust and public acceptance of industry. USA, Canada and many countries in Europe have started to consider the responsible care for Safety. The introduction of ISO standards (ISO 14000) for environments and-system maintenance indirectly helps in achieving safety in process plants.

Role of Chemical Engineers in New Millennium

Dr R C Jain

Principal
Engineering College, Raipur

I am grateful to Chemical Engineering Division, IE(I) & IE(I), Bhilai Local Centre for giving me this opportunity to deliver the P.C. Roy memorial lecture. We have the cream of Chemical Engineering fraternity present here this morning and hence I would like to take this opportunity of using this platform to share some thoughts and concerns with you as we have entered into a new millennium. There is all round euphoria celebrating the dawn of this new millennium. However, we have to be extremely careful in planning new strategies to manage the complex and sometimes contradictory demands of the society. I have chosen to speak on the topic "Role of Chemical Engineers in new Millennium" as I feel that ultimately the expectations of the society and the nation must be fulfilled by the application of scientific knowledge. The science and technology must be used for the benefit of mankind.

The economic, environmental and strategic spectrum of the world today is admittedly governed by the developments in science and technology. The emerging national economic environment is largely dependent on the global business climate and as such demands a new innovative and the channelling role of engineers so that the planet earth can have energy efficient, environment friendly and total quality products and machines providing a sound assurance for the survival of mankind in an era of fast technological growth.

Atomic energy, computers, production-line systems of manufacturing, aircrafts, telephones, plastics, guided rockets and television are some of the spectacular innovations of the modern age which have greatly influenced the relationships of nations and quality of life of the people. There should not be any doubt that these innovations in science & technology along with some more will surely transform the community of nations into a global village without physical boundaries. The unity of the world of nations and amity of the people will be an eventual outcome of these transformations. However, the management of such massive system with large number of variables and constraints in this global economic village of the future will require the genius and skills of scientists, technologists and management professionals far beyond our imaginations today. The engineers, the main architect of this change, are to play a pivotal role beyond design and manufacturing. They ought to ensure that technological developments could improve the quality of life of people.

In this context, it is interesting to note the editorials of two of the top national dailies (The Times of India & The Hindustan Times) on the coverage of recently concluded "Indian Science Congress" at Pune. The TOI writes in its editorial dated 7th January, 2000 captioned 'Democracy of Science' - "Those Indian women who currently trudge for miles everyday in order to bring home some firewood and one fragile matka of water must have greeted the news of their country's ability to make a VS-style anti-ballistic missile system with boundless pride and joy". The Hindustan Times has published similar views under a subtitle "Our scientists have become icons". But, is their work related to India's priority needs? This is definitely not a forum to discuss scientific priorities. However, the purpose of quoting the above statements is to feel the pulse of the people and accordingly streamline out strategies to face the challenges in various sectors concerned with Chemical Engineering.

Out of several burning issues, the three most important areas which need our attentions are environmental protection, energy audit and human resources. Perhaps in the coming decade, these three areas will play the most important role in determining the quality of human life on global basis.

ENVIRONMENTAL PROTECTION

We have started realising that the rapid pace of industrialisation and its impact on the population will boomerang on us unless we take adequate measures to ensure that the generated pollutants are effectively treated and the effluents let out are harmless. Environmental issues have become predominantly vital and not only Engineers but society in general has become quite concerned about it. The Chemical Engineers are generally accused of being the worst offenders for degrading the environment. The challenge today is to demonstrate that Chemical industries can flourish without rendering the environment unsafe for the vegetation, animal and human species. We all are aware that earth's resources are being overexploited due to spur in population. This, in turn, has been disturbing natural cycles like nitrogen, carbon, sulphur etc. There has been an appreciable increase in the level of atmospheric carbon dioxide from about 300 PPM to 350 PPM over the last 50 years. We are also interfering with the natural nitrogen cycle in a big way. Chemical fertilisers, on one hand, have increased the food grain production. However, this has totally disturbed the natural soil composition and its ability to regenerate itself has weakened beyond repair. This is a very alarming situation.

According to a survey, the demand for minerals, food, land and energy as a result of population growth are increasing at a rate of about 6.5% year. The question is what can be done to arrest this trend. Government on its part has been doing what it can by promulgating regulations through various pollution control boards at state and central level. Several acts and ordinances have been issued from time to time but the situation is far from satisfactory. The emphasis is on controlling the pollution, whereas time has come when we should think in terms of prevention. Prevention is possible only through development of better process technology. To my knowledge, not much is being done in this direction. I will strongly advocate the industrial R&D agencies to make a strategic change in the basic thinking, so that the focus is on prevention rather than control.

ENERGY AUDIT

The availability of energy from various sources like thermal electric, hydroelectric, nuclear power, biogas, solar, tidal, wind, ocean thermal, geothermal and others is going to play a vital role in the overall development of industrial activity, transport, agriculture sector as well as domestic utilisation. In the recent past we have seen how dependant we have become on the power supply in almost all walks of life. Life stands still without power. Large industries are going in for captive power plants. However, medium and small sectors are facing the ugly prospects of even being at the brink of closure. The exhaustible sources of energy from coal and petroleum are already under serious scrutiny. On domestic front, 80% of the rural population still depends on firewood, cowdung and vegetable waste. We need to think of an integrated plan of action to provide reusable energy sources. Concentrating on energy conservation in industrial sector, it has been reported that various conservation approaches in chemical industries can yield upto 28 % energy savings with appropriate adoption of the following:

o Process or Design modifications.
o Maintenance, insulation.
o Operation modification.
o Process integration.
o Waste utilisation.

Limitations which, in practice, restrict energy conservation efforts are (i) thermodynamic consideration (ii) support services (iii) downtime (iv) off-peak performance (v) operating rate Changes with demand (vi) product mix Changes (vii) environmental protection (viii) safety precautions.

However, substantial energy conservation is possible by suitable modifications in waste heat recovery devices, distillation with more plates or less reflux, efficient compressors or motors, pressure recovery in turbines etc. It is also widely known that considerable scope exists in improving the maintenance and insulation of steam systems, traps, condensate recycling, cleaning heat exchangers, optimum excess air etc. Optimising the operational conditions have resulted in dramatic improvements not only in production rates but also in energy requirements. Evolutionary optimisation (EVOP) and dynamic programming of continuous process have also reported to be among major operational modification steps without any additional investment, cutting down on energy requirements of the whole plant.

Various industries can adopt appropriate energy techniques depending on their nature of operation. In this context it will be prudent to point out that though each industry may be having its own energy audit cell but so far not much of data is available on what is the extent of energy saving actually obtained as a result of in house efforts. I feel a more concentrated and serious effort should be made in this direction.

HUMAN RESOURCES

Ladies and gentleman, I have spent three and half decades of my professional life in Engineering education and in generating human resources suitable for industries. A very large number of my students are occupying top technical and management positions in various fields of education, research and of course industries. I will, therefore, by instinct touch this topic which is assuming greater importance in the present context. India has the second largest population and the third largest manpower in the world. However there is a feeling that the engineering graduates churned out by academic institutions are becoming a liability rather than an asset. Apparently, there is over manning in industry at all levels and reduced productivity in our country as a result of which the cost per unit production is high. There is growing realisation that the industries must interact with academic institutions to ensure that the trained personnel fulfil their needs. This is a two way process which will give a definite direction for training and harnessing the enormous technical manpower needed by our country. This must be viewed not only in technical but also in social perspective. The career conscious young blood looks towards both academic institutions as well as industries to give them a chance of gainful employment. We must channelise their energy and see that they are not deprived of serving the society and the nation.

In the concluding part of this lecture I would like to go back to the newspaper quotes in the opening paragraph presuming they represent the thinking of general people and their expectations from engineering fraternity. Despite half a century of freedom, the scientific revolution and its achievements have yet to gainfully improve the lives of majority of the people in rural areas. We have to remember that availability of food, potable water, clean air, unpolluted atmosphere are more important that anything else technology has created or shall create. Incidentally, we as Chemical Engineers are concerned with all these basic parameters which are essential for sustaining life. Let us pledge in this new millennium that we shall fulfil our professional obligations towards society by setting our priorities right and strive for building a peaceful, spiritual and healthy nation.

Chemical Process Industries Past & Future

Dr S J Chopra

Executive Director
Centre for High Technology New Delhi

Abstract

The Chemical Process Industry (CPI) in India is multifaceted, plays a vital role in the development of the nation and has taken a giant leap during the last decade. The Indian scenario demands that the bulk of the technological activities in the Process Industries and the R&D Centres have to concentrate in the initial few years to come, on maximizing the productivity manufacturing systems, optimizing input such as raw materials & energy, etc., continual upgradation of several aspects of product design and distribution network.

The Chemical-Petroleum-Energy sector would be the principal growth accelerator. The CPI, to remain competitive in the business, as external constraints change, would be required to optimize its Process &Energy systems and evolve a viable Energy plan for the future. Eco-friendly innovations in product design would be the right way to reduce & control the impact of industrialization on environment. Efforts to achieve a paradigm shift in Environment preservation should be strengthened. The industry must increasingly focus on Environmental, Health &Safety (EHS) programs that provide business value. The country should have a long-term strategy for the crucial hydrocarbon sector to facilitate meeting the future demands. Similarly, Fertilizer Industry that is vital for food security calls for a pragmatic approach to bring it back on track with consistent policies.

Infrastructure services continue to remain a bottleneck to rapid and sustained growth of India's economy. Committed policies, regular monitoring and facilitating timely completion of infrastructure projects could only ensure rapid industrialization. Bestowed with abundant sources of raw materials, highly skilled manpower, well-established R & D facilities, potential &mature market, liberalized govt. polices and cheap labour, CPI is likely to play a dominant role in expanding the frontiers of human achievement.

I am very grateful to The Institution of Engineers (India), Cochin Local Centre for having invited me to deliver the Acharya P. C. Roy Memorial Lecture at the 17th National Convention of Chemical Engineers. Acharyaji was a great visionary, intellectual and entrepreneur. He is justifiably called the Father of Chemical Industry in India. It is a great honour to deliver this lecture. I offer my profound regards to this great humane person.

Introduction

The Chemical Process Industry (CPI), is essentially a basic industry and not an optional one for it bestows on the society innumerable benefits and makes people's lives easier, healthier and secure. The Indian CPI is incredibly diverse with wide spectrum of end products ranging from petroleum, drugs & pharmaceuticals, fertilizers, pulp & paper, plastic, fibres, pesticides, cosmetics, toiletries, paints, dyes & auxiliary chemicals. The Chemical Industry is the fastest growing sector of Indian economy and represents around 12% of manufactured output and accounts for approximately 10%of exports.

The industry has grown steadily since independence. The domestic consumption levels have grown significantly in the last decade and a steady rise would be expected considering the expectations of a positive growth rate in the GD? While the tariffs are to be further reduced to honour the commitments made to WTO, the new millennium would pose a serious challenge to the Indian chemical industry in terms of attaining global cost competitiveness. Besides the economic scale of operations, Energy & Capital costs and 'committed' labour output would be the KEY issues in the Indian scenario to achieve cost competitiveness. In view of all these and other compelling factors such as the fast changing human requirements, business competition, stringent environmental and safety regulations, ever changing technologies, increasing energy costs, and the like, the CPI is poised for undergoing a plethora of changes in the future.

The CPI in India is destined to grow leaps & bounds given the presence of large and ever growing domestic market. Nevertheless, the domestic Chemical Industries require developing a local strategy in order to offer a stiff and healthy competition to the onslaught of global players. The Indian Industry either faces the powerful world of super majors or surrenders the great Indian advantage to them.

In the post-liberalization era, Indian Chemical Industries are facing stiff competition from global players. Our high cost of manufacturing is one of the causes of concern. The current business environment is characterized by the collapse of time and space, competition is no longer restricted to any geographical domain and products & services can reach from any where to any where across the globe with lightening speed. This has forced the industries to be customer oriented and environmentally friendly to achieve that extra mileage by adopting cutting edge technologies and operational strategies that would give them definite advantage of cost, time, flexibility, value and quality. Thus, operational excellence and rejuvenation of existing plants would be undoubtedly essential to ensure sustenance & growth.

The other important aspect to really concentrate upon is 'infrastructure services' that had become a major impediment in the development of CPI and continue to remain a bottleneck to rapid and sustained growth of India's economy. India needs to add 10,000 MW of electricity each year for the next 10-12 years to the existing generating capacity of 1,00,000 MW Thanks to liberalization, this field has been thrown open to private sector as well and the impact is steadily visible on the horizon. There is imminent need to develop the infrastructure support areas on war-footing such that it will foster over all improvement of the economy and at the same time provide strength for domestic manufactures to face global competition.

An attempt has been made to present the state of CPI and the vision for future. The future scenario of CPI growth-pillars and the areas affecting their sustenance are enumerated. Also covered in brief are the state of major process industries in the bygone-era and the changes in technical and economic areas predicted in these industries, CPI's growth potential & its role in nation building, the contribution of Human Resources and the like.

The Past and Present Scenario

The CPI has grown steadily since independence thanks to the well implemented five-year plans on a mixed economy with the control of key industries and thus economy being largely vested with state. The emphasis laid on the development of Science &Technology (S&T) in the second five-year plan followed by establishment of an extensive network of national R &D institutions for pure and applied research in the third plan was aimed to achieve self-reliance. The subsequent plans were aimed at maximizing the use of indigenous resources, employment creation through various Public Sector Undertakings in major areas of operation, modemization, capacity utilization, Energy efficiency (in the sixth plan) and consolidating the S&T infrastructure already built-up (in the seventh plan). Nevertheless, this emergence of the advanced S&T was some-how not being reflected in the nation's economic growth. Though the relative 'achievements' of indigenous S&T are considerable, it could have done much better. Both the evaluation of S&T and R&D tended not to be demand-driven, but to exist in isolation That a link was missing between the two amply clear by observing our poor growth rate of Per Capita Income. In other words, there has been very little significant spillover of emerging S&T and research by R&D units into the industrial economy. Socio-economic environmental conditions also played their part.

Till nineties, the domestic Chemical Industry was effectively insulated from the international market due to artificial barriers and there was little incentive to achieve global cost competitiveness under these circumstances. An attempt was made in the eighteen plan (1991 onwards) to correct the same and the results of liberalized economy are clearly visible. The various studies that have been carried out have highlighted that the domestic scientific output has not been commensurate in quality and creativity with the manpower & resources engaged. The emergence of India as a liberalized economy exposed the hitherto state protected domestic Chemical Industry to an ocean of competition from the global majors waiting in the wings to capture the potential and mature Indian market.

The present size of the Chemical Industry in India is of the order of Rs. 100,000 crore in terms of output while its contribution to GDP is of the order of 7%. The growth rate of Chemical Industry in 1994-95 & 1995-96 was very impressive at 10-12% though the same thereafter remained stagnant at -6%. Obtaining Government clearance for the proposed projects still take enormous time because of the many avoidable formalities and this really stand as a stumbling block in industrial growth. Current trends in the industry are characterized by a low growth rate resulting out of lower Per Capita Consumption domestically as well as reduction in exports. The chemical prices worldwide have fallen down considerably due to competition. Because of the constant increase in input costs, ever increasing power costs, coupled with the inherent costs-of both short &long term industrial financing, the overall industrial performance is going from bad to worse on account of host of reasons that are wholly outside the control of the industry. With the globalization of the national economy and also the decline of tariff rates as dictated by WTO agreement, domestic industries find it very difficult to maintain production and survive in the business.

The global majors in the Chemical Industries sector are gaining the necessary strength to tide over the crisis through technical and financial alliances, setting up economically viable world scale units through rationalization of capacities, benchmarking of Process parameters, Energy consumption, Manpower, Costs & Margins. The global mergers and acquisitions are aimed at developing the synergy to control operating and capital costs, focusing on core competencies, providing abundant support to Research & Development and in turn enhance global presence. For example, the merger of British Petroleum &Amoco Industries is proving successful. Also, M/s Solomon Associates, USA have been undertaking bi-annually the studies on "Comparative Performance of Fuels and Lubes refineries" geographical region-wise to help refineries worldwide to know where they stand and identify the best operating practices. These in terms create a competitive atmosphere and result in overall development. Many Indian refineries such as IOCL, BPCL, CPCL, HPCL and KRL have been taking part in these studies since 1996 and are consistently improving their performance. The Indian Industry is also slowly & steadily embracing the popular tools of mergers &acquisitions for consolidating and achieving growth. The merger of two rival companies like Rajdoot Paints & Berger paints is a glaring example.

One of the great problems that the chemical industry has faced for years is its environmental record and the perceptions of that record. The Environmental impact of industrialization has been on focus since the last decade. It has been the practice to address the environmental compliance issues as a separate, isolated function that is often disconnected from other business functions. The challenge faced by the domestic chemical industry is how to manage productivity and at the same time increase profits without causing damage to the 'environment'. In other words, it is a problem of how to effectively make use of processes and yet deliver environmentally friendly products. The increasing scrutiny of Industries' Environmental Performance is changing the way they do the business and perform their 'duty' towards the Environment.

Safety is another aspect that the Chemical Industries have to attach utmost priority considering the impact of it on the people nearby. People have the right to know what kind of industrial operations are taking place in their neighbourhood and what are the potential safety/health hazards/risks these facilities pose? The enormous advances in analytical methodology have made it possible to detect the presence of smaller and smaller impurities. The relationship between the regulator and the regulated depends not just on advances in service, but also in how we explain what the information means. The burden that it places on both scientists and the industrial community is an even greater burden of explanation and responsibility for public understanding. Otherwise the character of regulation, the relationship between the parties is not going to change unless we do more with respect to public understanding.

Vision:

Predicting the future scenario of Chemical Process Industry is both interesting and difficult. It appears definitely that prediction might have lost all its logic & meaning in this modern world where the pace of change has quickened so dramatically. A short term prediction, say the foray of CPI in the next half century would have been reasonaly reliable as recently as the mid 20th century when, even within its accelerating pace of change, there used to be a certain sequence of happenings that propelled continuity. But not so anymore in today's world where the change in Science &Technology, Public demands, Government policies, industry, art, social life are so frequent and explosive in substance as to deny even the semblance of a base. The life of a particular model of any innovation say, computers, telephones, etc. is so short-lived that by the time somebody acquires the model it becomes obsolete. It takes much daring to map the shape of things to come in future. The CPI through continuous improvements and growth can meet the requirements of an increasingly demanding and nontraditional human society. The rapidly changing needs of society, coupled with the aspirations of this great nation to become an economic Super Power, ensure continuous development of CPI.

The new approach of our system would be the corner stone of this industry from which many of its other features might follow. The broad picture of the CPI would be conjured upon based on practically every industry that could be through of, such as Space, hardware for Information Technology &Telecommunications (IT &TC), Textiles, Food, Public health-care, Rubber, Transportation, Energy, Environment, Materials, etc. Everything appears to be interpreted as a priority term in relation to other.

Additionally, the Chemical Industry would be expected to continue to produce such items as Agrochemical Soil improvers, Plant Growth Regulators, Pesticides and a host of other Chemicals to increase the food grain productivity and feed a world that is becoming dangerously unsteady by each passing day (population explosion). Crop Research and Management-Chemical, Physical, Bio-Chemical, etc. must find the answer to meet this ever-increasing challenge. In order to achieve the optimum distribution of such "Sustenance Chemicals", the needier third world nations would be the preferred locations for setting up of new facilities for commodity chemicals, leaving the so called developed countries to concentrate on the "growth sector" Chemicals such as Petro-products, Petrochemicals including Aromatics & Ethylene, drugs for dreaded diseases, Infrastructure Development, Versatile Materials, lighter and stronger polymer composites offering high performance coupled with fuel savings & enhanced safety in aerospace, defense and IT & TC applications, Food Packaging aimed at hygienity & Keeping freshness, and other such items. These involve multi-level improvements employing new processes. This might be the likely scenario of the future.

