TECHNOLOGY MANAGEMENT IN INDUSTRIES: A STUDY OF MAJOR CRITICAL FACTORS INFLUENCING SUCCESS OR FAILURE- ILLUSTRATED WITH CASE STUDIES

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CERTIFICATE

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It is with humility and reverence, I dedicate this work to:

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* **HIS HOLINESS SHRI BANGARU ADIGALAR** - Springboard of energy - **SHAKTHI THE AMMA**

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1.1 TECHNOLOGICAL CHANGE IN HISTORICAL BACKGROUND

Technological change and its impact on society has been perplexing human mind since ancient times. In ancient Greece Socrates is said to have criticized the art of writing which was being introduced during his time as he feared that the art of memorising would wither away. In medieval India, Emperor Akbar did not take serious note of a printed bible presented to him by an European traveller. A possible reason for this could be that there were thousands of caligraphers available around his capital who made more beautiful copies of Quran and the Emperor perceived a threat to their profession. In modern time also some apprehensions are being expressed against semiconductor technology which is diffusing rapidly in a range of industries involving computers, electronics and automation. Thus, it is not that only in the twentieth century that technological change has generated mixed reaction of hope and suspicion. However, with the onset of Science and Technology (S & T) revolution, not only that production system has been revolutionized but this phenomenon has led to environmental stress of various types and every sphere of human life is getting to be affected by it.

Science and Technology and society hold a dynamic inter-relationship. Technological change is observed to be spurred or inhibited by a complex set of intertwined factors such as socio-economic structure, resource endowment, innovative capacities, market conditions, ideologies and policies. However, the nature and magnitude of the impact may not be uniform and may vary in different organisational environments even for the same technology. It is also increasingly appreciated that technological change is not random but a systematic process which could be understood and hence *managed* in the socio-economically desirable direction. The significance of this development is demonstrated by the fact that technology management is emerging as a professional specialisation world over.

The technological change in the field of electronics illustrates many aspects of science, technology and society inter-relationship. In the late nineteenth century, this branch of industry, known for manufacturing valves were used for amplifications, rectification, inspired many academic scientists including Herty who set up the first practical laboratory demonstration of wireless waves in 1880's. Another characteristic feature of this period was that innovations were being made by the inventor-entrepreneurs. Marconi is an example who established a wireless telegraph company in 1897. This was one of the first systematic attempts in the area of applied R & D. Marconi also drew many scientists from university and this resulted in innumerable improvements in components, circuits and techniques. However, as the consistent government support continued of the well organised R&D, the Marconi Company not only managed to remain in forefront but also acquired major market share in other countries including the USA (1). So far the communication technology was valve based. However, the problem with the valves were that there was high consumption, there was limited frequency and the size was larger, the average life was also limited. To overcome these problems the Bell laboratory in the USA manufactured their first point contact transistor. Later in 1961, the integrated circuits were developed and by solving the problems of increasing density bigger integrated circuits or microprocessors were available by 1971. The semiconductor properties were known in the nineteenth century. The theoretical principles of physical behaviour were unknown until the emergence of quantum physics providing workable theoretical framework to explain all properties of semicondutor. However, not until the post war economy military and space demand rose that the Bell laboratory came out with semiconductors and computers. Radar was also patented before 1914 but could not be productionized before the II World War (2). In USA some companies like General Electric, and Radio Corporation of America (RCA) were technically sound and had professional R & D but could not survive in the race of computer market, whereas International Business Machines (IBM) which faltered initially caught up and assumed leadership with market knowledge.

Similarly, the RCA spent $ 130 million on the colour television project but could not survive. Thus professional R&D represents institutional response to the complex problem of organising the matching between technology and market demands.

In addition to market knowledge, the Bell Laboratory survived the technological race as its laboratory had capacity to bridge institutional gap between pure and applied science. The rest of the companies like General Electric, RCA, Philco, Sylvania had with to withdraw (3). After this technological change it was seldom possible to talk about inventor of any electronic product. As the electronic system grew more and more complex, the system required a larger number of components which was difficult for one person to invent. In addition the R & D process was also getting institutionalised.

In the chemical industry a major process innovation or technological change was a transition from batch process to continuous process of production. This allowed economics of scale from commercial point of view. Another important innovation influenced by commercial demand for innovations outside this industry is petrochemicals. In 1855, a chemistry professor at Yale University had already demonstrated the phenomenon of gas cracking. However,this did not find any commercial application until twentieth century when demand for petrol went up with the discovery of automobile and replacement of paraffin by electric lamp.

The interrelationship of R&D, innovations and technical change received attention on a wider and systematic basis only recently. In the classical economy, capital and labour were treated as the major factors for economic progress and technical change was treated as residual factor. With the institutionalisation of R&D, the organisational aspects such as leadership, communication, morale, size of the enterprise also came to be recognised as significant for increasing scientific productivity.

It is also important to note the changing perception of the nature of technology. There are some scholars who treat technology as latent public good implying thereby that technologies are widely applicable and inexpensive compared to the cost of inventions or discovery. However, the preceding view fails to take into account the difference in the socio-economic and resource situation under which technology is transferred or operated. Moreover, there is also an implicit assumption that there is free flow of technology transfer between firms, sectors and nations. It is also argued that "industrial technology is firm specific and costly if not possible to use elsewhere"(4). There are many other pathways or mechanism through which technological change acquires shape. Some of these could be categorised as reverse engineering, active monitoring of upstream or downstream technologies, publications, open meetings and scrutinising patents. In addition, there are several industries where regular "technology swapping" is widely prevalent. The industries which are strong in certain areas generate bargaining power to supplement their weakness by cooperating with other industries eager to take the advantage, as illustrated by the Airframes industries which co-operate with electronics and engine manufacturers, computer and semiconductor industry or the new biotech firms which establish strong working linkages with University research groups and marketing firms. Management of technological change becomes essential in the resource based industries such as leather and textiles. These industries have very little R&D activity world over and they mostly depend on innovations from outside their own group. Some of the problems also stem from the very structure of industry - small, medium, large, public or private ownership etc. These industries have significant role to play in the economy of a developing country like India. India also provides an interesting example to study technological change as she possesses a complex industrial structure aiming at a rapid economic growth, attracting investments with innovative incentives in the backdrop of a vast pool of technical manpower.

1.2 THE NEW TECHNOLOGIES AND THEIR SPECIAL FEATURES

It is now widely recognised that technology has had a substantial role in creating the prosperity that the industrialised nations enjoy. The willingness of industrial sectors to accept and utilise technological innovations has been one of the key factors. Results are easily perceptible in terms of enhancement of productivity, resulting from changes in production methods and quality improvement as well as good manufacturing practice. The number of personnel engaged in industrial R & D has nearly tripled in the last 25 years generating a steady flow of technologies for commercial applications. Among these, four sets of technologies are clearly distinguishable from others because of their power, speed and impact potential. These are:

Microelectronics and automation technologies
Biotechnology
New materials technologies, and
Information technology

These four are variously referred to as "emerging technologies", "new technologies", or "critically important technologies".

The most extensively analysed and discussed of these new technologies is microelectronics, because of the pervasive nature of this technology in terms of impact on other subjects and disciplines. Its influence has extended beyond the electronics industry and, together with computer aided design (CAD), computer aided manufacturing (CAM) and numerical process control, they form a set of automation technologies. The next important one is biotechnology, which has profound implications to agriculture and rural development in developing nations and therefore, offers tremendous potential for economic growth. Biotechnology encompasses human, animal and plant needs. New material technologies are making rapid forays into areas of traditional preserves, replacing the conventional materials. New materials are characterised by superior properties, lighter weight and cost advantage. To give one example, approximately 40 Kgs. of optic fibres now replaces a tonne of copper in the communication sector. Many new construction materials have been made available by the new materials technologies. Information technology has already emerged as an industry backed by advances in computers, tele-communications and materials. Its reach is as wide as its spread. The future of companies, nations and even individuals is going to depend on intellectual investments and managing of information.

Although it is realised that the new technologies can help economic growth of developing countries and raise the living standards of people, there is an apprehension that these technologies may be economically and socially disruptive. There is an apprehension that the poor among the developing countries, especially those who do not have the indigenous capacity to make informed technological choice, would become increasingly vulnerable to pressures from the economically stronger nations and thereby suffer in terms of national sovereignty. But, experience tells us that where technology is properly directed and adopted, the rewards are abundant.

The new technologies influence technological change rapidly, abundantly and extensively. It is therefore important that careful vigil is exercised especially during the critical periods of technological change. Transition can be brutal in which the rank of competing products and companies may be completely reversed, letting established markets disappear. For example, it took less than 5 years for the electronic calculator to wipe out the slide rule market. In 1950, 80% of American electronics industry used vacuum tubes. In 60's, the semiconductors relegated the tubes to the museum. In this kind of race, small and medium businesses some times, but not always, do better than the large companies because large companies in general have inertia and do not recognise the opportunities in time.