It is imperative to keep pace with global scientific advancement & technological innovations and apply the same after adapting to suit our logical requirements for improving the living standards of the poor and underdeveloped. In a world that is rapidly shrinking due to Information and Communication super highways, it should easily be possible for India to import the new technologies from other sectors of the world's advanced economies and sustain the production of the basic requirements of life. Technological changes improve productivity and stimulate economic growth. Also, new technologies generate new functions or bring about improvement in the performance of the existing facilities. The role of S&T changes in the economic progress of a nation is increasingly recognized in recent times. Of late, the developing countries like ours have been showing a phenomenal rise in the pace of economic growth. To become an Economic Super Power, S&T and economy need to be considered in an integrated manner rather than as separate entities.

The crucial issues for India such as to generate productive employment opportunities, supplying adequate amenities to the society taking care of Energy & Telecommunications services, transportation, developing new materials, chemicals & plastics, biotechnical products & services, health-care, etc. could be addressed only by taking note of global technological developments and certainly not by remaining immune and isolated. Technologies in all these sectors have substantial socioeconomic impact. Further, all of these are interlinked with several other industries and multiple products & services subsequently leading to a better quality of life.

The face of the global chemical market is fast changing. Western countries along with Japan would continue to be dominant. China, other eastern markets and India would increase output robustly. It is expected that Chemicals' tariffs would be eliminated virtually worldwide by around 2010 and as probable consequence there would be more non-tariff barriers along with growing international pressure' for their removal.

There is every need for increasing the funding for Research to essentially add muscle to the consistent growth of CPI. It is a well known theory that Industrial R&D strives and grows in a competitive environment. There certainly is hope that competitive environment in the post liberalized era would evoke the innovative instinct of CPI. The challenges ahead would demand developing new 'models'. The new 'context' has to create a new 'content' and therefore, a new model. The R&D centres should rise to the occasion and get ready for the daunting task ahead. As the stage of diminishing returns is reached, there would definitely be 'scarcity' in research funding with the progress of time and whatever little funding is there would be available only for advanced research i.e. in the areas of Oil refining, Petrochemicals, high performance polymers & ceramics, pollution control chemicals, high performing catalyst, etc. In view of this, the research organizations should gear up to meet the future challenges leaving behind the legacy of unaccountability and prove their real worth.

The general public has become very much conscious of its rights to live in a pollution free environment and hence it is high time that the CPI has to focus on clean processes. The trend must be towards a culture that eliminates pollution at the source itself. Industries should play a leadership role in preserving the environment. Pollution preventing approaches and eco-friendly techniques have to become an essential part of business operations in future. In the coming years, Chemical Industries would be required to adopt pragmatic approach so as to advance green-planet options that shift business beyond just compliance to regulations. There would be mounting pressure globally to increase motor fuel efficiency and reduce the emissions of pollutants. Therefore, the market for fuel additives and Catalytic Converters would continue to thrive. In Europe, the drives is on to reduce the average CO_2 emissions of new cars 25% by 2008. Fuel Cells look more likely to be 'preferred' fuel of the future. Energy prices would probably go up as a consequence of Environmental and market pressures. As a result, the efficiency of resource improvement would continue to rise.

It would be essential to identify innovative practices such as use of bio-chemicals etc., technologies, processes that reduce or eliminates the storage and use of toxic-substances, identify and reduce the risks to human health and the environment from existing and future exposure to persistent, bio-accumulative and toxic-chemicals in particular. The industry would also be required to ensure safety & hygiienity of the products and services rendered. Attempts to eliminate waste generation, focusing purely on end services of a product and conservation of natural resources would provide a positive business prospective and healthy competitive scenario aiming at overall growth of CPI in future.

In view of the factors mentioned above, CPI needs to exhibit the following key characteristics to ensure future sustenance:

• Ability to Cope with Change
• Innovation
• Development and Excellent Management of Resources
• Adherence to Stringent Health, Safety & Environment (HSE) Standards

Research & Development in Future

The Research & Development in the areas of S&T play a crucial role in continuously updating the Processes and techniques employed by CPI. An important aspect of the sustenance of the Chemical Industry is a constant search for efficient, simplified and yet cost-effective technologies. One of the greatest changes that has taken place over the last decade has been the evolution of Information Technology & Telecommunications. This information-communication revolution is beginning to change the way industries compete. The national R&D institutes should rise to the occasion and embrace this revolution to perform both efficiently and to world-class quality standards. There shouldn't be any hesitation to outsource expertise if so desired which could be developed further. As Internet explodes, corporations have an almost unlimited opportunity to capture the creativity and insight of a large section of global public.

The Key advancements might include the improved 3 -Dimensional models of molecular behaviour that are bound to revolutionize the way R&D is carried out. Improved models of Chemical Processes would emerge to enable Chemical Engineers design Plants that are more efficient, safer, cleaner & greener.

There is a general understanding that petroleum reserves of the world would be inadequate to meet our demand in the next 50 years, R&D efforts would have to be intensified to invert new catalytic processess for producing liquid fuels from Natural Gas and Coal. There is a 'catch' here. All these being fossil fuels would continue to burden the atmosphere with Carbon Dioxide. The only long-term solution thus appears to be to develop alternative, non-fossil energy sources such as geothermal, wind, water, solar and nuclear energy. Concerns about global warming will have led in 25 years to a revitalisation of the nuclear power industry. Without understanding the mechanism of global warming, one can get confidence that the consequence of apparently small changes in temperature can have dramatic changes on human being. If that is accepted, then the consequences of ignoring it, will become so apparent that people will be willing to say "we don't know whether fossil fuel burning is the primary or only source of global warming. But there are alternatives, and we ought to atleast ensure that the alternatives are available to us and start using some of them." Considering the need for achieving Energy Security and independence coupled with the enormous potential built into it, Nuclear Power would be called upon to play a progressively increasing role and as such research on 'Safe' use of Nuclear energy would in future, definitely, receive priority over the rest. Zero-tolerance would be the 'watch' word as we unlock this giant reserve. Other areas of interest of future include green fuels, membrane technology, biotechnology and high performing lightweight materials and speciality chemicals.

Converting Fuel to Electricity would be emerging as an important requirement globally and could be accomplished by direct Oxidation in a Fuel Cell. These cells operate at almost 60% efficiency operating on Hydrogen or Methanol compared to less than 40% in conventional Power Plants. It might be that the efficiency of this innovation depends on successful R&D to invent efficient catalyst for converting chemical Energy to Electricity, and also on improved materials of construction. Research efforts for improving the efficiency of capturing solar energy and its use by duplicating the performance of green plants, would gains momentum in future.

The emergence of new concepts and development of existing technologies would be the most remarkable aspect of the Chemical industry in the next century. The research would mostly be in the areas of Public health, Energy production, Environment, Spacy & Defense. Apparently though they are not directly related to Chemical Industry, in reality they contain a large component of Chemistry and Chemical Engineering substance.

The Research institutes would have to prove their worth for industries to continue to invest in R&D efforts. The output should be realistic and quantum. The fact that the service sector would continue to grow at the expense of the manufacturing sector puts pressure on R&D spending and focus of R&D and innovation would therefore shift from manufacturing to services. The key 'survival skill' would not be conducting R&D so much as to create 'innovation'. R&D would be the 'make' option in a make or buy world. More technologies would be available globally for license or exchange than ever before and indigenous R&D centres would have to 'complete' effectively with these external sources. Continual, substantial and transformational innovation would be the 'mantra' of success for survival.

R&D departments would have to 'redefine' themselves and would need to justifiably reflect deeply on their role in the corporation, and what the new 'realities' or 'challenges' imply for them and their function. It is high time that domestic corporate managements recognize 'technical innovation' as an increasingly important factor in the industrial growth and survival. The fact had already been taken note long back by their western counterparts and the difference is there to visualize. I

Thus, probably, the most important long-term strategic challenge for industrial R&D managers as we enter the 21st century, would be to enlarge their role from the increasingly limited management of the R&D function to the broader, more comprehensive and important corporate challenge of "Managing the system of technological innovation". The role of R&D in 'realizing' more out of existing facilities deserves serious attention. R&D efforts should be passionately supported. A close interaction amongst the R&D personnel, designers and operators is a must for effective results. They should do well in properly recognizing the relative importance of each other.

Govt. Policies

In order that our country marches towards the cherished goal of a developed nation, there is an urgent need to change the present methods of working and the mindset that has developed because of centralized managerial system. Private sector participation would be required along with more liberal and simplified procedures. Healthy competition leads to greater efficiency and innovation. In tandem with these requirements, Govt. of India, as apart of economic reforms, has laid down open industrial policies. 'License Raj' had been done away with. There are hardly any restrictions in importing raw materials of our choice or to out-source the required technologies for further innovations, thanks to liberalization. The Govt. would better like to take the ICMA into confidence and forge a cohesive approach while formulating its policies and future prospective plans on production targets, domestic sales & exports, areas of strength & weaknesses in technology and to draw up the schemes to make quality bulk chemicals available to users in the industry.

Govt. might in future concentrate to provide common facilities for pollution control, transportation of products and marketing facilities for a group of C. P. Industries located at a place. This would change dramatically the economics of small & medium scale industries. This would go a long way in stimulating the growth and harnessing the potential available indigenously. The encourage concepts of 'Tax Holidaying' and other financial incentives should be extended uniformly and generously to all types of industries, to attract investment. Domestic industry should be adequately protected from the onslaught of global players who are out there to capture the vast Indian market, though creating a healthy & competitive business environment would be in the interest of overall all round development of the nation.

It would be encouraging if govt. policies are better aimed at guiding the 'growth' in basic chemicals and infrastructure support areas in the years to come, to help foster overall improvement in the economy. Present impediments in the industrial growth arising out of lack of exact should be addressed immediately and rationalized approach in the areas of import duties, funding, developing infrastructure, redefining the labour laws, etc. would be essential for achieving the desired targeted growth in the industrial sector.

For the domestic industry to survive and effectively cater to the national demand, policy formulations need to be devised in such away that imported materials are not dumped freely into the Indian market which would deny a level playing ground for the indigenous producers.

Human Resources

A systematic planning would be necessary to make available the highly skilled manpower and to upgrade the technical expertise in the chemical industry, to meet 'quality' demands of the technology. It is also imperative for India's scenario to stream-line the excellent human resources already available in selected areas. Apart from adequate monetary gains, the employers are looking forward for something that reaches the heart i.e. true appreciation & affection. They have to love what you stand for and that's a big culture change.

Chemical Engineering field is well positioned to capitalize on the effects of globalization. Emerging issues of particular importance for Chemical engineers include 21st century business paradigms and intellectual property right protection. A special breed of techno-legal personnel would have to emerge to practice the art of valuing Intellectual Property, Patent reading, Charting unexplored routes and opportunities, setting up of collaborative programs so as enable the CPI to respond effectively to the demands of the century. The present-day engineer's ability to integrate scientific skills would alone not be sufficient to ensure professional or personal advancement. We would be expected to display a range of talents, knowledge and interests that extend beyond traditional engineering capabilities.

The future calls for focusing on the more precise interaction between industrial requirements and the development of Chemical Engineering Community. The community should rise to the occasion and develop, taking into consideration both the customer needs as well as environmental concerns. The challenges ahead could only be met by carrying out basic research (by national laboratories) and applied research (within companies) at the cutting edge of technology and the same time it is also essential that young engineers and scientists as part of their education curriculum should be integrated into this research effort and become fully committed to it.

Environmental Concerns in the Next Century

Chemical Process Industries would do well in future if they better understand the stepped up public demand for more accountability from them. The general people at large and NGOs in particular expect CPI to develop what they term as 'concept of ethics' & responsibility towards society that raises the business for the industries. The Environment & pollution regulatory authorities like CPCB and control boards at state level have started taking stringent action on the defaulters of the law. As such, the CPI should, on its part adhere to the strict norms, consistent with the global standards. The industry must demonstrate that they are 'more' concerned to maintaining clean & green environment. They should not consider this as a liability or waste of investment.

The Chemical Industry must prepare to address peoples' concerns and queries in an open, straightforward and honesty way. They must integrate Environment, Health and Safety into their business strategies. CPI should better pursue this aspect with vigour and passion and achieve improved financial performance, for lower waste & emissions cost less money. Also, the more safer the working environment the more healthier the employees and in term the better would be the productivity. The CPI should work cohesively with perseverance to convert liabilities into assets.

Green technologies for upgrading 'waste' products into useful ones, for e.g. converting liquid effluents for the recovery of industrial chemicals, should be acquired if not developed indigenously. Uses of semi-permeable membranes have been found to facilitate reduction in emission levels of environmentally hazardous effluents. Membranes have also been successfully employed in the field of solid-liquid separations for minimizing the amounts of suspended solids in effluents that is of particular importance in Waste Water Treatment facilities. Another major contributing factor for the rapid growth of Membrane Technology is the recovery of useful material from the effluents and other waste streams. Future would mark extensive applications of membranes in wide variety of areas such as Biotechnology, Food, Chemicals, Desalination of water, Medical and Petrochemicals.

The Pollution Control &. Environment Regulatory Authorities are expected to take a pragmatic view and consider practical difficulties & limitations while fixing the norms. They should discuss with industry representatives in advance for the simple and logical reasons that 'theory' is different from 'practice'. The small & medium scale industries would have a tough time ahead in adhering to the environmental norms given the relatively higher investment needs to treat the effluents. This might end up affecting their balance sheet. Although these industries are promoted in a large way by the Government and play an important role in the economic growth of the nation as well as creating vast employment, their 'unsafe' environmental practices could not be tolerated any further. Either collectively they should develop common effluent Treatment Plants or Government might consider setting up of such common facilities.

With current technology and strategic management systems, industries could be more effective in reducing the gravity of environmental impacts if their 'will' could prevail upon other 'reasons'. The 'green' challenge would be the prominent issue in future that would be relevant to every industry big or small.

Energy Management

Energy efficiency improvements play a vital role in leveraging operating margins of an industry/organization. Managing the consumption of energy is an important element in the process of providing cost-effective services and minimizing the indirect costs passed on to the community. According to one recent industrial survey, efficient management, best possible operation and preventive maintenance measures that require little or no investment could have around 10% in energy usage. The savings in Energy Consumption would in future be required from not only the point of cost cutting but also from the view point of conserving the sources of energy i.e. fossil fuels which are available in 'limited' quantity only, till at least alternative sources are made available on consistent basis at competitive prices.

Energy management is a well-planned program of activities aimed at reducing energy consumption levels of the industries and in turn the operating costs. The added advantage would be minimizing detrimental impacts on the environment. Establishing clear accountability and motivating the actual 'operator' with encouraging incentives is the 'key' if the potential is to be harnessed to the fullest extent. It is estimated that an annual energy saving potential of more than Rs. 5000 crore exists in our industrial sector.

Energy conservation has often been referred to as the "fifth fuel" emphasizing the importance of reducing/ optimizing the amount of energy used and auditing at regular intervals would help in this direction. The spiraling costs of energy necessitated conserving the energy in all the possible manner and Energy Auditing by an expert agency would help identify all these areas. Energy Auditing is an important and well-proven tool to establish the present energy consumption levels of the industries and to suggest economically feasible and practically implementable (without space constraints, etc.) conserving schemes with payback periods within 3 years. The next step would be 'Benchmarking' and 'targeting' the energy consumption levels of the industries. The Benchmark Energy numbers that serve as ultimate targets would provide a reference platform to compare the present Energy Consumption of the operating industries. The zeal to operate close to Benchmark number creates a competition that helps to reach international standards per excellence. This is not a one time exercise and should be carried out periodically.

The uphill task that energy managers are facing in the industrial sector is more of 'convincing' the top executives for financial commitments rather than drawing up of efficient Encon Strategies themselves. It is a disturbing trend that investments for Energy Conservation projects still have to compete with other projects for e.g. those concerning increased production, technology up gradation, R&D, quality improvements, etc. This tendency of thinking basically arising out of skepticism of achieving the envisaged improvement over the existing scenario and whether assured returns would really be realized, would need to be changed for the better future prospective in the growing competitive environment. A 'novel' scheme termed, as 'Shared Savings' is fast catching up in the industry sector. In this modus operandi, the fee to be paid to the external Energy Consultant would be related to savings acquired by Client. When there is such commitment from Consultants to share the risks associated with investment on Energy, then the industry executives' comfort level would be better to accept the outside expertise.

A strong case is emerging for increased international cooperation on clean and efficient Energy Technologies to commensurate with the challenges and opportunities including, especially, those connected with the Energy/Climate-range linkage.

Hydrocarbon Sector

The Hydrocarbon sector is perhaps the most gigantic both in terms of volume of business as well as supplying the Petro-products necessary for survival. 45% of the total energy needs of our country would be met by Oil & Gas sector alone. The refining capacity by 2025 would have to be around 358 MMTPA while the Gas requirements would be in the range of 391 MMSCMD to meet the growing demands of the nation. Hence, it would be prudent to have a long-term policy to facilitate consistently meeting the future demands of the nation. Issues such as developing regulatory and legislative framework for providing energy Security, Alternative Fuels that are eco-friendly in nature and acquiring technologies that are inherently safe, environrnentally benign, energy efficient and capable of delivering best quality products at competitive prices, etc. would be vital to ensure sustainable development in the future. The dismantling of Administered Price Mechanism for petroproducts from 2002-03 onwards would open up the Hydrocarbon market leading to a healthy, free &fair competition amongst PSUs, Private companies and International players.

The total investment in refining sector alone up to 2025 would be around Rs. 2500 bn. Govt. of India's vision - 2025 document manifests that it is committed to develop this sector as a globally competitive industry overcoming the unprecedented challenges like clean & green environment in terms of eco-friendly auto fuels, processing Heavy Crudes, flexible product-mix, upgrading the lower value bottom products, maximizing the Distillates production specially of middle Distillates, low-cost revamps/debottle-necking & capacity expansions, integrating downstream process units with Petrochemicals, Power generation, etc. There is a pertinent need to create additional infrastructure for efficient distribution and better marketing of Oil & Gas. According to recent estimates, the investment to develop marketing infrastructure would up to 2025 be Rs. 1350 bn.

Natural Gas would be the sleeping giant and the Energy of the future and might emerge as the preferred fuel of this millennium. It is environmental friendly and also a desirable feedstock. Serious efforts should also be made to find innovative technologies for cleaner fuels in order to reduce dependence on Natural Gas. It will become increasingly clear that it is a crime against the future to take petroleum and burn it. Not just because of global warming, but because we are burning away materials that are tremendously valuable for other uses. We need portable fuel. If we stop burning oil - and even if we don't, we are going to run out of it. We need to harness chemistry to make different liquid fuels. A hydrogen economy sounds good, but unless we develop good ways of storing hydrogen very densely and safely, there will still be a lot of liquid fuel needed. There is a need to stimulate the research & development of technologies for clean fuels such as clean Coal technology that could address not only the climate issues, but the full range of energy-related challenges of the 21st century, in all of their Economic, Environmental and global security dimensions.

Fertilizer- Industry

The Fertilizer Industry just like the Petroleum sector is also very Energy and Capital intensive and is vital for our Agriculture and Food Security. India is the third largest fertilizer producer in the world with an installed capacity of around 110.7 lakh tonnes of Nitrogenous and 36.5 lakh tonnes of Phosphatic nutrients. The demand for agricultural output is ever increasing in direct consequent to population growth, which in turn fuels the requirement for fertilizers.

India had so far not achieved self-sufficiency in Nitrogenous and Phosphatic fertilizers. The major factors that would help increase fertilizer availability include capacity augmentation, technological up gradation and infrastructural development. However, the present day fertilizer plants are mainly dependent on imported technology. Also, infrastructural development, particularly with reference to port facilities and railway operations, mechanization of handling operation at loading points, moment of fertilizers and optimum palletization need to be addressed immediately.

Indian fertilizer plants have significant import dependence, with most basic raw materials such as Rock phosphate, Sulfur and Ammonia being imported. Though the Retention Pricing Mechanism was compensating the variable cost fluctuations in case of Urea manufacturers, the vulnerability of Phosphatic fertilizer manufacturers to exchange rate variations is high. Building the requisite raw material linkages therefore assumes critical importance. The feedstock used is mainly Naphtha, Natural Gas and Furnace Oil. The Natural Gas would be the idealistic choice for it is economically viable and environmental friendly. But with the diverting of Nature Gas supply to other industries such as Power & Steel, non-availability of adequate feedstock has been a serious operational bottleneck for the fertilizer industry.

It is very surprising that this very vital industry has some how not been accorded its due priority over these years. The Industry has a feeling that high feedstock costs had put Indian Fertilizer industry at a disadvantage vis-à-vis developed countries despite their high energy efficiency of around 9.18 KCal per tonne of production. This calls for a pragmatic approach so as to streamline the whole gamut of issues clouding this vital industry including consistent policy framing for feedstock availability and rationalizing its cost, correction in the subsidy levels, fertilizer import & export, financial aspects, etc. to revive its lost glory.

Petrochemical Industry

The Petrochemical Industry having a multi-product base starting from the basic chemicals such as Ethulene, Propylene, Benzene and Xylene, etc., to Synthetic fibres like Nylon, PSF, PSY, etc. has been developing both in Public & Private sector. In India it has grown since the opening up of economy in 1991 and presently it is one of the fastest growing sectors at 13%annually.

The combined Petrochemicals production capacity of government owned IPCL Plants at Baroda, Nagothane & Gandhar is around 10.0 MMTPA. Apart from IPCL, other PSUs active in this sector include GAIL. With world-scale projects on each of its coasts (Haldia Petrochemicals Limited on the East with production capacities 0.42 MMTPA & 0.2 MMTPA of Ethylene & Propylene respectively and Reliance's mega Petrochemical Complex on the West with capacities 0.75 MMTPA & 0.4 MMTPA respectively) and surrounded by several downstream ancillary units throughout the country, India has the potential to become a major Petrochemical player not only in Asia but also globally.

Fine & Speciality Chemicals

These are the Chemicals with a very high value (price/margin), low to moderate volume of operation. Speciality Chemicals are mainly traded on the basis of 'Performance' in a specified function rather than product specs. And find major application in different categories such as Adhesives (Thickeners, Binders, Stabilizers, etc.) Oil field Chemicals (Corrosion inhibitors, Emulsifiers, Chemicals improving flow of Oil & Gas through pipelines, Demulsifiers, EOR Chemicals, etc.), Surfactants (Wetting agents, Dispersants, De-foamers, antifoamers, etc.), Rubber Chemicals (Vulcanization accelerators/retarders, antizonants, etc.) Water Treatment chemicals (Flocculants, Coagulants, Bio-codes, Loan-exchange resins, etc.), Polymer additives (Plasticizers, Antioxidants, Modifiers, Flame-retardants, etc.), Textile Auxiliaries (Sizing, Leveling, Dye fixing, Solvents & Anticreasing agents, Detergents, Acid releasing Chemicals, etc.), Additives in Paint & Paper Industry (pH stabilizers, Anti-setting, Anti-floating & Flow Control agents, Retention, Formation, Drainage Aids, Strength additives, Creping agents, etc.), Fuel & Lube Additives (Catalysts, Stabilizers, Functional additives, Anti-wear Chemicals, Pour point depressants, Viscosity modifiers & Anti-foamers, etc.), Cosmetic Additives (to generate different smells of perfumes).

The Fine Chemicals find their use mainly in Pharmaceutical, Pesticide and Herbicide industries, etc. There are also employed as an intermediate material forming a starting block for another substance with a recognizable end use. Both the sectors of Fine & Speciality Chemicals presently have a fragmented structure with large number of players because these are less capital intensive though more knowledge-based. The present market is valued around Rs. 3.6 bn.

Biotechnology

Biotechnology is becoming an important segment of healthcare industry in India for it promises to provide the "Key" to the treatment of many killer diseases, which presently have no cure. This is one of the reasons why major Pharmaceutical companies have started investing heavily in R & D activities in this field. This sector is mainly knowledge intensive and research oriented in nature that started initially in 1980s as a subject of 'academic' interest. Slowly it has developed as independent and mature industry with over 5000 Biotech companies working worldwide with a turn over of around Rs. 2350 bn.

A large number of biotech medicines are under development for AIDS, Blood disorders, Cancer, Diabetes, Genetic disorders, Infertility, Skin disorders, Growth disorders, Transplantation, Digestive disorders, Auto-immune disorders, Infectious diseases, etc. Opportunities in biotech include Fermentation technology that provides business to both Food & Pharmaceutical sector, in terms of manufacturing of Enzymes, Pharmacy-products, food ingredients, natural colours, etc. Other major industries that would be benefited by Biotechnology revolution are Agriculture, Pesticide, Fertilizer, Edible Oil, Effluent Control, Petroleum and Plastics. India has also achieved considerable progress in this area and the consumption of biotech products is increasing steadily. The domestic market is valued presently at Rs. 23.5 bn. that has the potential to reach Rs. 235 bn. by 2003. For ego the Vaccine market that is currently valued at Rs. 4.7 bn. is fast growing at around 20%. There appears to be new life for Contract Research Organizations (small scale) considering the trend to outsource the research efforts by the large pharmaceutical companies to optimize the operating costs. This would in term enhance employment opportunities.

The scope of Biotechnology is unlimited and the returns are higher. Other major advantage is it is environmental friendly because of which it would certainly be the most sustainable technology of the future. The major research in India is carried out at Government funded institutions like ICAR, CSIR and Dept. of Biotechnology (Ministry of S&T) with main objective of disease free crops, higher crop yield, etc. Apart from Government funding, MNCs also have pumped in considering amount of money in to the research efforts and the results are visibly clear and encouraging. Wockhardt's biotechnology based Hepatitis-B vaccine has shown impressive growth in recent past. Similarly, Dr. Reddy's Pharmaceuticals offers diagnostic proteins foe HIV infection, therapeutic proteins for vaccines and anti-virals.

The human resources that we have in terms of scientific skilled manpower should be put to optimum utilization to the advantage of domestic biotech industry and the government would do well to restructure the S&T policy to give the necessary boost with attractive incentives for this R&D intensive sector and open up new vistas in a bid to promote and encourage investment.

Instrumentation & Process Control

Properly designed and implemented Instrumentation & Process Control system based on Distributed Control System (DCS) or Programmable logic Controllers (PLC) is vital for any CPI such as Petroleum refinery, Petrochemical complex, Fertilizer Plant and Gas processing Unit. The extensive use of the Control Systems has gradually spread to other Process industries like Pulp & Paper, Cement and Fine Chemicals etc. The deployment of DCS, Coupled with the ease of connectivity due to the abundant availability and spread of PC as a routinely used tool for compiling and presenting design, operating & maintenance data, calls for sophisticated methods of control, like Advanced Process Control (APC) and linkaging with business applications. The benefits of implementing APC include improvement in plant through put, raw material & energy savings and better or consistent product quality.

Other softwares that are available include the one developed for real-time analysis of operating data and alarms so as fine tune the Unit/plant, increase the efficiency of operation and in turn minimize down time.

The entire range of latest Instrumentation and Control Systems are presently available, thanks to industrial and economic liberalization in India, for application in highly capital intensive industries like upstream & downstream Oil and Gas sector, Fertilizers, Petrochemicals, Power generation, Pulp & Paper, Steel etc. The wide spread adoption of automated Process Controls & Instrumentation have displayed visible gains in Process Industries through optimizing and producing a 'quality' product coupled with energy savings, safety, reliability and process stabilization. Sensors, Integration of Sensors, Computer platforms and Client oriented systems are among the latest international trends in this area.

The Information Technology effect

The chemical Process Industry shall start using Artificial Intelligence for design synthesis, and, in fact, run them. The fundamental understanding of chemical reactivity will advance significantly. Within 25 years, most reaction mechanism studies of the kind that we do now on simple reactions will be replaced by computational studies.

Right now, a computer can generate a complete reaction profile and create a movie showing everything that happens during a reaction. The problem is, we don't know whether it is accurate. We will get to the point where computations will be good enough that every time we check the thing, it will turn out to be consistent with experiment, and we will finally conclude that we don't have to do experiments any more. Such a capability will make it possible to predict what kind of catalyst you would need to add to make a reaction go, and how that catalyst would operate. You should also be able to predict what reaction would occur between two materials that have not yet been put together - predict product and reaction rates that haven't occurred yet. The combination of combinational chemistry and computational methods may lead us to the point where we actually have a library of catalysts designed to do specific things. This has tremendous implications because it allows you to produce compounds more or less on demand.

Besides the above, the art of integrating Enterprise Resource (or Requirement) Planning systems with the advantages of e-commerce is fast catching up globally to offer the customers real-time services. Indian industry is no exception. The Chemical companies are now exploring the possibilities of linking in an efficient manner the entire gamut of activities like Procurement, Production, Sales and Delivery processes in to one seamless stream of information for better business prospects. These IT technologies enable the manufacturers and distributors to forget new business strategies to establish competitive market. A recent study by KPMG singled out the emergence of internet facility as the greatest innovation that would bring phenomenal changes in the Industry in general and CPI in Particular.

Some of the numerous benefits that e-commerce would in future offer the Chemical Industry include leveraging existing technology and enterprise investments, reducing operating & transaction costs, providing direct access to lot-specific information, dynamic pricing, reaching new prospective customers, facilitating real-time order processing capabilities etc. which would in term increase revenues. The IT based systems are being viewed as Mission Critical Applications for industries desiring to provide enhanced service to their traditional customer base, improve their market share, optimize the costs and improve overall efficiency in order to stand apart in the ensuing competitive business environment.

Conclusion

India has several achievements to its credit in the global Chemical Industry. The annual growth of Indian CPI is estimated to be around 12-15%.The Process Industry has been playing a stellar role in generating technological innovations for use by practically any industry one would name including textiles, rubber, construction, entertainment, consumer products, health services, space, defense, telecommunications etc. The importance of Chemical Industry lies in that it helps wealthier countries to continue increasing its standard of living and poor countries to approach that of wealthier ones. For this to happen new innovations in Science & Technology, the two basic pillars of CPI, should be discovered, adopted and effectively commercialised to create national wealth.

Tremendous changes are taking place in the global economic scenario and the CPI is one of the sectors having a greater manifestation of these changes. The biological processes would be much more commercial than they are today. The interface between chemistry and biology would lead to increasingly elegant technologies that would model biological systems. CPI thus, has a great task laid out ahead to make rapid strides if it is to sustain in growth in an ever-increasing competitive atmosphere.

The next 25 years may turn out to be the golden age for our science. This will be an age during which Chemistry unlocks many of the secrets of biology, creates materials with almost magical properties, and contributes to the environmentally sound production of food and energy sufficient to feed the population and fuel the economic activities. The importance of protecting the environment perhaps has never been greater. The industry should ably demonstrate convincingly to the general public, with actions as well as words, their credibility as a responsible and group striving hard to keep the environment clean. The mindset of the Chemical Industry about environment management has to change. The trends towards becoming more efficient both in our collection and use of fossil fuels and energy resources would accelerate simply because there are higher value uses for them than burning them to keep us warm.

The process of innovation in the Chemical Industry is multifaceted. The Research & Development (R&D) centres, academic institutions, national laboratories would have to play a crucial role. R&D efforts require a long terms commitment from top management for the technology bought is always second hand and unless it is improved by research, the industry would soon be left out of the race. It would be desirable in future to have a statutory provision for reporting R&D expenditure in the company balance sheets. More investments are needed in R&D. We have to generate our own technologies and move from the "Information Age" to the "Innovation Age". Interactions among the Industry, R&D Centres, Laboratories and Academic Institutions need to be pursued vigorously at regular intervals. It is not only trade that would change as the Chemical industry restructures along product line and it becomes more global. Research and Development is in for some big shifts too. Like the industry, it would restructure vis-a-vis commodities and specialities, and it too will become global. Information Technology would dramatically change the way the industry interfaces with customers, suppliers and our employees. You would see a chemical industry that looks entirely different in the way it sources its raw materials, manufactures products, and sells the product.

To seize the immense business potential available, the need is to develop a strategy for Indian CPI. In a move to compete with international players, we need to Benchmark ourselves with the best in the world. The poor infrastructure availability in the country is detrimental to a sustained growth of the process industry. The pivotal role-played, in the growth of industries, by better rail roadways, transport facilities, proximity to business centres, uninterrupted supply of adequate Power at competitive prices is evident from the standards of the developed countries. Government and industry together should speed up the execution of the projects necessary to make available the requisite infrastructure facilities for the CPI.

The need for the CPI would be to adopt a bold approach with able support from Government and to aim at a position of strength and excellence globally in selected areas by using our main strength 'the manpower' to optimum advantage. Government should ensure a balanced growth in different parts of the country, consistent with the availability of feedstock, level of access to local & international markets, environmental factors, etc.

The Indian Industry, well and improving as it is now, has much more to look forward to in the coming years. The Indian scenario offers many positive factors which include large industrial base, location advantage, competent, dedicated &highly skilled human resources, well developed education system, established R&D centres, cheap labor force, sound legal framework &regulatory authority in place and a fast growing and liberalized economy.

More than likely, many of the changes that would occur, many of the innovations that would change the character of the industry have not even been thought about today. So, there would be many hills to climb in the chemical landscape and many precipices to avoid, but what should emerge is a continuing strong chemical industry that would be ever-increasing part of every day life.

Emerging Scenarios in Chemical Engineering

Professor M M Sharma, *FRS*

Emeritus Professor of Eminence
Mumbai University Institute of Chemical Technology

SALIENT FEATURES OF THE CHEMICAL INDUSTRY - I

• The Chemical Industry (CI) is an essential and not an optional industry and it is intimately and inseparably connected with the basic needs and desires of the society for food, clothing, shelter, health etc

• The CI has made our lives happier, healthier and wealthier

• The CI is an exciting, rewarding and entertaining industry

• The CI is a complex industry, based on good science, and will remain so

• The key drivers for the innovation in the CI include: Business bull; Technology push; new concepts

• Very high purity products, including that for bulk products like purified terephthalic acid, ehtylene glycol, phenol etc. are required with specifications for impurity levels

• The Chemical Industry was not a product of the traditional crafts, but arose through the deliberate application of scientific conclusions for Industrial purposes

• Development generally followed rapidly in the wake of new scientific discoveries, often by great leaps

• Scientific advances have always provided the basis for strategic planning

• Though little more than 150 years old, Chemical Technology has had a greater influence on our civilization than any other technological discipline Chemistry

• The chemical industry was the first science based, high-tech industry.

• From agriculture to transportation, communications and housing, Chemistry has transformed nearly every aspect of society and enabled nearly everyone on the planet benefits.

• The chemical industry is a knowledge-based industry; Chemical Innovation and the new knowledge that chemical research generates will be required to meet the needs of the 21st century.

THE CHANGING FACE OF CHEMICAL ENGINEERING

(Century-old discipline is ripe for expansion into materials and biomedical product development) Stephen K. Ritter, C&EN 4 June 2001, p. 43

In the future, more chemical engineering graduates will be involved in new product development, Wei predicts, and they will need the intellectual tools to be successful.

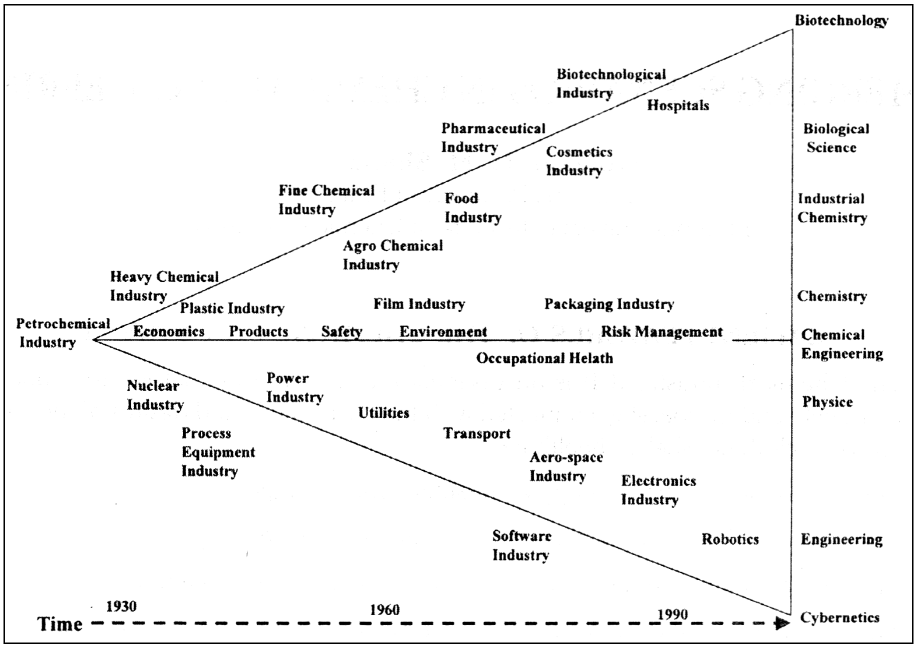
J. Wei "The time is ripe for the chemical engineering curriculum to include molecular product engineering as a core subject, and to teach molecular structure-property relationship."