The Gulf war in 1990 saw the American troops heavily and successfully using strategic defence systems. Visible from the ground, conflicts were handled by the robots and missiles were delivered by electronic commands. Advances in automation technologies, communication technologies and information technologies together made these possible. Stretching this further, future wars would probably need less and less armed forces or land warfare.

Artificial vision, hearing, speech and form recognition are now on the market, thanks to advances in artificial intelligence (AI). With the advent of 5th generation computers in this decade, AI is poised to go further throwing up fascinating and mind boggling opportunities. Fibre optics can help transmission of animated image. Just as voice, sound or text were sent in the past, image processing is now established.

In sum the world is now in an era of intelligence revolution aided by advances in these new technologies (5).

Impact of microelectronics

This is a sector of industry which has been most extensively analysed, discussed and debated, of the four emerging technologies. The sector can be divided into four groups: (i) the components industry which includes semiconductors and integrated circuits as well as a wide range of passive components, (ii) the information processing industry covering computer hardware and software, (iii) the information transferring industries notably the telecommunications and (iv) other electronic applications such as office/factory automation, instrumentation, business management and health care.

Starting with the radios in the 1890, the electronic industry has been impacted by a series of seminal events - the television in the 1930s, the electronic computers in the 1940s, the discovery of the germanium point contact in 1947 (which replaced the vacuum tubes), the invention of the integrated circuit in 1961, and the development of microprocessor in 1971. The latter in particular dramatically incorporated all the elements of a computer on a single chip. Ever since this became possible the subsequent inventions have been in the direction of reduction in circuit size and a corresponding increase in chip density. New inventions are unending, increasing the extent and speed of information that can be handled.

Interestingly there has also been a marked reduction (almost 35 percent) in the unit cost of random access memories, stimulating interest, demand and application of microprocessors. Banking, insurance, trade and telecommunications sectors have particularly benefited by these advances enhancing economic benefits as well as the quality of service. Agriculture is another area employing microelectronic devices for crop spraying, sorting, cleaning and packing, controlling animal feed rations, regulation of temperature in glass houses and propulsion tractors and farm equipment. In public utility services, notably electricity, water, road, rail and air transport, many actions such as reservations, accounting, billing, manpower scheduling employ microelectronic devices. Among consumer goods, microprocessor devices are used with ease in domestic appliances such as washing machines, ovens, vacuum cleaners, telephone answering and call analysis, door locks and bells. The entertainment industry is particularly impacted in television sets, hi-fi equipments, video games and public display systems in tournaments and neon-signs. An important aspect of these ramifications is that microprocessors have proved to be user friendly and dependable and cost-wise also widely accessible.

Impact of Biotechnology

The advent of this branch of knowledge and applications is proceeding at a rapid rate, absorbing and integrating advances in microelectronics and materials as well. The modern biotechnology has been shaped by advances in chemistry, cellular and molecular biology and genetics, with ability to deliver processes and products cleaner, faster and unfettered by economies of scale. The production of human growth hormones, insulin, diagnostics and many new vaccines are now biotechnology-based.

It must however be admitted that while traditional biotechnology has been successfully used to usher green revolution involving the farmers directly, modern biotechnology cannot be termed risk-free. It is highly research-intensive and needs large capital investments. However, the ability to direct and harness the applications in fields of direct relevance to plant, animal and human health care is a feasible proposition, with immense potential for the developing countries.

Bioprocessing and energy production is an area of high appeal to energy starved countries. Conversion of plentifully available biomass is an economically attractive proposition. In the longer term environmental pollution control, waste recycling and natural resource conservation will be impacted positively by this new technology.

Impact of New materials

Concern over depletion of non- renewable natural resources, high costs of metallurgical processing and demand for new materials with superior properties have combined to generate what has now come to be known as New Materials Technologies. Backed by high-science in many cases, the new materials are both organic (such as plastics, rubber) and inorganic (ceramics, new cements, metals, alloys) and include a fascinating array of composites (which combine new or traditional fibres with polymers, metals, ceramics and cements). The end products are noted for purity, durability or strength, light weight and performance superiority. Advances in this field are rapid, spurred by demand in the communications, constructions, defence and utilities sectors. New process technologies designed to joining of different materials employ laser welding, diffusion bonding and layer coating.

While the new materials are industrially exciting subjects for venture and profitable business, they have seriously upset the economies of countries which have abundant traditional material resources. It is no longer safe to rely on natural minerals for example. Optic fibres have relegated copper to the background and copper-rich country Zambia has been driven to the wall by lack of any more demand for copper in the communication industry.

So far as developing countries are concerned, the new technologies offer both hope and fear. Since technology transfer occurs as direct foreign investment, import of capital goods, licensing or professional services, there would be pressures on the scarce foreign exchange. Nevertheless, if carefully assessed, accessed and adopted, the new technologies or products thereof can help economic growth and raising of living standards. Korea, Taiwan, Singapore are visible examples of success.

Impact of Information Technology

Information Technology (IT) is a technological revolution whose effects are becoming increasingly visible. IT in essence, is a facile combination of wide range of other technologies by means of which many human activities in the spheres of production, distribution and circulation are being mediated by high tech information machines. Four broad areas of impact have emerged.

1. Industrial computing - the introduction of computing power into work processes across production sectors or stations.
2. Telematics - convergence of telecommunications and computers for message transmission and switching.
3. Office automation - a wide range of digital equipments capable of increasing the volume and efficiency of office operations.

4. Consumer electronics - a microprocessor based consumer products and systems linked to the media entertainment and recreation activities.

IT thus spans all sectors of activity from industrial tasks through structural sector applications to a more general macro perspective. Put in another way, its application encompasses

- Basic needs
- Government needs
- Primary industry - agriculture
- Secondary - manufacture
- Tertiary industry - services

Social Impact

A central concern here is employment. While it may not be possible to estimate the net effect of the new technologies on employment levels in the developed or developing countries, it is certain that the impact can be crucial and politically sensitive. Negative effects are easier to assess because they are generally visible such as lay-off of workers or factory closures and public outcry. Positive impact is very much there but depends on levels of employment and the sector in question. This has been studied in a number of sectors particularly electronics, textiles and clothing, engineering services, agriculture and energy.

Shedding of work force has been pronounced in the automobile industry. The introduction of automated welding at a car plant in Sweden reduced the number of welding jobs from 100 to 20, while it has been calculated that a fully computerised production line would cause a drop in total plant employment from 1030 to 50. In a UK car plant, use of robots caused an average job displacement of 2.6 jobs for each robot employed. It has been estimated that new technologies will reduce the work force in banking and insurance by as much as 30%. In the 1970s Citibank reduced its clerical staff from 10,000 to 6,000, the surplus being absorbed in other work after suitable retraining.

Gains are also there. In the USA electronics sector new technologies would estimatedly increase employment by 25-60,000 jobs during the period 1980-1985. The services sector is registering high employment generation, especially self-employment. In the USA, the highest employment generation is forecast in the information processing and transfer sector. In the developing countries the effects are yet to be quantified, partly due to lack of comparable experience with new technologies.

The overall impact of new technologies on employment would appear to centre less on numbers employed and more on new skills acquired by skills training, retraining, job rotation etc. Given the vast populations especially the young people in many developing countries, skills acquisition offers strong potential for the industrialisation process, and thereby increased employment.

Societies in general are in a constant state of evolution or revolution in response to different stimuli of which technological change is perhaps most important. The effects are felt in social structure, urban-rural divide, interest in leisure and entertainment, better health care, control on quality of consumer products and services and so on. At the same time there could be more threat to ecology and environment due to industrial and human activities expanded by the new technologies. There could be invasion of privacy by the advances in information technology and lack of control over flow and commercialisation of community data even transcending national barriers. There are options. Options in terms of the speed and direction of technological change, formulation of public policies and enunciation of priorities, especially of socially beneficial technologies and discouraging technologies with negative impacts. If so directed, technological change can be a powerful tool for economic and social growth, employment generation and eradication of mass poverty, malnutrition and hunger.

1.4 WHAT IS TECHNOLOGY MANAGEMENT?

It is well known that Technology has always been a key factor in the competition between companies but the fundamental changes in the industrial scenario of the 1990s have added a new dimension to manufacturers' dependence on technology for competitive advantage. Technological changes are rapidly taking place, the new technologies are advancing rapidly, national governments are introducing liberalisation policies to allow and accelerate technology flows, globalisation of economy is now a reality and is poised to stay and grow. International economic issues invariably pinpoint technology as a central or determinant factor. Quality rather than price is emerging as consumer preference. Increasing public concern on ecology and environmental issues and consumer demand for eco-friendly technologies in manufacture, have all joined to emphasise the invariable components of technology rather than technology per se.

Furthermore, technological life cycles are shortening, applying further pressure on competition. Meeting this challenge requires a radically new approach to product innovation with increasing emphasis on parallel rather than sequential development.