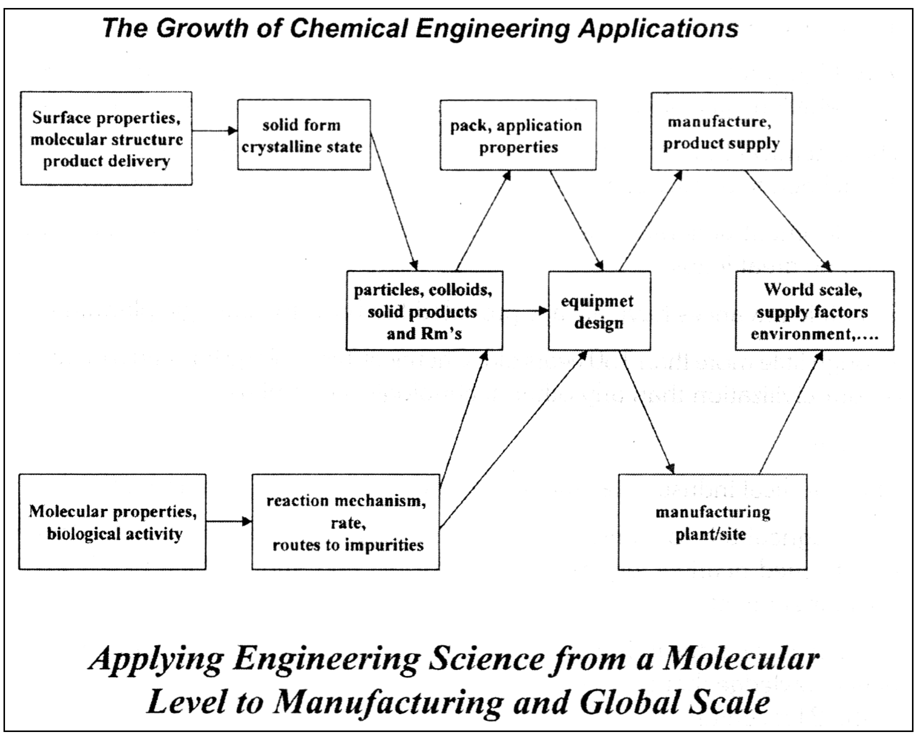
SOME REQUIREMENTS FOR EFFECTIVE CHEMICAL ENGINEERING IN THE POSTMODERN WORLD

J.M. Prausnitz (CES 2001,56,3627)

- More emphasis on quality controlled to assure process and product safety and reliability. More green chemistry to avoid pollution
- More attention to "Human" needs of employees and coworker
- Open honesty when there is a problem of public concern. In this day of Instant information, any cover up is counter-productive

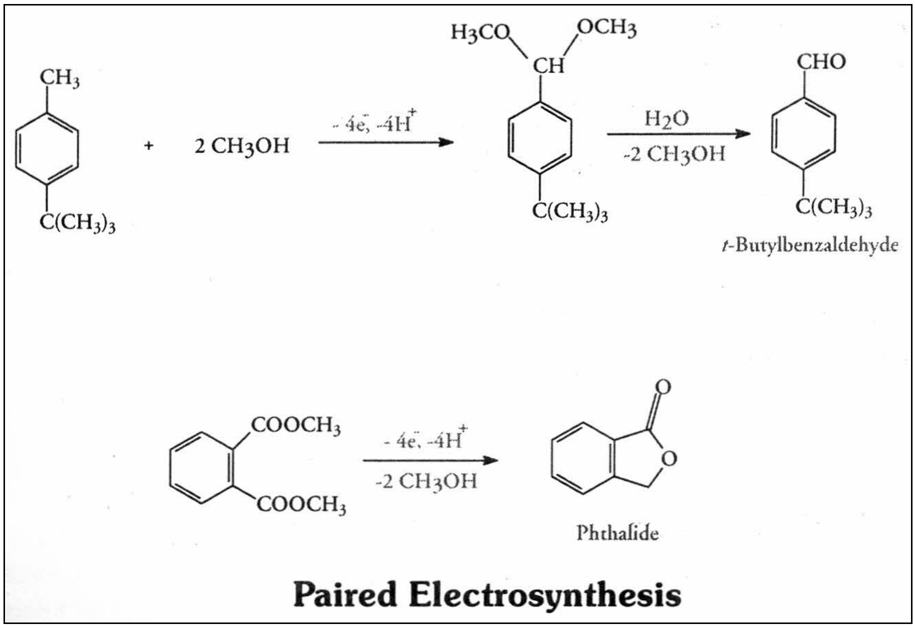
- A much increased effort to communicate through the media what chemist and chemical engineers do, how they do it, and why
- Build bridge to nonscientist. Listen with empathy and respond with humility when those who are "not like" reveal their discomfort with science and their fear of technology
- Do not assume that "we" are smarter than "they"

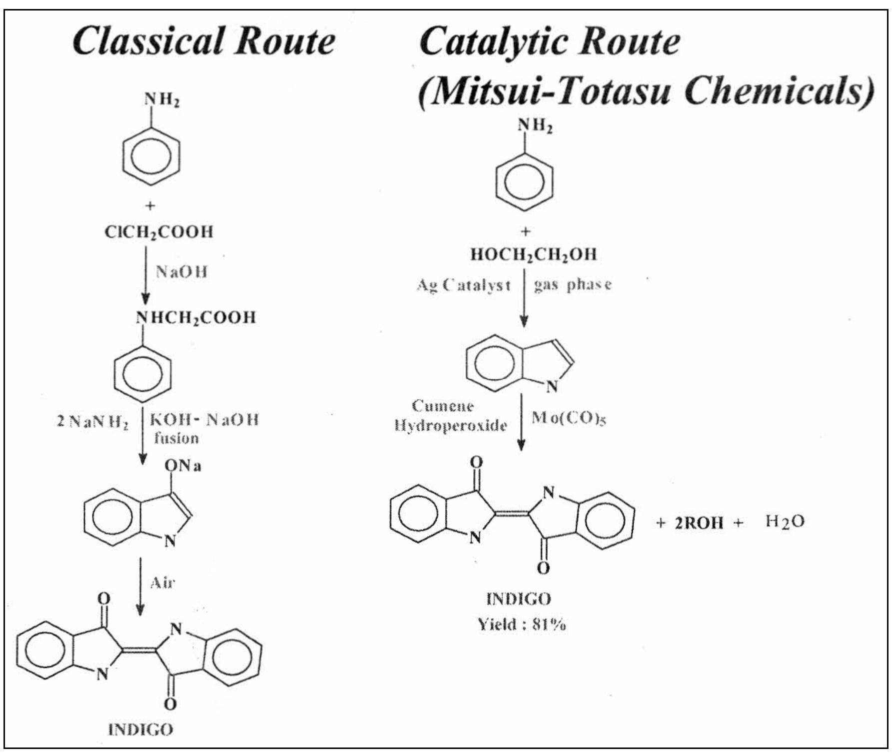




CATALYSIS

- The "in situ" methods by which the reaction is studied along with changes of the structure of the catalyst or the surface Intermediates have proved to be immensely helpful
- Thus XRD and EXAFS spectra of Methanol synthesis Catalyst activation have proved to be very useful
- EXAFS studies of low temperature shift catalyst indicate that the exposed Copper surfaces vary with composition of the gas phase.



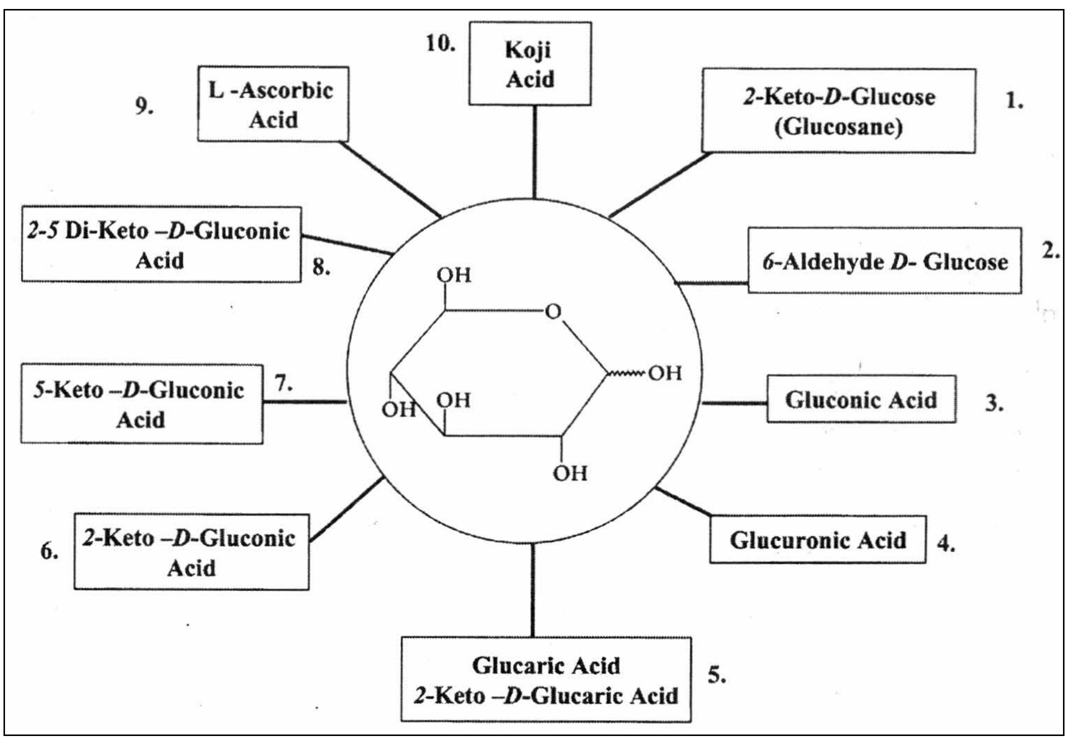


Engineering Oriented Successes

- Fluidized bed catalytic-cracking; Fluidized bed polymerization
- Continuous catalyst Regenerator (for reforming)
- Hydrotreating and Hydrocracking
- Pressure Swing Adsorption
- Simulated Moving Bed Chromatographic Separation
- Membrane Separations
- Reactive Extraction (Hydrometallurgy)
- Reactive Distillation
- Reactive Adsorption
- Higee Contactor
- Continuous Melt Crystallizers

Renewable raw materials

- Glycochemicals rather than petrochemicals to some extent
- Utilisation of carbohydrates, provided so graciously by nature via photosynthesis, available at 190 billon tons per annum in particular, utilisation of starch, sucrose and glucose; novel chemistry /biotechnology to take care of "over functionality" of sucrose / glucose
- Bagasse, available from about 200 m.t.p.a. of cane, for paper on a very large scale and some biotransformation



Our growing understanding of how polymers are used in nature and the need for a smaller impact on the environment have led to a greater interest in naturally derived building blocks for polymer structures.

All the permutations on polymer structure and distribution of chemical functionality can be found in the polymeric systems used in nature - polysaccharides, polypeptides, lipids etc have complexities by design, whereas the majority of the synthetically produced polymers have complexity as a by-product - and often one that is undesirable.

Materials science is a model for putting knowledge to work for public benefit. Its discoveries and its inventions combine intellectual creativity, hands on practicality, and interdisciplinary teamwork.

Man made polymers and composites came from chemistry, not from imitating spiders or trees. These too moved into the Pasteur quadrant.

Materials science got where it is today because of a remarkable, though unintended, recognition by both universities and industry that their interests lay in doing work that combined utility and understanding in the fashion of that Pasteur quadrant.

There is no doubt that Enantiomeric Compounds have moved decisively toward the center of attention; Enantiomers are related as non-superimposable mirror images, - The "Good" and the "Bad" isomer.

We ought to avoid "Isomeric Ballast" Or "Medicinal Ballast" Enantio selective synthesis is "The Challenge".

No aspect of Organic Synthesis is generating as many publications as the preparation of enantiomerically pure compounds 1990s Is The "Decade Of Chirality".

DuPont's biology efforts are now focused at microbes "as, programmable' manufacturing factories to make chemicals, monomers and polymers from different nutrient feedstocks", such as glucose and methane.

It is important to "acknowledge concerns about unknown risks", and industry "must do a much better job of engaging, listening to and addressing the concerns of all stakeholders in this global debate" (Holliday, Dupont).

Lonza Process

- The bio-transformation of 2,5-dimethyl pyrazine (DMPY) to 5-methyl pyrizene -2- carboxlic acid is an example
- The starting material the product and the carbon source (xylene) used for fermentation all inhibit the processed
- Row injection analysis (FIA) for on line control, modelling, and expert systems combine with computer control allow complicated feeding strategies to overcome the substrate inhibition.

Microreaction Technology Potentials and Technical Feasibility

A microreactor Isa three dimensionol structure that is used to perform chemical reactions and that is produced by means of suitable processes of Microtechnology in solid matrices.

The main advantages of microchannel reactions are quite obivious: The pathways for both heat and mass transfer are reduced substantially in the narrow channels.

Microchannel reactions are particularly suitable for strongly exothermic reactions, partial reactions giving unstable target products, and Mass Transfer limited reactions.

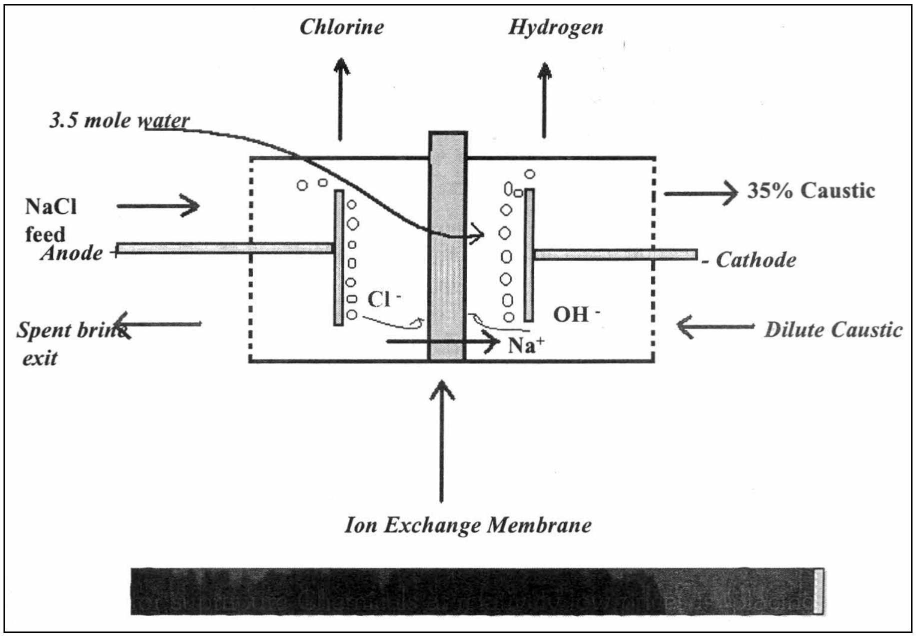
Laboratory experiments on mono- and dinitration of Benzene, mono- Flourination using Flourine gas have been conducted.

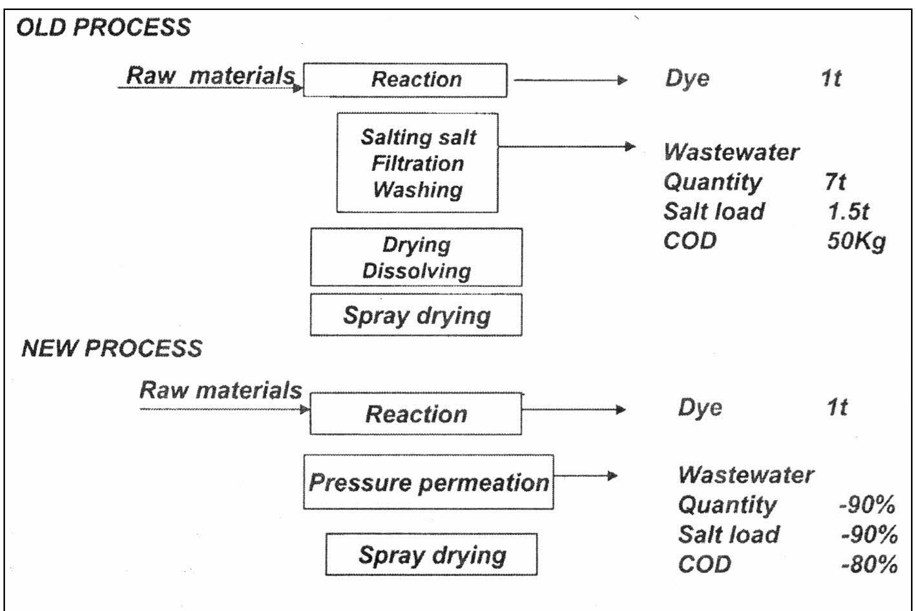
Role of Separation Technology

- The demand for suprapure Chemicals at relatively low prices is placing a heavy demand on Separation Technology
- A major part of the Capital Investment and energy cost in typical chemical plants is associated with the Separation Train
- In Biotechnology about 50% of the investment goes in Downstream Processing but, alas, it receives 5% attention
- New Technology, often hybrid, based on Adsorption and Membranes
- will unquestionably provide a major impetus for further improvements
- Further advances will be necessary in Affinity Chromatography

Separation Technology:

- Improving classical separations: distillation, absorption, extraction and drying (with respect to a.o. energy consumption)
- New separations: membranes, chromatographic, centrifugal, combining separation steps (hybrid system)
- Introduction of more fundamental transport phenomena based / innovative separation/ processe





Residue minimization by pressure permeation

Nanofiltration (NF) for Removal of Pesticides

Fenobucarb, Propyzamide, Chlorothalonil, Isoxathion, Tricyclazole, Carbaryl, Mefenacet, methyldymron, chloroneb, esprocarb and propiconazole (11 in all) have been tested. The highest desalting membrane rejected all pesticides at more than 92.4%, except tricyclazole.

The removal of pesticides, nitrates and hardness from ground water has been considered. Nitrate concentration has to be below 50 mg per litre and removal of hardness is desirable for reasons of comfort. NF removes pesticides and nitrate and hardness simultaneously and thus one step process can be adopted. Atrazine, simazine, diuron and isoproturon were pesticidal impurities and NF70, NF45, UTC-20, UTC-60 membrane were used and all of them removed pesticides satisfactorily and hardness is also efficiently removed. However, nitrate removal is not satisfactory except in NF70 where it is 76%. NF is an economically attractive proposition.

Nanofiltration (NF)

Recovery of Amino Acids from Aqueous Solutions Recovery of L-phenylalanine (LPA) and L- aspartic acid (LAA)from aqueous solutions with commercial NF membranes, ENSA 2 and ES20 (from Hydranautics Corporation and Nitto Denko Corporation) has been reported. The rejections of LPA and LAA by ESNA 2 were about 0 and 90% respectively, at the value ranging from 4 to 9. By contrast ES 20 provided rejections of both compounds at almost 100% irrespective of the pH value. Thus not only LPA and LAA can be recovered but also separated by choosing proper membrane and operating conditions. The feed concentration of amino acids were below at 200 kg. per cu.m

Process Intensification :

Equipment for reactions considered are:

1) Spinning disk reactor

2) Static mixer reactor

3) Monolithic reactors

4) Micro reactors

5) Heat exchange reactors

6) Supersonic and jet impingement gas-liquid reactor

7) Rotating packed bed reactor

Multifunctional reactors considered are:

1) Reverse flow reactors

2) Reactive Distillation/ Extraction/ Crystallization

3) Chromatographic reactors

4) Periodic separating reactors

5) Membrane reactors

6) Reactive extrusion

7) Reactive comminution

8) Fuel cells

Hybrid separations includes:

1) Membrane adsorption

2) Membrane distillation

3) Adsorptive distillation

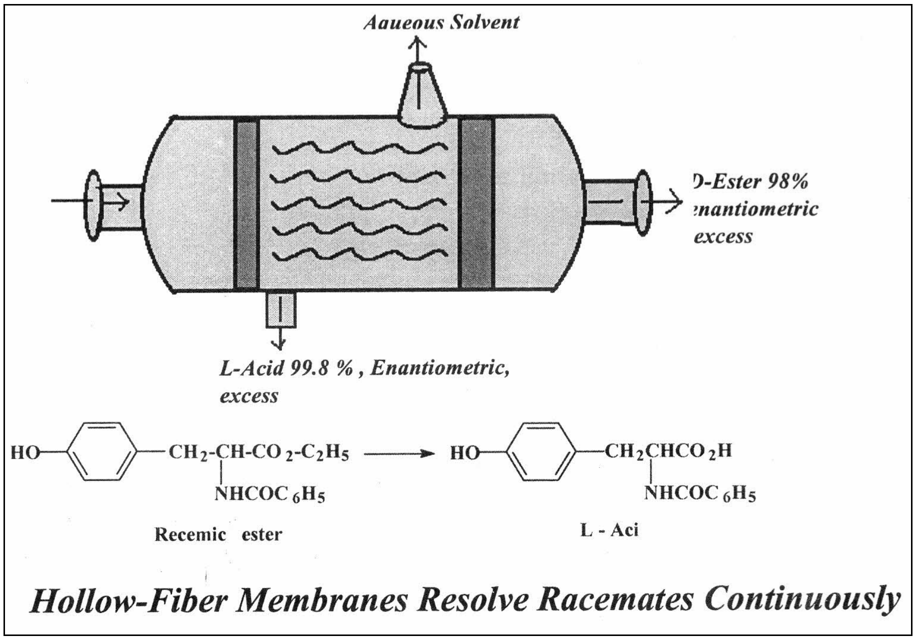
Rotating packed bed referred to above been used by Chinese for deaeration of flooding water in Chinese oil fields where 1 m dia machines have replaced conventional vaccum towers of 30 m dia

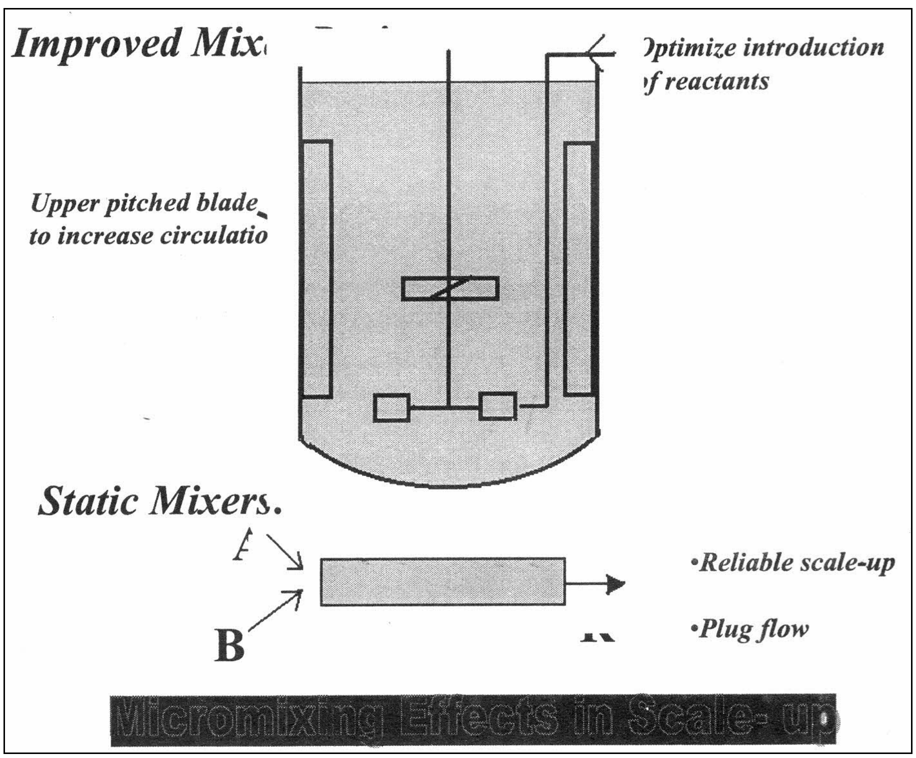
Nanotechnology

1) Encompassing both nanoscience and nanoengineering, nanotechnology suggests the ability to work at the molecular level, atom by atom, to create larger structures with a fundamentally different molecular organization, as well as the ability to fashion tailored nanoparticles that perform specific tasks.

2) Compared to the physical properties and behavior of isolated molecules or bulk materials, materials with the structural features in the range of 1 to 100 nanometers – 100 to 10,000 times smaller than the diameter of a human hair - exhibit important changes for which traditional models and theories cannot explain.

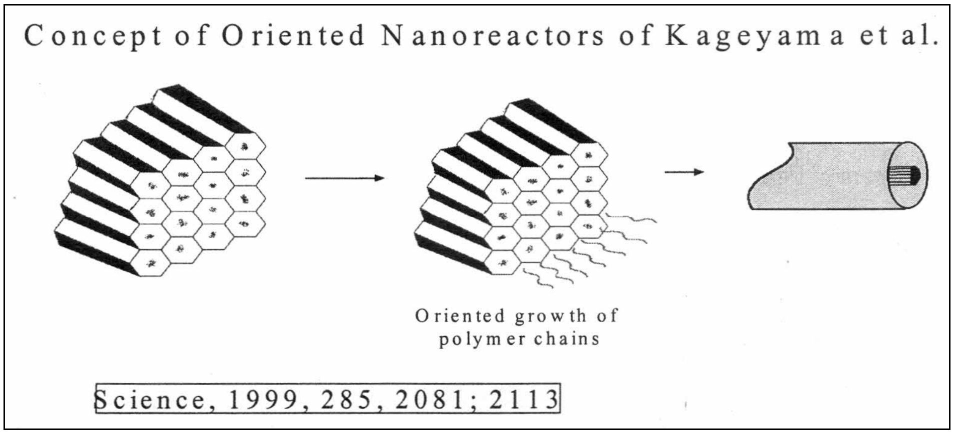
3) Developments in these emerging fields are likely to change the way almost everything - from vaccines to computers to automobile tires to objects not yet imagined - is designed and made.





A cluster of emerging technologies is at the interface of chemistry and material science, especially as applied to electronics.

The ongoing trend in the electronics industry toward smaller, faster, and cheaper devices requires innovative new materials, providing rich opportunities for the synthesis chemist.



Langmuir Gap - a loss of faith in the value of doing work that combines usefulness and fundamental understanding. Industry won't bridge it. Universities can't bridge it.

• Emergence of function - oriented CI rather than merely supplying pure chemicals e.g. Water treatment chemicals as a basket rather than individual pure chemicals; additives for fuels and lubricants

• Advanced materials :

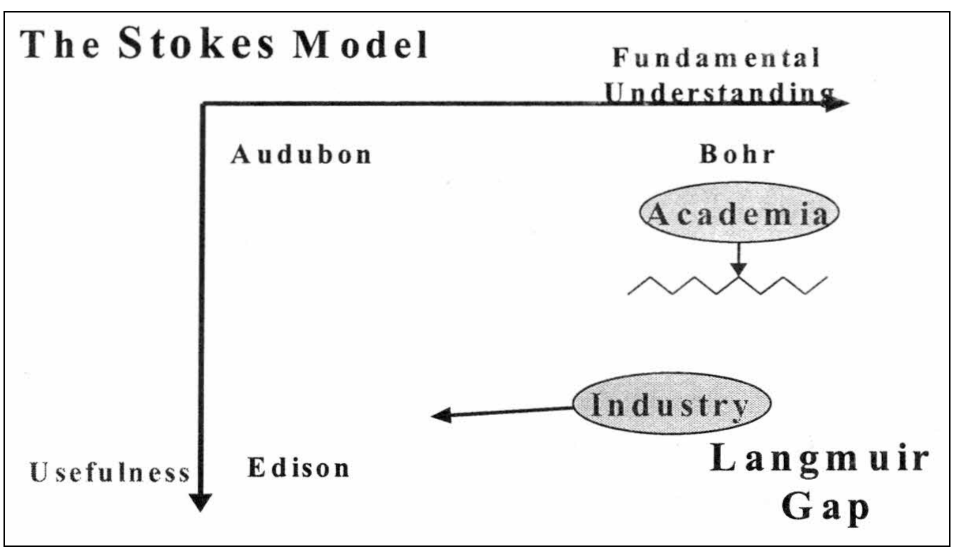
Polymer alloys and blends; composites, Role of molecular architecture

Replacement of metals across the board by polymeric materials; materials that repairs themselves

• Innovative polymers; simultaneous monomer synthesis and polymarisation

• Elastomers as strong as steel ;Elastic coating as hard as Diamonds

• Pushing known polymers to higher performance levels



Emerging Technologies

- Ethane vs Ethylene based processes for Vinyl chloride; Acetic acid; Ethanol etc.
- Propane vs.Propylene based processes for Acrylonitrile; Acrylic acid; Cumene etc.
- Butenes/ Pentenes/ Hexenes to propylene + ethylene
- Metathesis of alkanes
- Alkanes to Alkanols/ Ketones
- Polylactic acid
- Adiabatic reforming of Methane (power + syn gas); IGCC
- Fuel Cells based cars (Mini methanol plants based on natural gas)
- Membrane reactors
- Chiral Engineering
- Engineering of Polymorphs
- Reactor on Chip (Micro reaction Engineering)
- Processes without Separations
- Formulation Engineering
- (Vegetable) Plants to produce Chemicals
- Chemical Engineering has a tradition and culture of being an

'EVOLVING DISCIPLINE'

- Chemical Engineers are versatile as they are tuned to Micro or Molecular level as well as Meso or equipment scale and finally with the macro-scale integrated plants
- The coming age in chemical engineering will be exciting, Rewarding Edifying, and Boundless
- The innovative momentum of the Chemical Industry is Relentless

Indian Chemical Industry —Vision 2020

Prof D V Gupta

Professor of Chemical Engineering
Dean-University School of Chemical Technology
GGS Indraprastha University, Delhi

Ladies & Gentlemen

It is indeed an honour for me to be invited to deliver the Acharya P.C. Ray Memorial Lecture. Topic of this lecture is very timely and appropriate even as the chemical industry and education are undergoing a transition phase the world over. The world economies are opening in the wake of the globalization. As apart of WTO and GATT signatory, India is also poised to play its role in the new world order. Advances in science and technology are taking place at such a high speed that it is impossible to assimilate and produce the technology based on those scientific achievements. Computer and Internet have become order of the day and are affecting every walk of life. So is the case with industries in general and for chemical industries in particular. With this we have entered knowledge economy and the future seems to be dependent on technologies based on computer - enabled and more molecular level oriented technologies. With knowledge dissemination speeds so high, public awareness is on the increase, the world is becoming more like a global village and sensitive not only to local issues but also to the global issues. Environmental degradation (both air and water) is one such sensitive issue, which is affecting all of us. We are facing water scarcity & this problem is going to become worse with time. Similarly, fossil fuel is depleting fast and thereby dictating a search for newer types of energy. All the above put together shall have a bearing on the way the future chemical industry would look like.

Broadly speaking, chemical engineering is about transformation of matter and is thereby concerned with the production of energy as well as manufacture of useful chemical products. It deals both at macro- and micro-level. At micro level, it is an engineering discipline with deep roots in the world of atoms, molecules and molecular transformations. At macro level it is concerned with the production of useful products at commercial scale. Practice of chemical engineering has been in place since time immemorial and origin of this branch dates back to 1910's (Figures 1-4). It has evolved over a period of time from a chemist's viewpoint. Today it is more and more based on the fundamental principles of physics and chemistry.

Figure-1

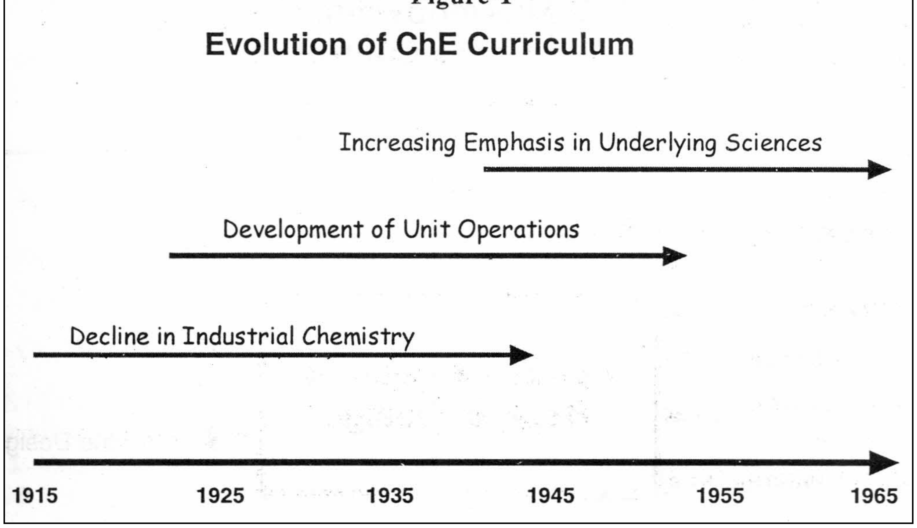


Figure 2

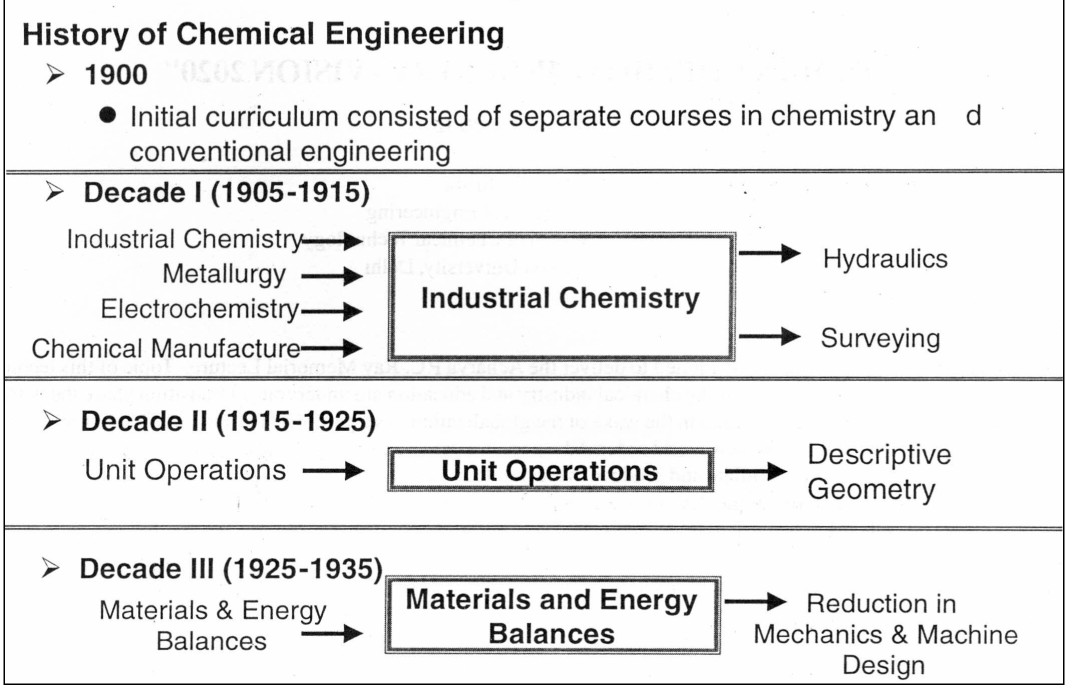


Figure 3

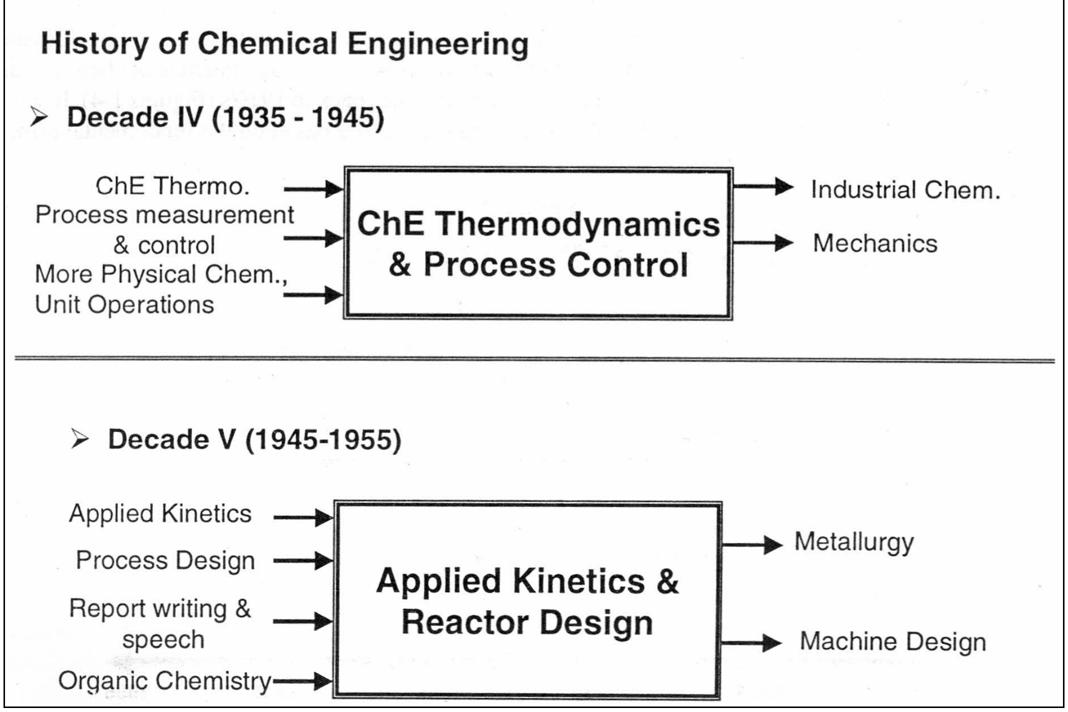
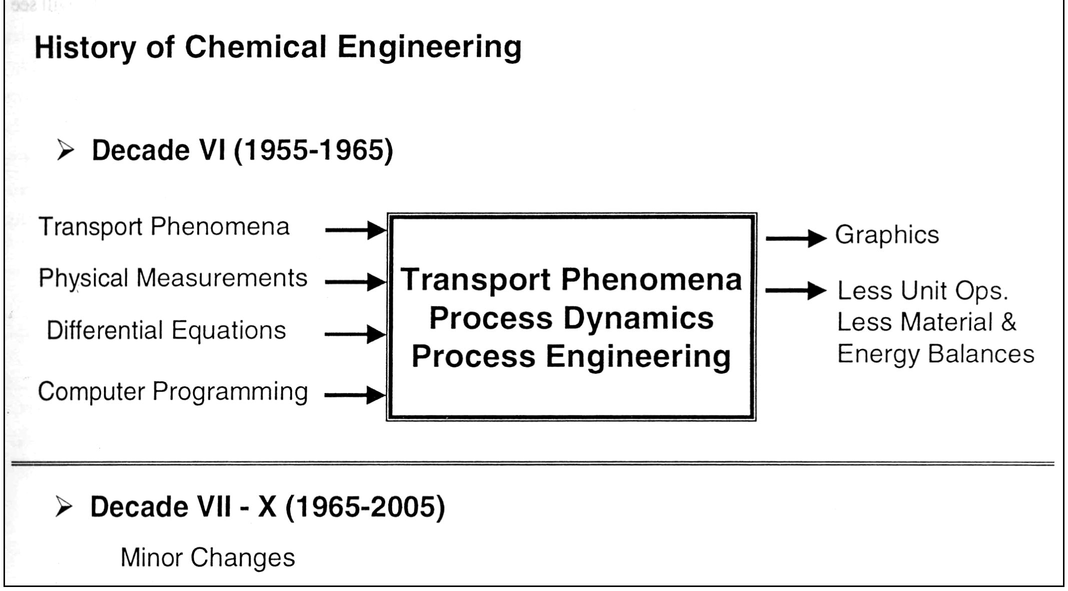


Figure 4



Chemical engineers and scientists are involved in developing and designing of processes in increasingly varied traditional and non-traditional activities. With the liberalized economy, more and newer opportunities are opening up. However, there are challenges too as no technology is 100% efficient. As a result, they leave a trail of pollution related problems. Increased industrial activities are also having their toll on energy. Energy resources such as conventional fossil fuels are depleting. There is a need to develop or explore new sources of energy or new routes of energy generation.