Technology is now making it possible to "re-engineer" business, by radically changing the way things are done, both to improve productivity and quality as well as to fight obsolescence.

It is now being increasingly realised that in the new industrial environment the ability to manage technology is much - and in some situations even more - important than the technology itself. Investment in R&D for creation of new knowledge or to maintain the ability to assess the new knowledge even if created elsewhere is extremely important for companies. Even this may only be scratching the surface. Much more important is the ability to manage the acquisitions, adaptation, assimilation and sustaining and updating of existing knowledge by imaginative association of personnel at all levels. From what used to be a simple linear model, industrial innovation is emerging as a complex interactive process influenced by a wide set of variables, places and institutions. Other developments or factors which emphasise the management aspect of technology are:

- R&D is becoming increasingly expensive and difficult for a single organisation to go it alone. Collaborative R&D is therefore important. Contact with relevant institutions is even more important for assistance in adaptation of technology including its blending with new technologies. Managing technology in such situations calls for special skills in inter-personal and inter-organisational relationships.

- Manufacturing is undergoing extensive metamorphosis employing flexible manufacturing, Kanban and other technology for organisation of production, fostering a new kind of interactive relationship between production and customer.

- Successful ability to cope with technological change also depends on having the right organisational structure and culture. People are as much assets of an enterprise as is capital investment. Hierarchical system of running an enterprise is no more relevant. Restructuring of production should go hand in hand with retraining and redeployment of personnel. Therefore, although globalisation of economy and liberalised industrial polices constitute a new dynamic environment for industrial enterprises, the exploitation of the opportunities is not an automatic process.

The key to success (of an industrial enterprise) lies not in the technology itself but in the way it is managed

Technology management would, on the basis of the foregoing analysis, bring into focus four core issues:

1. Managing the development and acquisition of technology (Technology Transfer)
2. Managing the technology assimilation
3. Managing knowledge and skills
4. Ensuring sustainability

CHAPTER 2

TECHNOLOGY MANAGEMENT IN INDUSTRIES

2.1 TRENDS IN INDUSTRIAL INNOVATION

"Researchers have succeeded in growing living fibres into a working semiconductor chip. They can now tap into nerve signals by linking a computer to a microchip implanted in an animal. This could mean a progressive linking of the brain to artificial limbs - no more 'phantom' sensation to amputees; no more dead ends"(6).

"Soviet scientists have become the first in the world to use a high temperature superconductor to measure the tiny magnetic field produced by human heart beat. Boris Vasilev has been vested with the honour of leading the country's research in SQUIDS, by the Soviet Government"(7).

"Functionalised polymeric membranes for energy conversion (EC) systems is a field of industrial research stimulated by two major factors; the visibility of solar-hydrogen as a renewable and clean energy source in the foreseeable future and the energy saving and pollution control demands of the chlor-alkali industry. It is possible to tailor polymeric materials to meet the desirable needs of EC systems"(8).

"The research activities in the field of side chain polymers incorporating non-linear optical moieties of pendant groups have grown steadily in the last few years due to their promise in future communication systems"(9).

"The advent of ever more powerful computers and networks is ushering in a new publishing revolution that would have a major impact on the way scientists obtain and report research information, promising to provide researchers with easy access to limitless information resources"(10).

"Ultrasound, sound pitched above human hearing, has found uses in medicine, in industry and in the home. It is a way of delivering intense bursts of energy to specific sites. The extremely high temperatures and pressures that ultrasound can generate make a 'sono chemistry' a unique way to make energy and matter interact"(11).

"An aspect of industrial endeavour which is growing rapidly is Solid State Gas Sensing. Manufacturing industry is motivated by three major concerns: to reduce cost through improved process control and efficiency, to avoid accidents and setbacks and to look for new products and processes. Gases play a central role in the second concern and their effective monitoring has always been a specialised activity in chemical and allied industries. Solid state gas sensing is unique in many ways and combined with advances in new materials offers immense potential in coal mines, oil rigs, effluent disposal, automobile industry and even domestic appliances"(12).

The above excerpts illustrate some of the recent trends in industrial innovation, stimulated by advances in high technology areas.

Japan provides an interesting example of the new challenges and opportunities. Japan has aimed for world leadership in Advanced Materials by 1990s and is moving fast in that direction targeting (a) high-strength/high-modulus polymers, (b) engineering plastics and matrices, (c) polymers for electronic applications, (d) membranes for separation of gases/liquids (e) biopolymers. The country has gained a strong foothold already in so far as (a) is concerned through innovative research and joint ventures (13) and is challenging USA who are ahead in basic research. The market for polymeric material for electronic applications is over five billion dollars a year. In membrane R & D Japan and USA are said to be even whereas in most areas of biopolymers USA is ahead of Japan. Japan being a country with practically no natural resources, material is vital to its future economy. Thus, despite financial setbacks in 1970s and 1980s Japanese firms built first rate R & D centres which are now in focus in the new race for world leadership. A particular advantage for Japan is active government support of R & D and science policy in cooperation with industry.

Recognising that survival and advance of Japanese industry would require an independent research capability in science and technology, Japan has established a Science City at Tsukuba which is home to over 50 private and governmental R & D institutions and two universities generating a synergistic and agglomerative effect and avoiding unnecessary duplication wherever possible. The result is a mounting flow of scientific information and industrially important technologies (14). Britain has also established technology concentration in Science Parks, which are strongly linked to Universities or research institutions enabling speedier commercialisation of research results. Academic-industrial links constitute the core in this initiative, which continues to expand. The first science park established in early 1970s by Heriot-Watt University in Edinburgh and by Trinity College in Cambridge progressed to 30 by 1987, the bulk of them preferring high tech research aras (15). Advances in information and communications technology has spurred the development of computers and communications leading to a fusion of the two called C & C technology. The human race is thus witnessing the third great revolution - the information revolution - after the agricultural and later industrial revolutions. Information and microelectronics technologies have combined with biotechnology to create bioelectronics technology holding out the possibility of building biocomputers using biochips. Computers are now artificial brains and communications are artificial nerves.

Perceivable characteristics of the new information society are (a) economy of scale is irrelevant (b) shift from 'speialisation' to 'collaboration' (c) 'flexibility' rather than 'concentration'. (d) move away from 'centralisation' towards'decentralisation' (16). These are recognised as essential elements of technology management in competitive industrialisation.

In its Report (17) on Future Technology in Japan - Forecast to the year 2015 the Japan Institute of Future Technology surveyed the following 17 fields.

1. Substances, materials and processing
2. Information, electronics and software
3. Life science
4. Outer space
5. Marine science
6. Earth science
7. Agriculture, forestry, fisheries
8. Mineral and water resources
9. Energy
10. Production and labour
11. Health and medical care
12. Consumer lifestyles, education and culture
13. Transportation
14. Communication

15. Urbanisation and construction
16. Environment
17. Safety

In each field specific areas were identified in terms of importance, time of realisation and high-interest, representing the voices of leading Japanese specialists on the likely directions of future advances in science and technology.

2.2 TRANSFORMATIONS IN MANUFACTURING

In an era of so-called build-to-order manufacturing, the old way of making things turning out standard products in large quantities for future sale is dead. Customers want the goods now and want them their way, or else they will buy somewhere else. Rhythm is a software (Cost $ 250,000) which can model an entire production pipeline, from raw materials to finished goods. It enables factory managers to keep track of orders, schedules, inventories, equipment purchases, critical inputs for manufacturing such as energy, in real time. Rush orders can be accommodated by reordering production schedules from desk top computer. In one manufacturing outfit where this is being applied late deliveries are already down by 30% (18).

Manufacturing in the advanced industrial world is undergoing rapid metamorphosis. It is only a question of time before it is everywhere.

Until twenty years ago, manufacturing was heading for long production runs of identical objects in ever expanding factories. There were giant factories and more giant factories. Productivity was no doubt emphasised but big plants were the trend. But today all over the world the whole concept of manufacturing has dramatically changed and taken a sharp ninety degree turn. The watchword is 'flexibility'. Consequently the giant factories are proving to be white elephants.

What has triggered this change? Information technology, no doubt. In the past, there was a problem of determining the precise amount of data that needed to be applied to a process and also the exact time of its application. For example how an operator can maximise the use of furnaces or a thin film coating machine. Digitisation of data and advances in computers sensors and information transmission have changed it all.

The new concept in manufacturing is based on the premise that production and the product are inseparable. Since computer aided design (CAD) conveys in precise numeric terms the item to be produced, coupling it with computer-aided manufacturing helps edit the programmes accurately. Quality control in the new factory uses real time and made-to-measure robots. Robot movement can be simulated on a CAD Screen.

Called flexible manufacturing systems the new order will help design and produce complex parts accurately and at a lower cost and with considerable flexibility to accommodate market demands.

For the factory of the future the new tools are Automation, Automated programmable machines and Industrial robots - at least for now.

Automation

Although numerical control (NC) originated in 1942 war time when Bendix was producing a rod for the injection pump in bomber motors, the expression was applied for the first time to refer to a system created to direct a three-axial milling machine in 1950. Operating on electromechanic principles NC continued its evolution and in 1960 one hundred displays using NC were put on exhibit in USA. The advent of electronics and microprocessors encouraged decentralisation through computer-controlled numerical control especially for small to medium-size production runs. Now CAD/CAM applies NC to its programmes.

Automated Programmable Machines

In the late sixties the auto industry was trying to cope with limits imposed by the banks of hard wired relays which controlled the sequential operations in production. Although they worked well any change in the programme required all wiring to be reorganised. The advent of programmable machines in 1970 solved this problem. In effect it did away with electromagnetic relays and acted as a small computer.

Programmable machinery market is increasing annually 35% and the major users are builders for networking communication between machines. Size is also decreasing. The Danish firm Electromatic offers a model of less than 10 cm that can be integrated into a control board with a mini keyboard like that of a computer. The Japanese have gone further, with a mini-automated device that can connect with a Walkman. Automation benefits by two other computer abilities: simplified dialog between man and machine, and networking. Automated machines are becoming data processing terminals linked to local area networks (LAN) and thus providing excellent communication facility.

Industrial Robots

Controlled by elaborate electronic systems, robots can effectively compete with programmes, numeric control or microprocessors.

The first industrial robot "Unimate" appeared on the market in 1962 from Joseph Engelberg, founder of Unimation, at the same time as the second generation of computers. Subsequent developments have been rather slow but the auto industry, particularly the General Motors, got interested as 90% of the mechanical parts in assembly are small mechanical components. In 1980 robots of the size of a human arm capable of handling 2.5 to 5 Kgs. of masses with a precision of 1/10 mm appeared, powered by six microprocessors to ensure hierarchical control and a seventh to supervise the entire unit. Subsequent innovators in Japan, Sweden, France and USA have augmented the evolution of robots, benefiting developments in electronics and computer-based devices. CAD and robotics joined hands, converging design and manufacturing. At Peugeot for example, the designer displays the sketch of a desired part on the screen, visualises the position of joints to be soldered while the robots preforms the operations.

Traditional industries are being transformed. The steel industry now employs many high-tech procedures. Continuous casting is monitored on screen; computer calculates material and energy flow; computer provides continuous information on the distribution of solidified or molten zones in the metal; the computer even talks to alert personnel. In a sense the steel industry is showing the way.

Another traditional industry - leather - is being impacted. Microprocessor control of tannery wet operations is now increasingly adopted with benefits in clean processing, productivity, quality and money. Whereas it used to take two weeks or more to design and produce footwear, CAD has now reduced the job to hours with saving in material costs.

Thus, manufacturing is undergoing substantial changes, and refinements. Even tasks traditionally reserved for humans are now being performed, even more efficiently, by the new tools. In the traditional textile industry now automatic positioning, tracking and laser cutting of fabrics are now machine-based. Even the form and fall of fabric are calculated by computer software. The robot has freed the human hand. Inspection, control, identification and direction will henceforth be performed by machines, over 400,000 of which worth $ 750 million are said to be in operation by now.

The modern factory is technology-driven, combining technology and methods. What is even more important than technology is Technology Management.

2.3. THE NEW INTERNATIONAL REGIMES AFFECTING TECHNOLOGY, INDUSTRY & TRADE

The Marrakech Accord

On 15th April 1994 in Marrakech, Morocco, Ministers from 117 countries signed an international treaty. This brought together atleast 25 agreements, declarations and decisions encompassing

a. Agriculture
b. Trade Related Investment Measures (TRIMS)
c. Geneal Agreement on Trade and Services (GATS)
d. Tariffs
e. Textiles
f. General Agreement on Trade Related Aspects of Intellectual Property Right (TRIPS) and
g. An agreement on establishing the World Trade Organisation (WTO).

After the second world war, major countries agreed on the need for 3 International Economic Institutions, two of which came into being and are well-known instiutions, viz. the International Monetary Fund (IMF) and the World Bank, which is also called International Bank for Reconstruction and Development. The third initiative, viz. International Trade Organisation, could not be established and had been the subject of consultations and inter-governmental meetings under the aegis of GATT (General Agreement on Tariffs and Trade).

The new international regimes concluded at Marrakeche brings under the ambit of WTO services intellectual property as well.

During the last one year, a document known as Dunkel Draft had been in circulation and it became the subject of intensive debates, discussions as well as outright protests in many countries. Because the Dunkel draft covered sensitive ares of agriculture and textiles which for decades had remained untouched by GATT, there were fears that agriculture and food security would be jeopardised, that farmers will have to buy seeds every year from multinationals, that public distribution systems will be adversely affected, that drug prices will shoot up and wipe out domestic pharmaceutical industries, that patenting of life forms and seeds will lead to destruction of biological wealth of many countries and that the Dunkel Draft was a red carpet for multinationals to economically dominate the less endowed countries.

India is a signatory to the new international treaty which is expected to come into operation on 1st January or 1st July 1995 at the latest. In the context of the subject of this dissertation, the GATT agreement is analysed and the implications assessed as follows (19):

Agriculture

GATT concerns itself with the following subjects:

a. Domestic subsidies

b. Export subsidies, including volume of subsidised exports.

c. Minimum market access commitment

d. Food Stock holding/food aid operations.

* Due to reduction in agricultural subsidies in industrialised countries, the international prices of agricultural commodities will rise.
* There is great scope for export from India. Bihar/East India will witness boom in rice exports.
* Corporates will have to help farmers introduce more productive agricultural technologies, arrange seeds etc.
* Domestic prices of agricultural products will rise.

Trade Related Investment Measures

* Applies to foreign investment policies and to the extent these affect trade in goods.
* Nature of restrictions
    i. Compulsory use of domestic products by the foreign company.
    ii. Restrictions on percentage of imported products in finished products by the foreign company.
    iii. Discriminatory trade policies on foreign companies when the same requirements do not apply to nationally owned enterprises.

General Agreement on Trade in Services

There are only two obligations viz."Most favoured nation" (MFN) status, and "Transparency" - prompt publication of all laws and regulations. Market access to each nation will be according to specific negotiated commitments.

* The banking, telecom and insurance services are opened for foreign investments.
* India should use these as a bargaining point for "body export" i.e. movement of skilled and professional people in Computer, Hotel, Health, Engineering, Construction and Professional Services.

Tariff

Phased reduction in tariffs to be achieved by 2000 AD.

Textiles

* Existing MFA (Multi-fibre agreement) i.e. quota system with six countries to be gradually dismantled over ten years in phased manner.
* During transition stage, growth factors to be applied to the prevailing quotas to ensure liberalisation.
* Implications for India: In a quota free world, we will face fierce competition from China, Pakistan, Bangladesh, Sri Lanka, Indonesia and Vietnam.

Trade Related Intellectual Property Rights

* This is the most controversial portion of GATT. It covers seven categories:
  i. Copy right and related rights
  ii. Trade marks

iii. Geographical indications

iv. Industrial designs

v. Patents (includes micro organisms/plant varieties)

vi. Integrated circuits

vii. Trade secrets

* Non compliance of TRIPS in GATT permits "cross-retaliation" in the goods sector.

* In the area of patent TRIPS differs from existing Indian laws, the most important being that product patents are not granted in India, only process patents.

* Transition period: 5 years transition for all developing countries. Where product patent is not provided, (as in India) additional 5 years is provided (meaning 10 years transition for applying TRIPS to food, pharmaceuticals etc.).

* Pipeline protection: Though there is a transition period of 10 years, India has to provide protection for products given patent in any other country during the transition period of 10 years.

* The areas of difference are:

Existing	**Proposed as per TRIPS**	**Implications**
1. Permits only "Process" patent in food, pharmaceuticals & chemicals & chemical sectors. (F&P)	Product patents compulsory in all sectors including food, pharmaceuticals & chemicals	Has major implications in drug sector,
2. Duration a. 7 years in F&P Sectors b. 14 years in other sectors	uniformly 20 years	Patent right can be enjoyed for a longer time than at present.
3. Compulsory licensing broadly worded	To be given on merits of the case after approaching the patent owner for obtaining a licence on reasonable commercial terms	patent owner enjoys more protection - though within reasonable limits
4. In case of process patent, there is a view that the burden of proof is on the plaintiff.	Burden of proof in case of product patents placed on the alleged infringer	....
5. Importing does not amount to working of the patent	Patent rights are available equally regardless of local or imported products	Reverse engineering of imported products will not be easy anymore
6. No system for protection of plant varieties	Effective protection of plant varieties to be developed	Explained later
7. Patent of life forms not permitted	Microorganisms to be patented.	Explained later

Commercial Implications for drug sector

Even for a patent drug, the following facts are to be kept in mind before presuming an increased price, viz.

(i) Only 10-15% of the drugs available in market are normally patented.