CHALLENGES

- Globalization of market
- Public awareness for higher environmental performance
- Financial market demands increased profitability and capital productivity
- Higher customer expectations in terms of Quality etc.
- Changes in labor / skilled person work pattern (Global work force)
- Impact of information age

OPPORTUNITIES

- Speed & memory of computer
- Robotics / instrumentation
- New markets are opening up resulting in potentially big business

It would be appropriate to assess our potential and where we stand today. The following figures show the employment statistics for initial placement, data complied by AIChE (Figure 5-7). These chemical engineers are working in areas as diverse as Electronics, Food /Consumer products, Fuels, Business services etc. These jobs are available at entry level from B.Tech. through Ph.D. We are entering in the WTO and IPR regime. There is a need for in house R&D not only for existing processes and products, but also for developing newer products in order to remain competitive. As to the salary of chemical engineers, they are the highest paid in the US and I hope, in near future, India will see the similar trend. Table-I summarizes the salaries being drawn by engineers of different branches.

Figure 5

Employment Statistics for Initial Placement : AIChE

B.Tech.

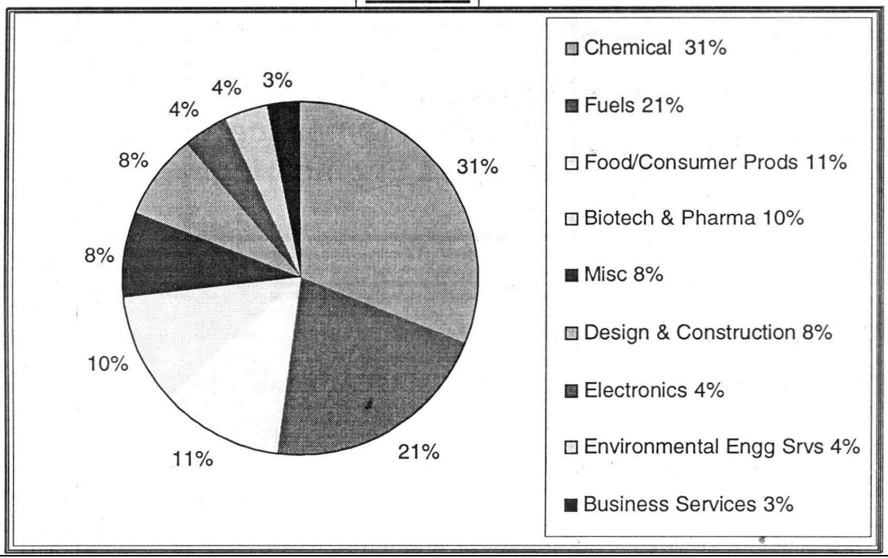


Figure 6

Employment Statistics for Initial Placement : AIChE

M.Tech.

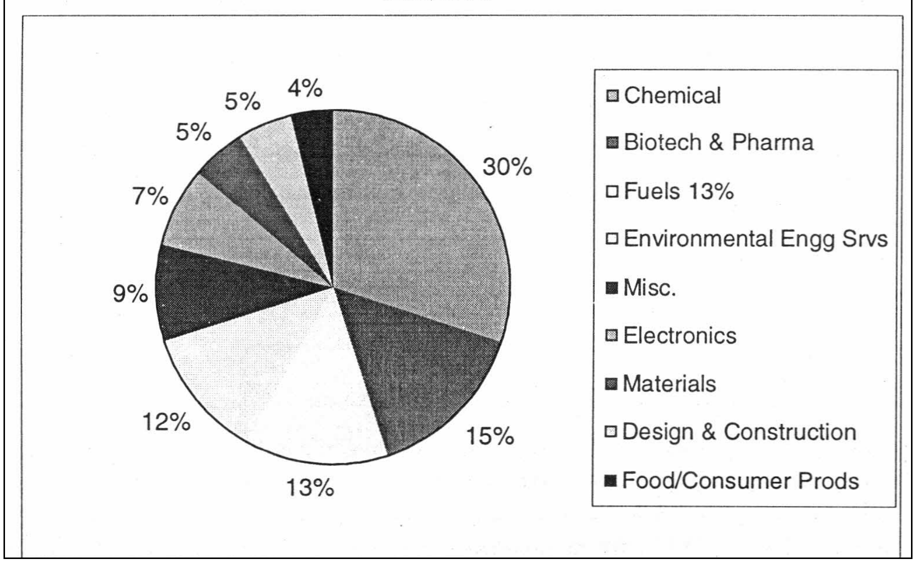


Figure 7

Employment Statistics for Initial Placement : AIChE

Ph D

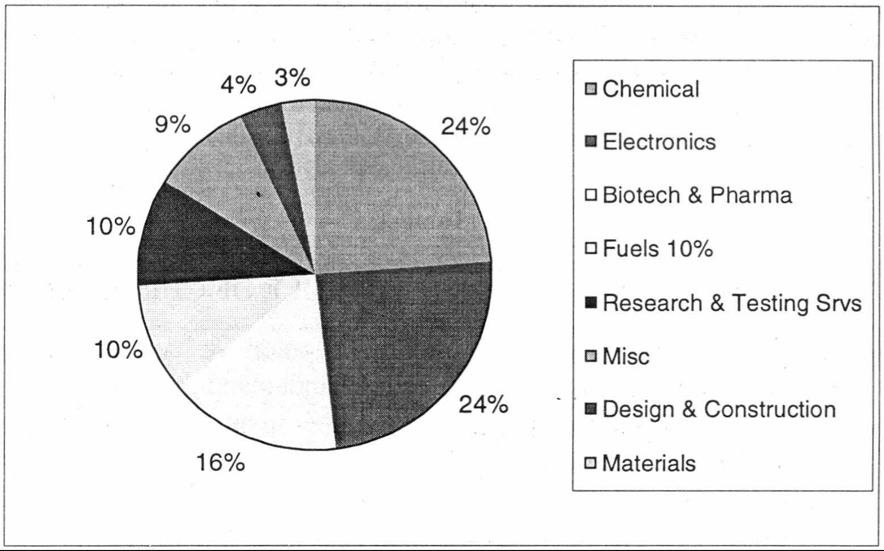


Table-1

Salary structures in different disciplines

Share of engineering disciplines is highest & among engineering disciplines chemical engineering leads the salary wagon.

BS Starting Salaries

Field	Starting Salary
Chemical Engineering	$58K
Electrical Engineering	$55K
Computer Science	$51K
Civil Engineering	$45K
General accounting	$45K
Information science and systems	$44K
Business administration	$40K
Marketing	$39K
Liberal Arts	$32K

As far as core chemical industries are concerned, these are involved either in producing a product for captive use or as a raw material for other industries so that they touch almost every facet of human life. The products range include agricultural chemicals, pharmaceuticals, specialty chemicals, industrial gases, rubber, soaps, detergents etc. Other industries are also recognizing the importance of chemical engineers for a variety of reasons e.g. Biotechnology industry are employing chemical engineers for the development and design of processes etc. Table-2 below demonstrate the role of chemical engineers in different industries. Even in the same industry a chemical engineer can be employed for doing a variety of jobs e.g. Design Engineer designs the manufacturing facilities and equipment to develop new or improves process. Other designations include Plant Process Engineers, Technical Manager and Production Engineers etc. Typical designations for a chemical engineer and the activities they are involved in are tabulated in Table-3.

Table-2

INDUSTRY	ACTIVITIES	ROLE OF CHEMICAL ENGG.
Biotechnology	Creation of products to be used in other industries using living cells & materials produced by cells, e.g. antibiotics, insulin, waste reduction	Develop & design processes to grow, handle and harvest living organisms & their byproducts.
Electronics	Electronics material processing, manufacturing of microchips & intricate circuitry	Material development & production. Design of Process Control Equipment etc.
Energy	Energy production from fossil, nuclear & synthetic or renewable fuels	Production processes, environmental monitoring, research and development & process safety. Also involved in developing alternate energy sources
Food Processing	Handling, processing, preparation, packaging & preservation of food & beverages	Formulate new products, change ingredients for better flavor, modify processes for more consistent texture & packaging etc. Total quality control
Engineered Materials	To manufacture materials with special properties & for special applications, such as for aerospace, electronics, photographic products	Develop materials with different properties such as weight, strength, heat transfer, reflectivity, purity etc.
Environmental Safety & Health	Safety & loss prevention of employees, environment and infrastructure	Green engineering processes, process safety and loss prevention. HAZOP studies, Hazards Review. Operational Readiness & Review (ORR)

MEETING THE CHALLENGE

Improve efficiency in the use of raw materials, use of recycled materials, generation & use of energy.

- Try to strike a balance between economic and environmental considerations
- Investment in R & D on a long-term output basis.
- Interaction among government, academia, and industry
- Development of newer products or modifications in the existing ones in light of advances in basic chemistry research.
- Better use of information technology tools: Modeling of the chemical processes, better plant wide process control, complete automation of industry complexes, generation and analysis of data using computer age tools & equipment.
- Train personnel in international law and intellectual property related laws, implications of WTO and GATT Improve operations with a focus on better management of the supply chain. i.e. logistics inside & outside the industry, better production management etc.

Table-3

SN	Designation	Activities (A Chemical Engineer is Involved in)
1	**Process Design Engineer**	• Design manufacturing facilities and equipment • Develop new or improved processes as a member of a team of engineers
2	**Plant Process Engineer**	• Overall technical management of chemical process plants and ensure efficient functioning of a plant, trouble shooting, minimizing unscheduled shut downs etc. • May be involved in design work for project improvement
3	**Technical Manager**	• Manages the engineering staff and programs at a facility such as R&D and daily operations of the engineering functions (typically with an additional qualification e.g. M.S. or MBA). Interacts with outside customers
4	**Manufacturing / Production Engineer**	• Supervise the day-to-day operation of a manufacturing unit
5	**Process Safety Engineers**	• Look after the safety aspects of individual processes or plants
6	**Quality Control Engineers**	• Focuses on product as well as manufacturing process quality aspects, as relates to specifications, shelf life etc.
7	**Environmental Engineers**	• Develop techniques to recover usable materials from waste • Design waste storage and treatment facilities • Laisioning with regulatory agencies
8	**Control / Automation Engineer**	• Focuses on performance aspects of processes • Design instrumentation for controlling chemical processes & plants as a whole
9	**Product Engineer**	• To develop a product
10	**Project Engineers**	• Mainly concerned with the design and construction of a specific process in a facility & its start-up
11	**Project Manager**	• Manages ongoing operations in a certain project. This includes the construction phase
12	**Research & Development**	• Modify existing processes or products, and may develop altogether a new process or product
13	**Consultant**	• Typically has advanced degrees viz Ph.D, Gives specialized advice to different customers
14	**Professor**	• Teaches and conducts research in a University environment

To remain competitive in the global economy is no easy talk. We have to attack the problem from many angles. Broadly, we can divide them into.

1. Chemical Engineering Sciences
2. Management
3. Computer & IT
4. Manufacturing
5. Regulatory Agencies etc.

In this talk, the issues related to technical aspects of the vision shall be discussed.

CHEMICAL ENGINEERING AND BASIC SCIENCES

Chemical engineering science is at the base of product development in the society, whatever product or facilities we use are directly or indirectly related to chemical engineering. Chemical engineering cannot be viewed as a single branch of engineering & science. Rather, it has input from so many areas viz. basic sciences, biotechnology, material science ere to name a few. As in other branches of engineering, the development in one area of chemical engineering lead to the development in other area and vice versa.

Basic sciences provide us with the tools, which are essential for the meaningful synthesis of organic & inorganic raw material into products. Approximately 90% of the synthesis is catalyst based. In order to take its full advantages, research should be initiated in this promising field of surface / interface science. Its result should be utilized in developing processes, which are more labour friendly, less energy dependent, least harmful to the environment and with minimum generation of waste.

ROLE OF BIOLOGICAL SCIENCES

It is not an oversimplification that the role of biological sciences is increasing steadily. Scientist are working overnight in developing products simulating life e.g. robots, biochips etc. therefore it is apt that in future more & more products be developed through biotechnology routes. Inherently, biotechnology processes are less polluting & less energy consuming; bacteria can manufacture chemicals even at very low temperature and pressure e.g enzymatic production. This is the issue affecting both education and industry. We have made changes accordingly in our own curriculum. The biotechnology education should be integrated in chemical engineering course. This will better enable chemical engineers to work in biotechnology industries, which shall be producing chemicals through biotechnological routes. It is the responsibility of all chemical engineers, government, manufacturers, and the consumer that they cooperate in this collaborative effort of realizing a dream of making the biotechnological mission a success. Still, biotechnology research is mostly carried out at lab scale or in the R&D section of the industries. Time has come that chemical engineers lend their support to biotechnologists and help them establish institutions and industries where the fruit of biotechnological excellence could be made available to the mankind. Chemical engineers can provide assistance in the following areas

1. To discover, develop and make available more effective, powerful and efficient biocatalysts
2. Help develop more efficient process technologies based on the chemical engineering principles.
3. Use results of biotechnology research in health and agriculture. This is possible through commercialization of lab scale biotechnology research in say, enzyme discovery etc.
4. Government encouragement & support is essential. Government should participate in pre-competitive biotechnology R&D, etc.

MATERIAL SCIENCE

It is a common wisdom that humanity's development is closely linked with the development in material sciences e.g. Stone Age, Iron Age, and Copper Age. etc. Newer and newer synthetic materials are revolutionizing our society in this century and will continue to do so in the coming centuries. Present era could conveniently be termed as the age of engineered materials.

Humans started with the very raw form of materials. Metals wood glass, natural fibers, synthetic polymers and composite materials have been in use traditionally. With the advances in chemical engineering and allied sciences, these materials are now being replaced by products with lower weight and higher strength. Better energy efficiency, higher performance and durability, increased design and manufacturing flexibility, and quality of the materials can be achieved if-

I. Industry and academia work together to promote interdisciplinary approaches to materials science, including the integration of computational technology

2. Adopt molecular level approach for understanding of structural properties so that tailor-made materials could be designed and developed.

3. We should work in the direction of defining new approaches for disassembly and reuse of materials.

PROCESS ENGINEERING & SCIENCE

Process Engineering is at the core of chemical engineering. It dates back to 1930's. By applying the principles of process engineering and science, one is able to develop, scale up and design the chemical manufacturing facilities. Like other engineering disciplines, the earlier methods used in process engineering were somewhat crude and empirical. With the development in basic and allied sciences, understanding of the processes and the parameters has improved considerably over the period. With improved methods of process engineering, we shall be able to utilize our capital, energy, and other resources in a much more efficient way. We can design processes where generation of waste will be minimal. Process should be safer, environment friendly and conscious of human health. In order to achieve above objectives, government and academia should work together for developing relevant process software & real time measurement tools. New frontier areas of unconventional reaction & separation should be explored. These include plasma, microwave, photochemical, biochemical, supercritical, cryogenic, reactive extraction and distillation & membrane reactors.

DEVELOPMENT IN MEASUREMENT TECHNOLOGY

Whatever we do in science & engineering, it must be measurable. If we are unable to quantify anything or to put simply, we are unable to tell it in numbers, it is of not much use. Measurement therefore, is an enabling technology and is of critical importance. Improved chemical measurement techniques provide us with the tools that accelerate progress in chemical science, biotechnology, materials science and process engineering by providing reliable data to evaluate current and emerging technologies. Keeping in view the importance of this aspect, the industry should focus on it and start developing Centres of Excellence specially dedicated to process analytical chemistry. A special task force should be established which will assess the industry-specific requirements of measurements to be made. Real-time measurement tools be designed for ensuring acquisition of reliable and online data.

PROTECTING AND IMPROVING THE ENVIRONMENT

Today, we are facing many environment related problems. This is in a way, result of inefficient technologies and are mainly caused by the release of chemicals from the industries through their effluents and gaseous emissions. In order to improve the situation, I would like to stress the following salient points.

- Fundamental investigation of combustion processes.
- Application of Biotechnology to waste degradation.
- Interdisciplinary studies of the environment's capacity to assimilate the broad range of chemicals that are hazardous to humans and ecosystems.
- Developing new chemical engineering design tools to deal with multiple objectives of 1) Minimum cost, 2) Process Resilience to changes in inputs 3) Minimizations of toxic intermediates and products 4) Safe response to upset conditions, start up, and shut down.
- Cost effective management of hazardous waste
- Improve existing technology (e.g. incineration) or develop new technologies for rendering the destroying hazardous waste into non-hazardous.
- Initiate research to facilitate multimedia, multi-species approach to waste management e.g. Acid rain and the leaching of hazardous chemicals from landfills demonstrate the mobility of chemicals from one medium to another.

SURFACE AND INTERFACIAL ENGINEERING

Whether we talk about chemical reactions, material science or microelectronics processes, surfaces and interfaces play an important role. This is one such area, which has implications across many engineering disciplines, Chemicals engineers play an important role in this promising area. Following are some of the examples where we as chemical engineers can contribute towards welfare of the society.

- Developing high strength concrete for roadways and buildings.
- Inventing new membranes for artificial organs.
- Newer developments in heterogeneous catalysis.
  - Synthesis and modification of novel catalysts with enhanced capabilities
  - Integration of the above capabilities with traditional knowledge in analytical reaction engineering of catalysts, thereby designing better processes involving catalysts.

CONCLUSION

Chemical Industry is one of the oldest industries in India and the world over. The Indian Chemical Industry ranks 12th by volume in the world production of chemicals. We have just entered WTO and GATT regime. In order to remain competitive in this open economy era, as a nation, are obliged to follow a path with vision for success. In this brief talk, I have tried to touch some of the issues related to chemical and allied industries for achieving success in our endeavour. We should promote R&D efforts in academia and initiate the R&D in industries. Cooperation of industry, academia, Government is essential in this collaborative effort. Everybody is a stakeholder. If we do not join hands today, we will miss an opportunity to excel and may loose the game.

I thank you for giving me a patient hearing. I feel if this vision is followed and concerted efforts are made it will take India to a new height.

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Semifluidized Beds: Concept- Development-Applications

Prof (Dr) G K Roy, *FIE*

Former Director, National Institute of Technology, Rourkela, Odisha

Concept

The phenomenon of semifluidization is a unique and novel technique of fluid-solid contact and can be viewed as a combination of a batch fluidized bed at the bottom and a fixed bed at the top. A semifluidized bed is formed when a mass of fluidized particles is compressed with a porous restraining plate at the top. This gives rise to the creation of a fluidized bed and a fixed bed in series within a single containing vessel. Obviously this unique feature of a semifluidized bed can be exploited in a variety of practical and industrial applications. A fluidized bed has the disadvantages of (i) back mixing of solids (ii) attrition of particles, while that of a packed bed suffers from (i) segregation of solids (ii) non-uniformity in bed temperature and (iii) channeling. The above disadvantages of the individual ones can be taken care of at least partially in a semifluidized bed. The internal structure of a semifluidized bed can easily be altered to create an optimal operating configuration with appropriate distribution of the bed materials in the two sections viz. the fluidized and the packed.