(ii) Nonpatented medicines are always available as alternatives, keeping prices in control.

(iii) If domestic companies are able to manufacture the drug in India, the patent holder would prefer licensing the product and selling would be at a reasonable price.

Patenting of micro organisms & plant varieties

* Plants and animals are excluded from patentability, but microorganisms can be patented. However, "Microorganism" has neither been defined nor are there any parameters for its scope.

* It is upto each country to develop its own rules for discriminating between a "biological discovery" (which is not to be patented) and an "invention" (which can be patented).

* There is a wide debate on the ethical, social and religious values of genetic manipulation. The British Medical Association has expressed a view that Europe should not go as far as U.S.A. in patenting GMOs (genetically modified microorganisms) and that all living organisms should not be patented.

* In any case, naturally occurring substances (e.g. Neem etc.) or genetic material will not get patented.

* Farmers' right: There are certain standards set by the 1991 revision of UPOV convention - a convention for protection of plants established by 20 industrialised countries. This convention restricts the use of farm saved seeds only for growing subsequent crops on the farmer's own holding.

This has caused a fear that Indian farmers may be restricted in their traditional exchanges of seeds in the village community. This (fear) is not true. The TRIPS agreement has specified only three conventions to be followed, namely

- Paris convention - for Industrial Property (patents)
- Berne convention - Copy Rights.
- Washington Treaty - integrated circuits.

TRIPS does not specify that we have to follow UPOV or any other norm for the Sui generis system.

* Similarly we are free to provide for Researchers' privilege to permit the use of our protected variety to breed another new variety without the authorisation of the original plant breeder.

Other provisions in GATT

- * Anti-dumping Duty

- The member country must provide transparent guidelines for deciding whether injury is caused and the procedures for anti-dumping guidelines.
- Countries like USA cannot retain anti-dumping duties infinitely. There are rules on how long anti-dumping actions can remain in force.

Discussion

TRIPS

Technology is the most valuable asset and a dominant factor to decide international competitiveness. By utilising the developing countries' potentials of large land, manpower and so on, industrially advanced nations are gaining an upper hand by shifting to knowledge-based industries on the intellecutal goods and get benefited by them. TRIPS is thus a major aspect for consideration in terms of technology management encompassing copyright and related rights, trade marks, territorial indications, patents and trade secrets. TRIPS provides for product patents without exception with a duration of 20 years life. Compulsory licensing will be applicable on a case to case basis, if the seeker is not able to get a licence on reasonable terms.

This would mean the present Patent Act 1970 (applicable only for process patents) will become redundant and a new patent policy will have to be evolved and the time allowed by TRIPS is five years for such switching over.

TRIPS provides for patenting microorganisms and microbiological processes as an obligation. 'Microorganism' does not have a clear definition. As biotechnology inventions deal with living matters and have been proceeding on a rapid rate, there are serious apprehensions. Patents are given for inventions and not for discoveries. In the case of bio-products, it is difficult to determine where the discovery ends and where the invention begins. But, in terms of technology management, biotechnology is a futuristic technology impacting agriculture, industry, food, medicine, environment and ecology. This will be driven only by knowledge and intelligence rather than labour or finance. India has already established a strong base in this field and is poised to strengthen its international stature.

Furthermore, the ability to evluate, optimise and take the right decision in an area of economic importance where technology is the basis calls for efficient management of technology.

Trade Related Investment Measures

This agreement applies to investment measures related to trade in goods. They relate to compulsory use of domestic products or limitation on the use of imported products in relation to the value or volume of local production or exports. In a sense, measures covered by TRIMS are those that are applied in a discriminatory manner onforeign investors and entrepreneurs when the same requirements do not offer to nationally owned entrepreneurs.

Textiles

Textiles and clothing constitute a very important and fundamental industrial sector for any country. For two decades GATT disciplines stayed out of textiles and clothing. The new regime does away with bilateral agreements and arrangements and brings them under the ambit of the GATT agreement.

Textiles rank at the top in India's exports accounting for nearly 30% and therefore any change in international policy is a serious matter for consideration. Just about every item under textile and clothing is covered which means even those items which are today not covered by quotas will get included in the new regime. It would imply that India needs to strengthen its competitiveness in this export oriented sector as there will be fierce competition from China, Pakistan, Bangladesh, Sri Lanka, Indonesia and Vietnam, who have been traditionally very active in the garments production and export. To maintain competitive advantage it is important that Government and Industry get together and put in place an effective programme for upgradation of technology, quality and marketing skills. Indian garment industry, despite its brilliant export performance, is not caring for modernisation and diversificaion. The importance of technology and management of technology is at once obvious.

Services

GATT integrates services sector, includes commercial persons and movement of intellectual persons. Due to vast human resources and skilled technical personnel, such imports is to the advantage of India.

India can gain by participating in strategic areas like computer and related services, hotel and tourism, health, engineering, construction and professional sevices.

Overall Assessment

The world trade which has grown five times since the second world war, has been responsible for the enormous prosperity of the industrialised world. The new Treaty signed by 117 nations is a comprehensive trade deal not known to mankind so far in the world. GATT is an agreement by which the world conducts the trade. Free enterprise and free world trade are significant results of GATT - there are no losers; every member who utilises GATT scheme correctly can win.

The big time national winners succeed only through international trade and as a result they could transform the society and wipe out poverty. India did not take part in the global phenomena as it did not engage in free trade so far. In the name of promoting self-reliance, it put a barrier for itself denying free trade. Hence people of India so far did not get the benefit of global prosperity. By the new agreement all the nations agree to lower import duties and eliminate the licences and quotas in a phased manner. This would result in a higher standard of living for the the whole trading community in the world, and would create a borderless system.

Due to GATT, people in South Korea and Japan can buy cheaper rice, Americans can buy cheaper textiles from countries like India, and India will get cheaper synthetics but best quality. Even though India is not still a part of the world trade system, because of the recent economic reforms it has committed itself to be a part of it, the results will be visible within a few years.

The world share of India is just 0.4% and it shall get a big gain from GATT. India needs the world more than the world needs India.

A mistaken notion is that the exports are good and imports are bad and with the result the country takes up the task of protecting inefficient local companies, who cannot make cheaper or better quality products and compete in the world market. Because of the GATT agreement, citizens of the country will get the world's best products and such imports will innovate and motivate the local products, and will bring down the cost and improve the quality. We have a sustainable advantage in the new market, as we were the last to enter the world.

The new international treaty agreed upon by 117 countries are self-executing in nature. This would mean that countries like India will have to bring their laws, regulations, administration and judicial framework in line with the obligations and commitments provided for in the treaty.

The agreement establishing the World Trade Organisation stipulates that "each Member shall ensure the comformity of its laws, regulations and administrative procedures with its obligations as provided in the annexed agreements". Perhaps only in the area of patents including patenting of microorganisms and protection of plant varities, there is a major departure for India from its policies, laws and regulations. India will have to enact a new Patent Law, a new legislation for protection of integrated circuits and new legislation for protection of plant breeders' rights. Taken as a whole it looks India would be more of a gainer than a loser by the international treaty, but what is important is to manage the opportunities carefully, imaginatively, efficiently and turn them to the country's advantage.

2.4 GLOBALISATION OF TECHNOLOGY AND ECONOMIC REFORMS - IMPERATIVES AND OPPORTUNITIES FOR INDIA

The Global Scene

Mahatma Gandhiji fought for the freedom of India. Pandit Jawaharlal Nehru, as a strong planner, introduced five year plans investing monies in public sector while simultaneously encouraging private sector. This formed a strong base for the economic growth of India. During the period of Prime Minister Indira Gandhi, many Laboratories, both in public and private sectors, were formed for a faster industrial growth.

Industrialisation is the only way to create job opportunities and earn revenue to the country's exchequer.

It was Prime Minister Rajiv Gandhi who determined that whatever was done from the time of independence needed to be consolidated, more foreign investments should be invited and the Government should have a more pragmatic approach for opening up its economy, so that India got the right place in the world market.

Even though the basic plan was conceived during Rajiv Gandhi's period, the implementation devolved on Prime Minister Narasimha Rao, ably supported by a professional Finance Minister Manmohan Singh and P.Chidambaram, the then Commerce Minister.

India, unfortunately, is in a wrong location in the world trade, in the sense neither it belongs to the West along with the European community nor does it belong to the Asian block, which is quite strong.

If the whole world is bifurcated into segments, America has the best buying power in the world; but, the laws are becoming stringent there and Americans are now looking out for support from developing countries, where the laws and regulations are not that strict either on the input or on the intermediate or final product.

The manufacturing cost in USA is also quite high compared to the developing countries. USA is more a finance based economy - the highest salary drawn in the world is US $ 1.10 billion for a single individual who belongs to the financial discipline. Moreover, the Americans have a philosophy of having their CEOs to be a Lawyer or a Financial Expert, and not a Technocrat.