Development Investigation Domain:

Design and development of semifluidized bed systems for various physical operations and chemical processes are to be founded upon investigations. Since the conceptualization of the semifluidization phenomenon, over the last five and a half decades, extensive studies have been made to provide a qualitative as well as quantitative picture of the macro and micro behavior with respect to bed dynamics. The output parameters of relevance of such studies have been,

(i) Onset (minimum) and maximum semifluidization conditions- G_{osf} and G_{msf} respectively in terms the mass velocity based on empty column cross section

(ii) Top packed bed height in case of semifluidization, h_{pa}

(iii) Semifluidized bed pressure drop, P_T

The input parameters for the above items have been,

(i) Particle size: d_p in case of mono-size particles and d_{pavg} in case of mixed particle-systems

(ii) Particle density: ρ_s in case of mono-size particles and ρ_{savg} in case of mixed solid systems

(iii) Initial bottom static bed height before operation, h_s

(iv) Bed expansion ratio, R (h/h, where h= height of the top restraint)

(v) Diameter of the conduit, D_T

(vi) Velocity of the fluidizing media, (G_l /U_l in case of liquid and G_g/U_g in case of gas)

Keeping in view the multi-phase phenomena in chemical engineering processes (viz. heat and mass transfer, separation and mixing, chemical and biochemical reactions) involving mono-size as well as mixed size homogeneous and heterogeneous solid phases, investigations relating to these aspects have also been taken up extensively.

Data Analysis: For the analysis of the data, tools adopted are

(i) Dimensional Analysis,

(ii) Factorial/Statistical Design

(iii) Response Surface Methodology

While exhaustive investigations have been conducted relating to hydrodynamics of semifluidized beds with the development of realistic models of fairly good accuracy for R&D applications, only a few studies have been made with respect to heat and mass transfer, which are more of system-specific nature. In a similar manner, limited RTD studies are available in MT reactor (conceptualized semifluidized bed reactor) under cold conditions.

Applications

A few of the important applications of semifluidized beds are as under,

Chemical Reactors: An MT reactor system which is a combination of mixed (CSTR identical to fluidized) and tubular (identical to packed bed) reactors is theoretically more efficient than either of these operated independently specifically for fast exothermic reactions (e.g. adiabatic oxidation of benzene). For exothermic reactions, a CSTR is superior to a tubular reactor up to a certain conversion after which a tubular reactor is more efficient. Thus an optimal conversion condition can p be obtained by modeling the semifluidized bed reactor as CSTR and a tubular reactor in series.

Ion Exchange: A fluidized bed followed by a fixed bed (as is the case of a semifluidized bed) increases the efficiency of resin utilization by improving the liquidres in contact. The fixed bed acts as a polishing section, handles the ion leakage from the fluidized bed and prevents elutriation of resin particles.

Process developers: Asahi Chemical Co., Japan, Bayer A.G., Germany and Lewitt Co. U.S.A.

Filtration: For filtration purposes, the fixed bed section functions as deep bed filter and turbulence generated in the fluidized section scours the deposited solids, delaying the build-up of pressure drop.

Industrial applications: (i) Removal of insoluble ash and mineral matter from coal oil obtained from hydrogenation and dissolution of coal (ii) Removal of fine particles in a hot flue gas from power plants (iii) Removal of fines from the product gas in Fischer-Tropsch reactor.

Treatment of waste water in Semifluidized bed bioreactor: When microorganisms are attached to inert supports their effectiveness is immensely improved in the degradation of hazardous organic contaminants and nitrogen compounds, in the reduction of total organic carbon (TOC), BOD and total suspended solids and in the conversion of volatile solids to methane gas. The attachment of microorganisms to natural or synthetic supports is achieved by a process called 'cell immobilization.' Solid matrices like polyacrylamide gel, calcium alginate, porous glass/ plastic beads, activated carbon polymeric materials have been used for the immobilization of cells.

The use of a semifluidized bed would eliminate the disadvantages of a fluidized bed viz. the elutriation of the particles coated with microorganisms and unstable bed operation. The semifluidized bed would also reduce or eliminate plugging of the bed by solids (waste or microbial cells) experienced in fixed bed operations.

Conclusion

Semifluidized beds can be used in any application where fluidized or fixed beds are commonly used. Furthermore, the versatile semifluidized beds allow operation in the completely fluidized mode, completely packed (fixed) mode or any degree of the semifluidized mode to accommodate any process change or decaying activity of the solid bed materials used in process. However, wider acceptance of semifluidized beds in chemical engineering operations warrants for microlevel investigations in gray areas relating to heat and mass transfer domains for the development of appropriate and realistic models for shop-floor applications.

Downstream Processing: Current Problems and Future Prospects

KSMS Raghavarao

Department of Food Engineering CSIR-Central Food Technological Research Institute, Mysore
raghavarao@cftrises.in

Downstream processing (DSP) is an integral part of any biological product development and the final cost of the product depends largely on the cost incurred during DSP for its recovery. Many fermentation processes do not see the light of the day due to the high cost of downstream processing. The problems encountered in conventional chemical process look pale when compared to bioprocess. Biomolecules are labile with respect to heat and shear encountered during the processing. Scale-up problems are considerable duri4g downstream processing using conventional methods which are expensive at large scale, making them uneconomical unless the product is of high value. The downstream processing of biological materials requires purification techniques which are both economically feasible and delicate enough to preserve their biological activity. While developing a large scale isolation procedure, it is mandatory to consider processing time, energy, manpower, good manufacturing practices, recycling of chemicals, sterilization and cleaning-in-place (CIP) of equipment apart from separation efficiency. Thus, there is a need to develop downstream processing methods that are simple, delicate enough to handle the labile biomolecules, efficient, economical and environmentally benign with flexibility for continuous operation.

Downstream processing (DSP), despite its importance and critical role in deciding economic feasibility of a given process, continues to receive scant attention, when compared to the R&D efforts in the area of fermentation. One of the main reasons for this partisan treatment to DSP is the erroneous assumption that once the target biomolecule is produced by the fermentation process or available in a natural source, its DSP, that is, separation and purification is not difficult. In fact, DSP is difficult mainly for two reasons. First the target biomolecule often is being present in low concentration and the second, the presence of several undesirable compounds (which are to be treated as impurities with respective to target biomolecules). As a result, a series of unit operations are required for the DSP of biomolecules, while overall productivity reduces with each step in this overall downstream processing train.

For the success of the commercial production of biomolecules, there is a need for efficient separation techniques as nearly 50 to 70% of the total production cost depends on the purification strategy. An effective downstream process, not only should achieve the required purity and recovery levels of the desired product in a safe, reliable and reproducible manner but also do so in a cost-effective manner.

One way of making the downstream processing cost effective is to increase the productivity of a given protocol. The productivity of given DSP protocol can be considerably improved by a relatively new strategy, namely, process integration. Such integration could be of two types: (1). Intra-integration, for example, designing the process conditions in such a , way that various unit operations such as filtration, centrifugation, extraction, purification, concentration, etc. occur in a single step of extraction itself; (2). Inter-integration, for instance, integration of one unit operation with another, say extraction with membrane processing or different type of membrane processes with each other, for achieving the desired selectivity and purity of a given biomolecule.

Liquid-liquid extraction using aqueous two-phase systems (ATPSs), popularly known as aqueous two-phase extraction (ATPE), is one such method which has potential to offer such possibility of process integration. Unlike conventional liquid-liquid extraction involving Organic/aqueous phases, it may be noted that ATPE employs two aqueous phases. It is really an engineering marvel to design a phase system where both phases contain > 80-90% (w/w} water but still they exist and behave as two separate independent phases. This process methodology is very versatile and has several large scale/industrial downstreamt processing applications.

ATPE has been successful to a large extent in overcoming the drawbacks of conventional extraction processes such as low solubility and denaturation of biomolecules in organic solvents. The important step in ATPE is the selection of suitable ATPS which gives the desired partitioning of the biomolecules (cells, bacteria, protein/enzymes etc.) under consideration. After identification of the most suitable phase system, appropriate process parameters/conditions must be arrived at depending on the objective of the given partition step. If ATPE is used as the primary purification step for the removal of cell debris from the fermentation broth containing the desired product, the aim is to partition the debris and the product into opposite phases. Then in subsequent partition steps the desired/required degree of purity of the product is achieved. In all of these extraction steps, while standardizing the system conditions, attention should be given to factors such as partition coefficient of the target protein/enzyme, contaminating materials, volume ratio of the system employed. It should be noted that the cell debris, itself being a biopolymer, contributes to the formation of phases and affects the phase volume ratio. A few case studies for downstream processing of selected biomolecules such as phycocyanin, anthocyanin, beatalains etc. are presented to illustrate the concepts proposed above.

The objective of this Sri Acharya PC Ray Memorial lecture is to draw attention of academic, institutional and industrial researchers at large to the downstream processing and its importance in enabling several processes economically viable not just technically viable besides developing cost effective processes for the products of societal benefit. Even if some of the aspects discussed here are addressed by researchers in detail, the objective of this special lecture is considered fulfilled in view of the increasing importance of downstream processing.

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Challenges and Opportunities in Chemical Engineering

Dr V G Gaikar

Bharat Petroleum Distinguished Professor of Chemical Engineering
Department of Chemical Engineering, Institute of Chemical Technology, Mumbai
vg.gaikar@ictmumbai.edu.in

At the outset, let me thank the Institution of Engineers, for considering me for this honour of delivering this prestigious memorial lecture in name of the India's possibly the first chemistry teacher becoming an entrepreneur, Acharya Prafulla Chandra Ray. I had heard about him in my very formative years in UDCT, then from my own mentor, Professor Man Mohan Sharma, in his introductory lecture to us on chemical engineering. I accept this honour of giving the memorial lecture in his name as a great privilege memorial lecture in his name as a great privilege of giants like him and do our bit towards the development of science and technology.

Acharya P. C. Ray, as he was famously called, was indeed one of the famous scientists that India has ever produced. He was an eminent scientist an exemplary entrepreneur, a patriot and a passionate teacher. He single handedly established "Bengal Chemical Works", with a princely sum of Rs. 750/- then, which produced herbal products and indigenous medicines because of his passion for Ayurveda. He faced severe financial crunches in his endeavour but never gave up. The company later became India's first pharmaceutical company as 'The Bengal Chemical and Pharmaceutical Works Limited'. This led to the employment generation of many unemployed Indians, then. His example becomes more important in today's context when unemployment in educated youth specially in 15-17% amongst the engineering graduates and postgraduates, is becoming a point of concern for all.

We as members of Chemical Engineers' fraternity, and as teachers and researchers, have to keep abreast with the changes that are taking place in the area of Chemical Engineering and their impact on our livelihood, in particular, and on the society, in general. We are at the cusp of the rapidly changing technological landscape, mostly in electronics, telecommunications, big data analytics, and artificial intelligence. The advances in biology and bioengineering too are breathtaking. This expanding knowledge base not only keeps all of us on our toes but also makes it exciting for newer possibilities and potential opportunities across all the fields.

Let us rewind a bit and review the major technological breakthroughs that happened in the past that had led us where we are. Chemical Engineering literally fuels the world and it's $80 trillion economy. Without efficient fuel generated from cracking crude oil, the machinery of the modern industries and vehicles won't run. Right from the days of first thermal cracking experiments under pressure at Standard Oil company and later catalytic cracking to recent hydraulic fracking with horizontal drilling, chemical engineering and allied fields have travelled a century of petroleum exploration and refining to provide increasingly higher quality motor vehicle fuels and jet fuels Unleaded gasoline, chemical treatment to ensure removal of sulfur from fuels and catalytic convertors to clean up automative exhaust; all have been possible because of developments from chemistry which are brought to practice by Chemical engineers. We need to appreciate that crude oil which had been the main stay of all activities, is handled almost to level of 1000 barrels per second, i.e. close to 95 million tonnes per day globally, and goes through a myriad of processing operations, transported across length and breadth of continents, even to other side of the world and yet is available at very affordable cost, with probably the best safety record amongst all heavy industries. Chemical Engineering developments have helped us in broadening our energy options from coal to natural gas, nuclear, solar photovoltaics and high energy density nickel metal batteries.

The lifestyles in increasingly populated urban/rural areas have given rise to associated problems. Chemical engineering has helped us in finding newer and better ways of solving these problems by raising production of food grains, developing safer fertilizers, purifying water, mitigating industrial and municipal waste, bioremediation of large scale leakages, and easing life in general in the fast-paced lifestyles.

Polymers rule our world, in all kinds of form. Nylon changed the way we prepare our fabrics and PET, bakelite, polymethyl methacrylates, polyethylene, polypropylene, Teflon and PVC, made . plastics popular in daily use items, all because of a series of inventions in multifunctional and efficient catalysts and their large scale manufactuing. From synthetic rubber to KEVLAR vests, a whole new set of materials, with diversity and distinctive properties, have been brought by Chemical engineers in the market; in many cases, by bringing new raw materials and replacing scarce ones, at affordable cost. You might have heard of 'Bhabha Cavach, a product based on carbon nanotubes having light weight but strength of steel, all because of chemical engineering that went into making the materials in tonnes, and bringing down the cost of CNTs to as low as 15 Rs./kg. At one time, CNTs were worth gold on weight parity.

Continuous and mass production have become hall marks of Chemical Engineering. From high pressure and high temperature Haber Bosch process for ammonia, to spun soyabean fibers to packaged food, chemical engineering has been responsible for food security and food choice in convenient forms. Chemical engineering innovations in medical field run the gamut of antibiotics to drug delivery to bioengineered tissue implants to transdermal patches for insulin dosages and sunscreen lotions that help in saving millions of lives, where the engineering blends seamlessly with basic sciences and biological systems.

Solar photoresists, dry polymeric light-resistant films, robust glass optical fibres, thin liquid crystal displays, integrated chips with as much as 20 layers of semiconducting materials, and increased storage in solid state devices have all been possible because of engineering manufacturing principles, which is driving the current digital revolution.

Just a decade ago, CRISPR, cyber threat analysis, data analytics, exascale computing, drones and fracking, were obscure or even nonexistent terms. Today, face-to-face video chat is possible because of ubiquitous and extraordinarily powerful smartphones. When we are in awe of these technological marvels, let us not forget that chemical engineering and material processing goes into the production of every component of i-phones and electronics that now boast processors with 7nm gap in transistors, responsible for high speed computations and mobile computing. Today, not just delivery of consumer items but inspection of tall flare chimneys in refineries and underwater pipe-lines or cleaning of clogged pipelines is possible by remotely operated inexpensive drones with light weight parts and high capacity batteries. Who had ever dreamt of these products at the turn of this millennium? loT, looming large over horizon, and business disruptions like JioFibre coming soon in the market, will probably change the way we analyze our data from chemical plants and operate them.

It is very important for chemical engineers to realize the major changes that chemical engineering is going through:

(1) Traditional core areas of ChE expertise – such as process synthesis, transport processes, process analysis and design,- are being augmented by new expertise in science and engineering at molecular and nanometer scales, biosystems, sustainability, and cyber tools;

(2) Faster and cheaper computational power is driving extensive use of mathematical modelling and numerical techniques in education, design, projects and operation of chemical plants;

(3) Standardization of routine operations through extensive use of softwares (e.g., ASPEN FLUENT, HYSIS, PR02, COMSOL-Multi Physics, etc.), but without necessarily knowing the internals of the software;

(4) Multidisciplinary and multiscale nature of operations that demands increasing collaboration with other engineering disciplines and with programmers to build and develop such softwares and systems for operations;

(5) Robust and secure instrumentation, online optimization and digital control for safe operations;

(6) Advanced material and manipulation at nano- scale, i.e., nano-engineering and material design becoming an integral part of chemical engineering;

(7) Process intensification and desire for Sustainable Development in all aspects;

(8) Ongoing evolution of the education and profession - including the need for new modes of education; high standards of performance and conduct;

(9) Effective technical, business, and public communication;

Our world is a complex and evolving place. With global population expected to reach 8.5bn in another 10 years from current 7 billion, demands on resources such as water, energy, food and raw materials shall be far greater than anything we have experienced in the history. How do we meet the expectations of a modernised, global society whilst minimising the impact that we have on our environment? The Institution of Engineers, UK, had raised a question, a couple of years ago, that aptly covers the major concerns of engineering professions.

"What does the society need, what are the desirable outcomes and how can chemical engineers work in partnership with others to make it happen?"

Chemical engineering remains central to the delivery of sustainable water, energy, food and healthcare. Chemical engineers can and will play an important role in the design and realisation of solutions for the grand challenges we face today. We have to provide technical skills and knowledge, and contribute to the complex technical, and in some cases, ethical debates about the issues. The grand challenges for the engineering fraternity shall remain in four areas: water, energy and environment, food and healthcare. Each is these areas are affected by cross-cutting issues such as education, safety, and advances in technology, sustainability and product and process lifecycle.

Water

Chief among concerns is the quality and quantity of water, which is in seriously short supply in many regions of the world. Both for personal use - drinking, cleaning, cooking, and removal of waste - and large-scale use such as irrigation for agriculture. Water must be available and sustainably provided to maintain quality of life. New technologies for desalinating sea water may be helpful, but small-scale technologies for local water purification may be even more effective for personal needs.

Availability of clean water for drinking and domestic cooking is coming under increasing pressure because population growth, rapid industrialisation, and agricultural demand. Water scarcity is being aggravated by inter related environmental problems - e.g. desertification, salination and pollution and climate change. Limited access to water will continue to drive technology advancements for purification desalination, and recycle capabilities. Environmental factors, such as desertification, deforestation, uneven precipitation, and reducing water levels in underground aquifers add further pressure.

The climate change is being discussed in light of recent deluge all over the country, when entire month's rain precipitated over just eight days. The flood gives rise to new problems. Water purification has to be done at affordable cost and at local levels. Do we have sustainable solutions, other than chlorine tablets, that offer quick local solutions rather than transport of large volume of clean water from distance to the affected areas? The sludge left behind in cities and villages by the floods, has to be disposed of or treated as quickly as possible to avoid outbreak of diseases. Do we have quick flexible and transportable solutions for them?

Water scarcity restricts development and expansion of agriculture and Process Industries, along with now mandatory zero discharge of polluted water. Chemical engineers have an important role to play in resolving the challenges associated with treating and recycling wastewater and reusing 'grey water' making industrial and community water reuse economical. Cost-effective and robust technologies are needed that treatwaste water, remove contaminants (at macro and micro levels) and recycle water and dispose associated byproducts, such as concentrated saline water. Advanced treatment technologies can recover valuable materials from wastewater, including metals, nitrates, phosphates and biogas. A low cost treatment process to remove contaminants and to reduce pressure differential with improved hydraulics, can be game changer. ZnO nanoparticles, instead of Ag, can bring down cost of decontamination in water purifiers.

Development of technologies to recycle process water in industrial plants using advanced digestion granular treatment processes, fixed film biomass reactors, anaerobic ammonium oxidation processes and membrane separators, will have important role to play. In particular, membranes have already proved their worth and their use is likely to grow in water recycle. We still need reliable manufactures of membranes in India itself.

Energy

The demand for energy is increasing rapidly in the country with increasing population and their aspirations for better quality of life. Personal mobility and the movement of goods remain an economic necessity. Meeting this demand is a crucial challenge for the decades a head in view of finite and non-renewable resources such as crude oil and coal.

It is time for the auto industry, researchers and everybody working towards the development of next generation products and to make up their mind that it is going to be electric vehicles. On one hand, the dependence on import has to be brought down on the other, we have to provide better and flexible mobility to society. Although the time-lines are getting relaxed for political reasons because the policy of EVs has already started affecting employment in the auto industry and ancillary units. Electric, electronic and hybrid cars, are deemed more efficient, safe and reliable modes of transportation. Over the next decade, this will lead to newer verticals and opportunities for auto component manufacturers, who would need to adapt the change via systematic research and development. We have a long way to go on this front. Battery technology has to and will evolve. We have started making batteries and motor controllers are in the final stages of design and development, as shown by IIT-Madras. We need to recycle old batteries, even cell phone batteries, for lithium cobalt, manganese, and nickel. We throw away 300 million cell phone batteries every year. If we recycle and extract, we can recover almost 90% of these strategic metals. The recycle industry will be entirely chemical engineering efforts.

We cannot do away with the fossil fuels completely. From 44% in 2013 to 56% in 2018, our dependence on coal has increased for energy, so also it on the crude oil, which increased from 23% 30%. Natural gas contribution has increased only marginally from 6% to 6.17% in the same period. Coal-fired power plants account for 59% of India's installed electricity capacity today. Thus, fossil fuels shall remain the major energy source in the short- to medium-term and their climate impact must be mitigated via carbon capture. Considering that our energy consumption is likely to increase to contribute 18% of global consumption in 2035, it is the biggest challenge for chemical engineers in all respects.

The Impact of unconventional fossil fuels, particularly the rise of shale gas, has taken energy markets by surprise since beginning of this decade. The oil prices went through ups and downs over the last five years. The exploitation of shale gas and coal bed methane continues to be a debatable issue. The main energy sources are susceptible to geopolitical flux as seen in the current situation in Gulf straits. Our dependence on external resources will have to be brought down from current 85%. The target is to reduce it at least by 10% in the next five years.

India can never become self sufficient in crude oil, unless we find significant oil reserves off-shore or explore elsewhere on the globe in partnership. Energy strategies require vision and long-term thinking supported by a vibrant research base. GoI has taken steps to reduce the import by 10% in the next five years, by using agriculture waste to generate alcohol for blending with gasoline and biodiesel from used cooking oil for blending with diesel. Agriculture waste from rice paddies and wheat or soybean stalks are available plenty but lot of engineering developments and Life cycle analysis (LCA) are required for an integrated biorefinery approach to cut down the cost of 2G alcohol to gasoline level to justify its use in fuel. Alcohol based industries were once common in India. Using alcohol as feedstock may again become popular in view of import cost of petroleum oils. Generating alcohol for blending directly from sugar cane juice may be adopted by sugar industry in view of controlled price of sugar, provided remunerative price is offered by the fuel industry.

Biodiesel from neat vegetable oils is not commercially possible, because of import of edible oil is significant in India even if not at the same scale as petroleum crude oil. Oil seed crops are the second most determinant category of crops for our agricultural economy, post cereals. The self sufficiency in oilseeds attained in early 1990's could not be sustained. Total vegetable/edible oil import was around 11.7 million tonnes a year ago, worth Rs 730 billion, or US $ 10.2 billion, at today's exchange rate. If our yield improves from existing case to even global average yields, Indian edible oil production would grow by 67% to ~13.5 million tons on the same area of cultivation. And if our yields improve to global best rates, Indian edible oil production would become three times the existing 8-9 mn tons production and India will be self-sufficient on existing cultivated land. Using more scientific approach to increase productivity of our land, we may generate surplus of edible oil for converting into biodiesel, enough for 5-10 blending in diesel, saving sufficient foreign exchange. It will require concerted efforts, water management, controlled irrigation instead of flooding approach, increased density of seeding and seed culture development. The central government has prepared a five-year schedule to double India's edible oil production and reduce import dependence, through expansion in sowing area and yield.

Using waste cooking oil to generate biodiesel is perfectly feasible option but logistics of collecting the used oil alone might be a major deterrent for building large scale SO plants. It is estimated by an LCA, that there is a critical radius of collection zone, beyond which more diesel will be spent in collecting waste cooking oil than the SO generated using it. The sources for such used cooking oils will be major food processing industries and hotel chains, which will put constraint on locations where such plants will be situated. The SO technology is mature and it can be scaled up easily, but for the want of easily accessible and affordable feedstock.

The technology of 2G ethanol, on the other hand, is not yet mature but feed stock material is available across the country. Although lignocelluloses is the most abundant plant material resource, it usability is curtailed by its rigid structure. As a result, an effective pretreatment is needed to liberate the cellulose from the lignin seal and its crystalline structure so as to render it accessible for a subsequent hydrolysis step. Acid hydrolysis, steam explosion, ammonia fibre expansion, organosolv, sulfitepretreatment, AVAP (SO_2- ethanol-water) fractionation, alkaline wet oxidation and ozone pretreatments have been extensively studied. The major catch is to minimize the formation of degradation products because of their inhibitory effects on subsequent hydrolysis and fermentation processes. Most pretreatment processes are not effective when applied to feedstocks with high lignin content. One can consider chemical engineering principles, that are required for efficient and cost effective operation at each stage of production: pre-treatment of biomass, reduction of size for reducing time for pretreatment, acid hydrolysis of solid without generating furfural and/or hydroxymethyl furfural which are inhibitors in biological process later, delignification, enzymatic or acid hydrolysis of cellulose fibres, fermentation and finally recovery of alcohol. Each stage is unique and requires modifications for different sets of raw material. The current technology is not economical and demands several technological innovations to overcome financial constraints in commercialization. Each energy input point and cost factor will have to be looked into. The ability of the fermenting microorganisms to use the whole range of sugars available from the hydrolysate is vital to increase the economic competitiveness of cellulosic ethanol.

Cellulases and hemicellulases used in the production of cellulosic ethanol are more expensive compared to their first generation counterparts. Enzymes for cellulosic ethanol production are projected to cost 20-40 times more. The cost differences are also attributed to quantity required. The cellulase family of enzymes have a one to two order smaller magnitude of efficiency. Therefore, it requires 40 to 100 times more of the enzyme. For each ton of biomass, it requires 15-25 kilograms of enzyme. More recent estimates are lower, suggesting potential to reduce to 1 kg of enzyme per dry tonne of biomass feedstock. There is also relatively high capital costs associated with the long incubation times for the vessels that performs enzymatic hydrolysis.

Compared to the biological route that uses large volumes of water, fast pyrolysis remains yet the least-appreciated and underestimated route to produce hydrocarbons, either as fuel or feedstock, from agricultural waste. Imagine a biorefinery starting with a variety of agricultural waste as biomass, corresponding thermal processes and trains of catalytic and non-catalytic reactions and separation techniques to obtain desired products. This will be a major challenge as we have to scout for robust technologies to get sustainable operations over long run, competing with current crude feedstock.

Nuclear industry can decorbonize the global energy, with no CO_2 emissions, but as on today, the contribution of nuclear energy to the energy basket is very small. Chemical Engineers with their knowledge of chemical reactors and nuclear fuel reprocessing are of big help in this sector. ICT, Mumbai, has been involved in this program very actively. India's fast breeder reactor technology that can use abundant source of Thorium, has potential of unlimited energy supply in not too distant future. According to plan, 30% of the Indian electricity in 2050 will be generated from thorium based reactors. Indian nuclear scientists estimate that the country could produce 500 GWe for at least four centuries using just the country's economically extractable thorium reserves. India has only around 1-2% of the global uranium reserves, but one of the largest shares of global thorium reserves at about 25% of the world's known thorium reserves. Thorium itself is not a fissile material, and thus cannot undergo fission to produce energy. Instead, it must be transmuted to Uranium-233 in a reactor fuelled by other fissile materials.

Energy Efficiency

Chemical engineers should take note of a 2012 Global Energy Assessment Statement that 66% of the energy produced is wasted. The chemical industry is among the most energy intensive and industry should find ways and develop systems to be more energy efficient. The need to promote greater energy efficiency with dramatic improvements in existing processes of industry has been recognized. This also means developing advanced manufacturing processes that use resources efficiently while minimising energy consumption. There is dearth of professional who can conduct energy audit of the chemical plants. Expertise is required to analyze complex and/or mega scale chemical plants to identify the pain points for improvements. Heat exchange networks and pinch technology have become common but process changes are also required for maximizing the energy usage.

Future energy solutions must be sustainable as well as affordable. Linked to this is the need for smarter energy management, with a flexible grid that delivers energy to where and when it's needed, and new and effective ways to store energy when we have a surplus. This is particularly important given the growth in intermittent renewable energy sources such as wind and solar. Cost-effective storage of solar energy to enable distribution at times of peak human demand remains a critical issue. Development of reversible processes for energy storage and utilization that have rapid start up and shut-down characteristics is, therefore, of prime importance.

Ultimately, to maintain and improve quality of life sustainably, we need widely available carbon-free or ultralow carbon energy. Over the years, the H/C ratio of fuel has already increased. The use of coal for fuel will likely decrease further elsewhere but India may continue to rely-on it at least in medium term, and natural gas may become the dominant source of transportation and power-generation fuels. Biogas or natural gas or methane produced from farm/agro/crop/domestic waste can also be used in a decentralised manner near to the rural / consumption areas with lower land and water foot prints. India has set the target, in 2019, to produce 15 million tons of biogas/bio-CNG by installing 5,000 large scale commercial type biogas plants which can produce daily 12.5 tons of bio-CNG by each plant.lt would be interesting to see the progress in remaining four months of the year. The role of energy storage at scale, alongside managing electricity supply and demand, will be central in allowing renewables to reach their full potential.

Climate change adds a challenge to drastically reduce emissions of greenhouse gases. Carbon capture and utilisation may play a role, using CO_2 as a feedstock for chemical processes, microalgae or plant growth and mineral carbonation. As on today the major outlets of the captured CO_2 are in beverages and a few chemicals but these can recycle only a small fraction of CO_2 generated in thermal power plants. It has been suggested that CO_2 collected from emission sources may be stored in geological formations. But each of the steps of separation of CO_2 at source, compression, transportation, and storage requires additional energy. The studies have estimated that CCS equipped power plants would require an additional fuel input of minimum 25%. Careful attention must be directed towards energy balances and rigorous life cycle analysis for new processes for CO_2 reduction. Our interest is in the efficient recycling of CO_2 from a combustion point into a hydrocarbon as fuel that can be used within the current energy infrastructure, by use of sunlight. CO_2 is a stable molecule and CO_2 conversion makes sense only if the input energy is from a renewable source. Such solar fuels offer a ready means of readily transporting solar energy. We have been able to reduce CO_2 to methanol, ethanol and formic acid, using CdS photocatalyst, in nanoform under solar radiation with rates varying from 57 to 1200 mol/g/ h. If we can take these numbers to 100's millimoles of product per gm per hour of catalyst, we will have sustainable solar fuel production. The major problem still remains with intermittent availability of sunlight and storage of sun light becomes critical for continuous operation.

Food

The Indian food industry is poised for huge growth, increasing its contribution to world food trade every year due to its immense potential for value addition, particularly within the food processing industry. Agrifood start-ups in India received funding of US$ 1.66 billion between 2013-17 in 558 deals. The Indian food and grocery market is the world's sixth largest, with retail contributing 70 per cent of the sales. The Indian food processing industry accounts for 32 per cent of the country's total food market, one of the largest industries in India and is ranked fifth in terms of production, consumption, export and expected growth. Global food production has broadly kept up with population growth. In India too, the cereal productivity has increased by a factor of three in the last fifty years. But limited availability of land and water, and the impact of climate change, can disrupt this equilibrium. It is still possible to meet demand without increasing energy, water or land use and minimising waste production by adopting appropriate processes. The ever-increasing demand for food will be satisfied by the application of enhanced farming and food-generation methods using non-traditional farming techniques, new bio- based active agents, and data sciences. There are opportunities for chemical engineers and other disciplines to work with the agricultural industry to solve problems with water management, crop rotations, controlled release of nutrients, weed and pest management and harvesting technologies.

Agriculture practices account for 30% of greenhouse gas emissions, and new farming methods are needed to reduce it. It will be necessary to ensure that the land and water from which food is obtained maintains the right qualities to produce food sustainably. Chemical engineers are working on processes to improve the overall efficiency and sustainability of producing food, including developing low-impact solutions such as CO_2-enriched hydroponics.

With as much as 30% to 50% of the food produced being wasted, we need to minimise this waste. Energy recovery from food waste through incineration, anaerobic digestion, pyrolysis, gasification or production of fuels and chemicals through fermentation is preferable and required necessary system developments. Urbanisation impacts the population centres in many ways which must adapt to accommodate expanding population in a sustainable way. Chemical engineers support the quest for sustainability by creating new products and alternative materials with greater atom efficiency, reduced ecological footprints, and renewable feedstocks.

Global inequalities in food availability mean that there are regions of significant population density that cannot be supported by the land around them. More effective transportation and storage of food and drink are a partial solution, but more should be done to enhance local production. Crops taken on floating hydroponies, a local example in North East itself, is another way of having agriculture without soil. Vertical farming is another possibility with periodic restoration of fertility of soil.

Health Care

India is the largest provider of generic drugs globally. Medicine spending in India is projected to grow 9-12 per cent over the next five years. Better growth in domestic sales would depend on aligning product portfolio towards chronic therapies for diseases such as such as cardiovascular, antidiabetes, anti-depressants and anti-cancers that are on the rise. Ageing populations and faster detection is shifting the focus in healthcare from curing disease to treating the effects of advancing age. Preventative medicines will continue to gain ground, as will biological and biochemical engineering. Transplant organs manufactured from biological materials and safer, more sustainable biochemical production methods will become commonplace. There is a shift from small molecule drugs to biopharma products. In the future, there will be greater use of biosensors. Chemical Engineering will play an important role in translating scientific discovery and innovation into high quality processes and products such as new medicines and medical devices, in the growth of biological materials for transplant organs, tissues and bone.

In India, managing infectious diseases still remains a challenge. Outbreaks of dengue and malaria are prevalent. Antimicrobial resistance is on the rise. While the health of people in general is improving, many are still unable to access basic sanitation and clean water, particularly in rural areas. There are significant cost pressures associated with new product development, and responding to changing legislation is a constant challenge for the pharmaceutical industry. Chemical engineering expertise will help reduce the complexity of API manufacturing and make processes easier to scale up and control. Chemical engineers can also improve cost effectiveness in a whole range of areas from vaccine manufacturing and formulations to overall equipment effectiveness. There is considerable potential for application' of Chemical Engineering principles in manufacturing processes that will use more sustainable feedstocks and generate novel products.

Manufacturing

The increasing economic power and the rise of the middle class drive demand for more materials, energy, products, and access to technology. The manufacturing therefore needs new, more efficient methods of materials production. Process intensification, energy intensity improvements, and zero emissions technologies are buzz words. Consequences of previous and current waste generation will require new industries built around the reuse and recycle of existing landfill materials. Demand for lighter-weight, more-durable materials that are fully and easily recyclable will increase. Manufacturing is responsible for 16% of global GDP and 70% of total global trade. There is increasing pressure on all chemistry-using industries to improve material and energy efficiency. Demand for new products and enhanced properties will require us to identify alternative materials and develop new manufacturing processes. This requires greater atom efficiency, reduced ecological footprints, or the use of novel feedstocks, including biomass.

Chemical engineering plays a vital role right across the manufacturing industries - from primary resource extraction to the production of finished goods. There is also significant scope to identify and exploit new renewable resources, design more flexible manufacturing plants, and reduce raw material consumption. Chemical engineers play a role in embedding proactive process safety at all process industries; from design and development to operation and decommissioning. Developing a common understanding of risk and sharing best practice is of paramount importance. There are many so called training programs offering a variety of certificates and diplomas. However, there should be a mechanism to validate and accredit such certificates. Institutes like "Institution of Engineers' can play very important role here.

We have merely scratched the surface of the challenges that chemical engineers will face in the next decade. The problems described here merely illustrate the complexity of the tasks that must be mastered. Through the engineering accomplishments of the past, the world has become more connected. The challenges facing engineering today are of the planet as a whole. Meeting all those challenges must make the world more sustainable. Professional organizations such as Institution of Engineers can play a major role in collaborating and exchanging ideas with industry, government, regulators and other stakeholders, such as operators, service providers, regulators and academics, to meet the challenges ahead of us. Chemical engineers shall play a vital role in longterm planning, risk assessments, informing and adopting proper regulation and responsible practices.

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About Chemical Engineering Division Board

The Institution of Engineers (India) has established Chemical Engineering Division in the year 1961. This Division consists of quite a large number of corporate members from Government, Public, Private sectors, Academia and R&D Organizations. Various types of technical activities organized by the Chemical Engineering Division include All India Seminars, All India Workshops, Lectures, Panel Discussions etc., which are held at various State/Local Centres of the Institution. Apart from these, National Convention of Chemical Engineers, an Apex activity of this Division is also organized each year on a particular theme approved by the Council of the Institution. In the National Convention, several technical sessions are arranged on the basis of different sub-themes along with a Memorial Lecture in the memory of '**Acharya Prafulla Chandra Ray**', the renowned Professor of Chemistry, which is delivered by the experts in this field.

In order to promote the research and developmental work taking place in the field of chemical engineering, the Institution also publishes Chemical Engineering Division Journal twice in a year, where mainly the researches and its findings are focused.

Due to multi-level activities related to this engineering discipline, this division encompasses the following emerging and thrust areas:-

- Advances in Fuel Cell Technology
- Advances in Material Sciences: Bio-materials
- Automated Rigorous Monitoring of Process Plants
- Bio-degradable Material and Bio-technology for Environmental Protection for Chemical Industry
- Bio-fuels like Ethanol and Bio-diesel towards Energy Security and Environmental Protection
- Bioinformatics
- Biomass Gasification
- Biosynthesis of Chemicals
- Biotechnology applied to Chemical Processes
- Chemical and Bio-sensors, Food Safety and Bio-security
- Chemical Warfare and Preparedness to Face it
- Clean Coal Technology
- Digitization in Chemical Engineering Industries
- Environmental Degradation Arising out of Mineral Fertilizer Usage
- Food Processing Industry
- IoT for Chemical Engineering
- IT in Process Industry
- Safety Culture in Chemical Industry
- Security and Safety of Process Plant Installations and Facilities
- Security of Chemical Insulations
- Use of Nanotechnology in Chemical Engineering Applications
- Zero Discharge Manufacturing

In order to promote the research and developmental work in the field of Textile Engineering, the Institution also publishes '**Journal of The Institution of Engineers (India): Series E**' in collaboration with Springer, which is an internationally peer reviewed and Scopus Indexed journal & UGC-CARE listed. The journal is published twice in a year and serves the national and international engineering community through dissemination of scientific knowledge on practical engineering and design methodologies pertaining to chemical and textile engineering.

The Institution of Engineers (India)
8 Gokhale Road, Kolkata 700020
Phone : +91 (033) 2223-8311/14/15/16, 2223-8333/34
Fax : +91 (033) 2223-8345
e-mail : technical@ieindia.org; iei.technical@gmail.com
Website : http://www.ieindia.org