They have their own independent market because of their buying capacity and with the money power, they are able to penetrate the entire world market.

The European community has a close network. They have their own formula and understanding within Europe for the products manufactured by them and exported from one country to the other. Here again, the environmental areas are being tidied up and some countries are very keen to the extent of banning use of chlorine bleached papers and insisting for only recycled papers. Some industries producing chlorine have been shut down and selling the plants. Here also, the cost of conversion is very high.

In the Asian block strong leaders like Malaysia, through their Prime Minister Dato Mahatir Mohammed, with their strong economy, long range industrialisation policy (Vision-2020) and high indigenous development and export markets, have taken the lead for the benefit of the Asian block.

Japan, of course, is the best managed industrial economy in the world, essentially because of their well coordinated policy of adopting technologies developed elsewhere, and improving upon them to a level of excellence to capture the world market. Also, most of the projects and labour intensive jobs are being subcontracted to India and other developing countries where they are able to get these done at a cheaper conversion cost.

Among the other countries Australia has its own economy because of the rich national wealth. They are able to progress in spite of the fact that there has been a strong recession. As far as China is concerned, in recent years, investments from America have gone very high with a 34% growth rate. Even though they have the world's largest population, because of efficient and dynamic planning and performance, they are able to lure foreign entrepreneurs for investment in their country. In fact, their Government is willing to discuss across the table even long term commitments including cost of labour to the entrepreneurs. China is able to produce materials at such a cheap cost that they are able to penetrate the world market. India is left behind. The market here is far bigger and if properly exploited, will be the single biggest market when compared to other Asian countries. Unfortunately, it does not have an understanding with other Asian block or the European block and hence, has to suffer as an independent non-aligned country. With the abundant skills and opportunities available in the country, it was a dream of Rajiv Gandhi to transform

India in a systematic manner and to open up to private enterprises for faster industrialisation, to bring in stricter discipline in public sector undertakings, and to run the whole country in a more professional way, the ultimate ambition being to have the best industrialisation, increased agro production, increased job opportunities and a good economic growth.

Realities in India

India has all along been protecting the local industry in many areas, to the extent the local manufacturers' interests are not disturbed. Even today, all the developed countries like USA, part of Europe and even small countries like Malaysia and Indonesia provide protection for indigenous goods. Even though any commodity can be imported there from any part of the world, a tariff system is in existence to protect the local investments, local manufacture and local talents.

The mentality of the entire Indian industry and manufacturers should fall in line with the global scenario, which fundamentally calls for a perfect system (e.g.) ISO. Even though ISO has certain problems with regard to revealing the process secrets to an independent authority, yet because of uniform systems prescribed and quality standard acceptance by international agencies, this provides a level playing ground to all countries in the world market. For example, in the field of fabrication, whoever is accredited to use 'U' stamp of American Society of Mechanical Engineers (ASME), is recognised as equivalent to that of any standard fabricator in the developed countries. So, many industries in India have adopted ISO as well, as they could modify the quality systems in view of the abundant skill and infrastructure available in the country. The country is poised to face the world challenges.

But the level playing ground has not been created. In order to achieve the desired results one has to be competitive in the world market. To achieve this, the input costs have to be comparable all over the world. But, in India, the import tariff still exists; the indigenous materials are not fully free from local taxes i.e. the raw materials procured from Indian market even for export are not fully exempt from the local taxes like Excise Duty, Sales-tax etc. Also, for the imported raw materials and other inputs, port facilities, quick port clearance, customs clearances, the import tariff, are not very conducive at the moment.

Dumping of materials from abroad is very much prevalent e.g. caustic soda. In the advanced countries, chlorine is the main product and fetches a very good price. With the result, they are able to dump caustic soda at whatever price they get. This affects the local industry very badly. Such areas need to be protected with sufficient tariff. Although the Government has anti-dumping regulations and they do act while such dumping is proved, the procedures are very complicated and it takes quite a long time. If one wants to be a global player, one should realise that the buyer or client should not hold huge inventory and would like the products to be delivered at the respective factories on time. This depends on shipping times and the capability of the manufacturer to effect deliveries to the customer at the right place at the right time.

The immediate result of inviting foreign monies and opening up of the economy has brought in Rs.3,000 crores and following are the areas of investments:

1. Fuel & Oil Refinery	17.6%	7. Elec.Equipment/Electronics	9.7%
2. Power	16.1%	8. Hotel & Tourism	3.5%
3. Food Processing	11.3%	9. Indl & Agricultural Machinery	2.4%
4. Metallurgical	10.2%	10. Glass & Ceramics	3.8%
5. Chemicals	7.0%	11. Other Industries & Services	14.4%
6. Transportation	4.0%		

A closer look and analysis of the above would go to prove that such monies have been invested only in speculation like shares of companies which have been giving good results, i.e. selecting some of the blue chip companies through financial institutions and earning easy money without any contribution to Indian economy.

Another disadvantage of the economic policy is that all along the country had an upper hand with the Indians holding 60% equity in any venture and no foreign company was allowed by the Government to hold more than 40% shares. This gave an indirect strength for the industry to negotiate with the foreign companies who hold the technology and to invite global partners. Today, when things have been opened up, it can be seen that many of the international companies who were holding only 40% have gone automatically to 60% with controlling shares. This is definitely a disadvantage.

The Government's idea of bringing in more money for the power sector will be detrimental because of the minimum returns assured to them like fertiliser industry. The Government has assured 16% return to all the industries in the power sector. The power cost in India is already high and even with this, the Electricity Boards are already running in loss, although inefficiency and subsidised power cost to agriculture are two main resons. There is also the disadvantage of cost of feedstock viz. coal, fuel etc. With the minimum 16% return, the average power cost which is Rs.2.50/kWh now will go to Rs.5/kWh. A question then arises, how the industry can face the global competition with such a high power cost.

Research & Development : Many of the foreign companies would try to take advantage of the government's approval for 100% foreign investment in R & D area. They would be able to hire Indian scientists paying 3 or 4 times the salary they are drawing now, which will even then be far cheaper than the wages prevalent in advanced countries. The scientists would be tied down with secrecy agreements and there will be no way for the Government to know about any unacceptable products, toxic materials or ecologically damaging results that could arise out of such R & D ventures. Even then, there is no way to hold them in case they decide to wind up and leave after their R & D work is over. India will do well in the long range and in this game atleast 25% of the industries which are not efficiently managed and who are not able to improve their technologies may have to close down. This will definitely create employment problem. Power cost in India is one of the highest and even then the quality of power is poor - right from steady supply to frequency. This tells upon the ability of the Plant and the quality of the product. With globalisation, the cost of power will, as pointed out earlier, go further high and therefore industry should plan ahead to cope with this problem.

All over the world it is mentioned that the labour cost in India is cheap and so the conversion cost. This may be true, but what is equally true is that the efficiency level of production is also very low. The industrial production in India when compared to any developed country is hardly 20%. Hence, all the calculations on conversion cost and the workmanship have to be taken at 5 times to make it comparable. Of course, there are cases, where the conversion cost is not so high.

Concluding Remarks

To avoid disaster and high inflation and to achieve a reasonable economy, the only way is to open up the economy as has been done and to have global market for the Indian manufacturer.

As the first result of the globalisation, the cost of finance has come down reasonably and most of the financial institutions and the banks in the country have brought down the finance charges. They need to be brought down further, to keep up with the world financing patterns. The idea is to enable achieving the desired result, but in the process the Government should be very vigilant and should be very cautious in not getting entangled with all types of technologies and pollution proned industries.

Infrastructure, including banking system, has to be improved radically and drastically and operation of foreign companies in India is to be very carefully and properly monitored. Even though in today's situation, the foreign exchange position is comfortable, it has to remain so always and this calls for a close monitoring in the foreign exchange front.

2.5 THE IMPORTANCE AND TIMELINESS OF THIS STUDY

India is a rapidly industrialising country. Technology is the key to industrialisation. There is already a huge investment in the country both in intellectual power and material power - intellectual power by way of good educational background and material power by way of investments in well established laboratories. There are over 3.2 million scientists and technologists for a population of 800 million. There are over 100 well equipped public-funded laboratories pertaining to civilian research and development, and equal level of private investments.

Investments in science and technology are highly profitable and it is well known that the level of technological advancement outweighs simple capital formation in determining the ability of an economy to grow.

Because the recent economic reforms will bring more money, more technology, more trade, more jobs, more economical prosperity has to come. At this time, India cannot afford to lose or take any chances. In 47 years since independence, people of the country have learnt many things - both do's and don'ts.

Because globalisation and new investments stimulate free flow of technologies, Technology Management comes into sharp focus.

In the world of technology marketing chances of incomplete or imperfect technology being sold cannot be ruled out. It is necessary to avoid getting stuck with an inferior technology. To avoid mistakes, it is important to learn from our failures and successes. At this time, even though the economic reforms will bring in very many innovations and revelations, this is also the time for the technology users/buyers to guard themselves adequately so that they get technologies which are pollution free, non-hazardous, eco-friendly, highly energy economic. Technology selection should be based on informed judgement and systematic evaluation.

Now, after globalisation, manufacturing is increasingly shifting to East. India is very important for large manufacturing. Therefore, technology will play a key role. By studying both successes and failures, it should be possible to pinpoint critical factors which are necessary for benefiting from technology and technological change, to avoid losses and not to be left behind. This underlines the need for the present study.

In this study two cases of successes and two of failures have been analysed to obtain clear guidelines to arrive at major critical factors governing technology management in the Industry -

i. technology development & acquisition,

ii. technology assimilation, and

iii. sustainablity

all within the broad framework of Technology Management in Industries.

CHAPTER 3

SUCCESSFUL EXPERIENCE IN TECHNOLOGY MANAGEMENT - A CASE STUDY OF CHLOR ALKALI INDUSTRY

3.1 CHLOR ALKALI - AN INTRODUCTION

Caustic Soda and Chlorine are two important basic chemicals. They play a very fundametlal and vital role in the industrial development of any country, and are even regarded as indicators of chemical industry growth in a country.

The discovery of chlorine two hundred twentytwo years ago (in 1772) by the Swedish chemist, Carl Wilhelm Scheele, was destined to exert a profound influence upon future generations. Chlorine would grow to become one of the most versatile commodities, finding its way into hundreds of applications and products beneficial to the health, comfort and enjoyment of the people throughout the world.

3.2 INDUSTRIAL AND ECONOMIC SCENARIO

The relationships of chlor-alkali industry to society originated long ago; the germicide properties of sodium hypochlorite were known before the French Revolution. They evolved along the last hundred years and established the chlor-alkali industry as a building block of the chemical industry and a major contributor to the development of industry and the economy.

Today, considering caustic soda and chlorine are directly related products

- more than 50% of the turnover of the world chemical industry depend on chlorine chemistry,
- about 25% of the manpower of the chemical industry depend on chlor-alkali industry
- a large share of the investments of the chemical industry (more than 30%) is related to chlor-alkali business (20).

This is due to:

- the availability of salt as a raw material (Fig. 3.1 exhibits the comparison of availability of sodium chloride - a natural resource and oil and natural gas).
- the intrinsic properties of chlorine
- its reactivity
- the large samples of molecules to which it can give birth. The compound has become a major raw material for the chemical industry today.

The chlor-alkali industry is thus a major purveyor of intermediates, and also a source of products for other industries; packaging, building, engineering and automotive industries.

Caustic soda is also widely used: in the food industry, in detergents, in the chemical industry , textile, paper, food processing and soap manufacturing.

All along the industrialisation process which took place over the last century, the chlor-alkali industry played an important role.

It contributed to:

- the development of health, with the eradication of water-borne diseases;
- the development of pesticides and the synthesis of new drugs;
- the satisfaction of consumer demands for better living conditions including more food and better housing
- the protection of crops and plants
- the development of new techniques in the engineering industry, in the automotive industry and electronics

3.3 USES OF CHLOR-ALKALI PRODUCTS

Caustic Soda is used in the manufacture of

Pulp and Paper

Newsprint

Viscose yarn

Toilet and Laundry soaps

Detergents

Dyestuffs

Drugs & Pharmaceuticals

Vanaspathi

Petroleum refining etc.

Chlorine is widely used in the manufacture of

Paracetamol

PVC

Pulp and Paper

Bleaching Powder

BHC

DDT

Cotton Textiles

Organic Compounds like

Metallic Chlorides,

Refrigerants, Chlorinated solvents, etc.

and as such for water disinfection

Another co-product is Hydrogen which is used in the manufacture of

Hydrochloric Acid

Hydrogen Peroxide and

Hydrogenation of oils, and

as fuel for automobiles.

Hydrogen is widely used in Electronic Industry and in Defence. Being the lightest gas, hydrogen in liquid form is used as fuel for space-crafts (Fig. 3.2). Hydrochloric Acid phosphoric acid, is used in the ossein, manufacture of dyestuff, rare earth metal, chlorides, in metal pickling and demineralisation of water, and for a variety of industrial uses (Fig. 3.3).

HYDROGEN FUELLED AIRCRAFT

FIG: 3.3

HYDROGEN MANIFOLD TRUCK

3.4 GLOBAL SCENARIO

The total world caustic soda capacity is 51 million tonnes per annum(21, 22), with North America and Western Europe having the major production facilities. The regional distribution of installed capacity (1988) was as follows:

Region	Mill. tonnes/annum
North America	13.86
Western Europe	12.43
Eastern Europe & Russia	5.26
Japan	4.78
Asia/Africa/Middle East	3.35
Latin America	2.39
China	3.82
India	1.33

During the last 5 years, the production and demand have been increasing at about 2.44%.

While in North America, most of the production facility has been based on diaphragm process, in Western Europe, most of them are adopting mercury amalgam process.

Japan has been the fore-runner in adopting the state of art ion exchange membrane cell technology. Almost all the plants which were operating on mercury amalgam process have changed over to membrane cell process.

The biggest production facility in the world has been built at Houston, USA, by Formosa Plastics with a capacity of 1900 tonnes per day of chlorine, and was commissioned in 1993.

3.5 INDIAN SCENARIO

Commercial production of caustic soda in the country started in 1941 with the commissioning of two 5 tpd plants, one at Rishra (West Bengal) and the other at Mettur Dam (Tamil Nadu). Progress in new capacity installation was rather slow in early years, and till the early sixties the requirements were being met through imports, ranging in the region of 50,000 to 80,000 tpa. Installed capacity increased from 1.21 lakh tonnes in 1960 to 3.9 lakhs tonnes in 1975. Indigenous production also rose sharply, with the result that dependence on caustic soda imports was completely avoided since 1970. The installed capacity increased to 8.26 lakh tonnes in 1980 and currently (1993-94) the installed capacity is 13.35 lakh tonnes.

Till early 1980's the conventional processes for production of caustic soda/chlorine were diaphragm process and mercury amalgam process.

The year 1985 saw the advent of pollution-free state of art ion exchange membrane cell process in India with the commissioning of the India's first ion exchange membrane cell caustic soda plant of Chemfab Alkalis Ltd., Pondicherry.

The regionwise and process-wise installed production capacities of caustic soda in India, as at 1993, are as under:

	Tonnes/annum
Mercury process	962,854
Diaphragm process	99,010
Membrane process	246,527
Total	1,308,391

Apart from the above 3 processes, a small quantity of caustic soda is also produced using a chemical process, and the total installed capacity on this process in India is 27,700 tonnes, making the total installed capacity for production of caustic soda in India to 1,336,091 tonnes per annum.

The caustic soda industry in India has invested Rs.5000 crores and provides direct job opportunities for 100,000 people, apart from the indirect job opportunities for 500,000 people. This industry is the major consumer of salt and thus provides a great support to the salt industry.

3.6 MANUFACTURING PROCESSES

General

There are 4 manufacturing processes adopted for manufacture of caustic soda, viz. Diaphragm, Mercury, Membrane Electrolyzer and Chemical process. Of these, chemical process is followed only to a negligible extent (23-25).

Typical block flow diagrams of the three processes, viz. diaphragm, mercury and membrane electrolyzer are in Fig. 3.4, 3.5 and 3.6.

Caustic soda is produced by electrolysis of saturated solution of sodium chloride (NaCl), which is known as Saturated Brine.

$$NaCl + H2O \xrightarrow{\text{Electrolysis}} NaOH + H + Cl$$

Normally, sodium chloride contains a lot of impurities like calcium, magnesium, sulphates etc during its natural process of production.

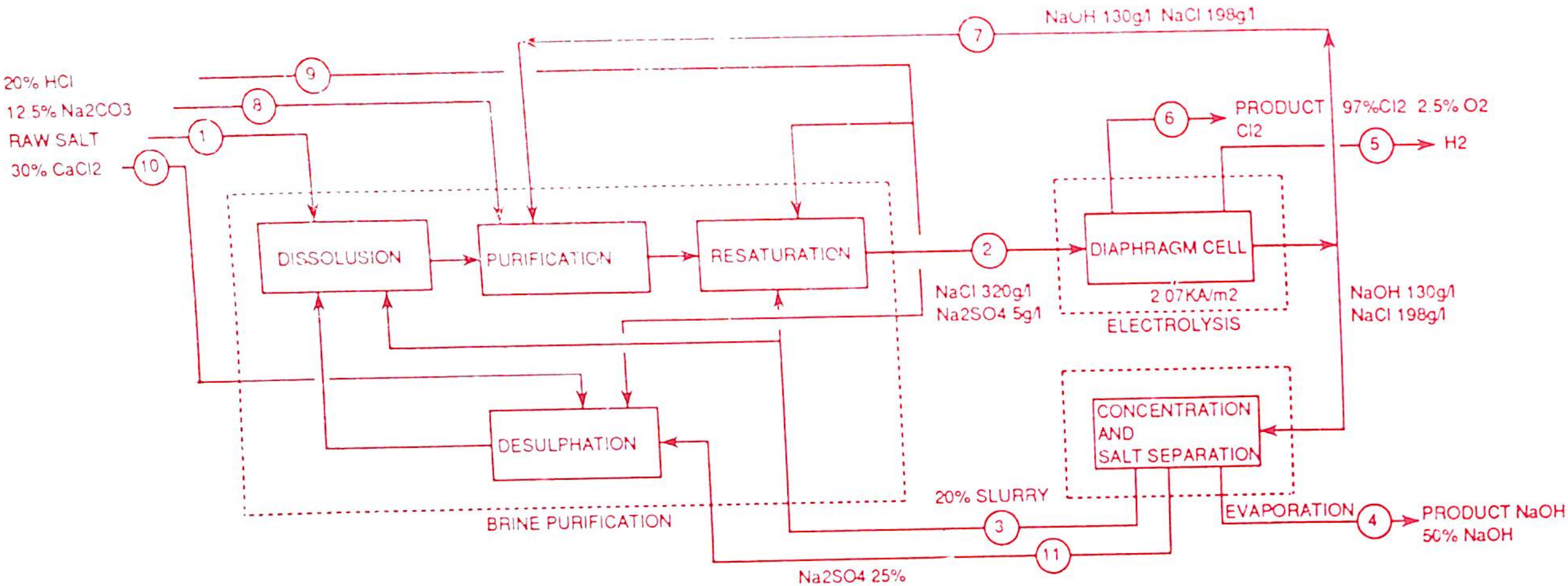
These need to be removed before it is sent into the electrolytic cells for electrolysis.

In order to remove the impurities, sodium bicarbonate, sodium hydroxide and barium chloride are added in required quantities to the brine. Then, the brine is passed to a clarifier/settler, where the impurities get precipitated and settle down.

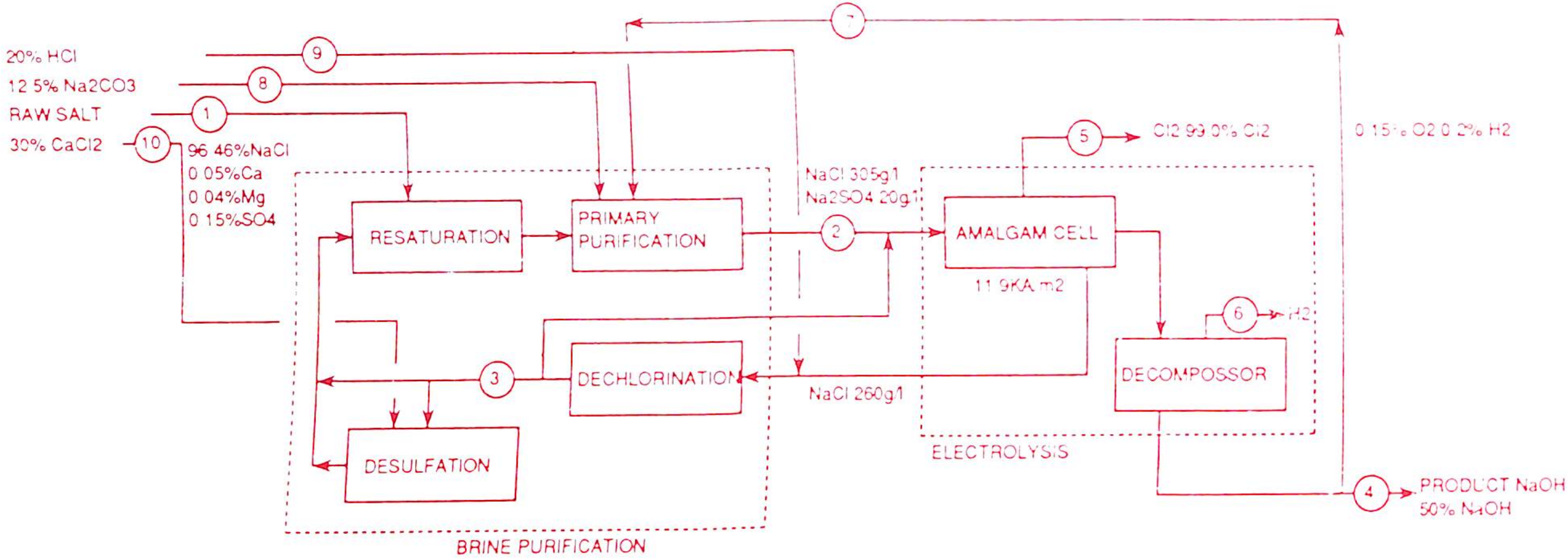
The brine is then passed through a series of sand/anthracite pressure filters to remove the carried over impurities.

The purified brine is then sent to the electrolytic cells where, by passing AC rectified direct current through the brine, electrolysis takes place. The NaCl is split into Na (sodium) and chlorine. Na is made to react with H2O (water) and thus NaOH (Sodium hydroxide) and hydrogen (H2) are produced.

For electrolysis, on the electrical side, the high voltage/low amperage AC from the public distribution system is made into a low voltage/high amperage DC in a Transformer/Rectifier and the electrolytic cells are connected to the Rectifier/Transformer through aluminium/copper busbars. The DC current is passed through the anodes to cathodes to enable electrolysis to take place.

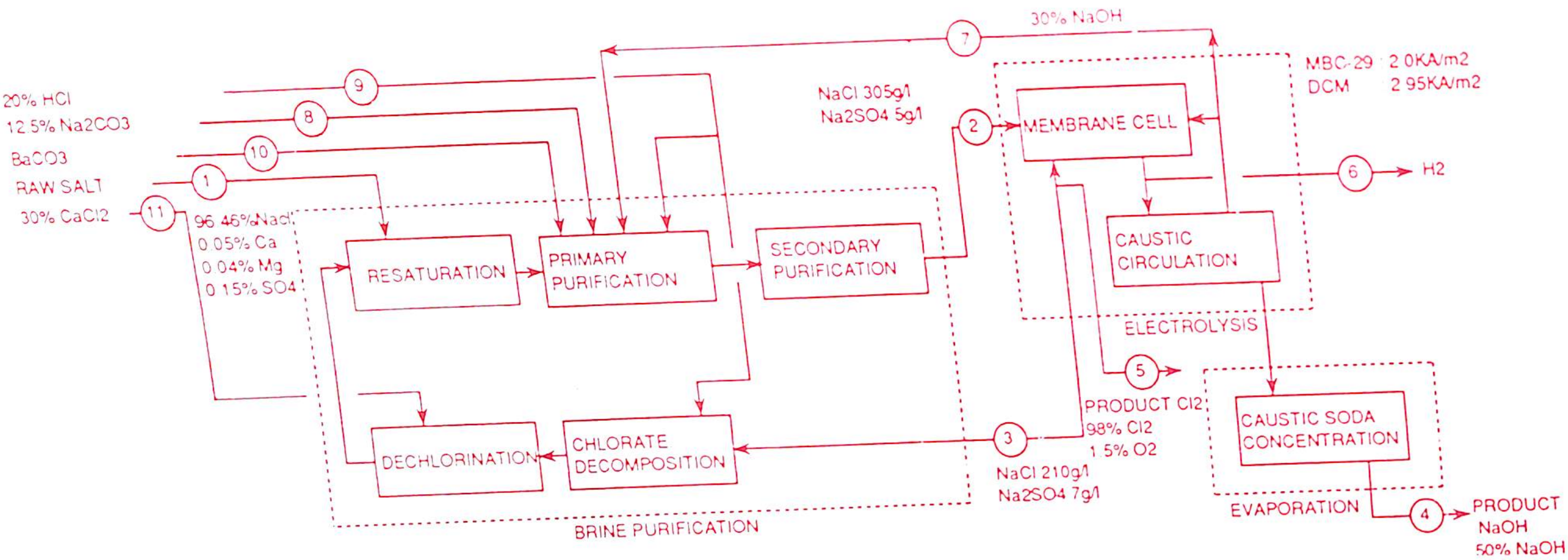


PROCESS FLOW DIAGRAM OF DIAPHRAGM PROCESS



PROCESS FLOW DIAGRAM OF AMALGAM PROCESS

FIG: 3.5



PROCESS FLOW DIAGRAM OF IEM PROCESS

Diaphragm Process

The electrolysis in a diaphragm process cell is as detailed below.

The reaction at the anode side is:

$Cl_2 \text{--->} 1/2Cl_2 + e$

At the cathode side, which material is iron, nickel or other similar metals having a small hydrogen overvoltage, the following reactions take place:

$H_2O \text{--->} H + OH$

$H + e \text{---->} 1/2H_2$

Therefore, the total electrolytic reaction is:

$NaCl + H_2O \text{--->} 1/2H_2 + 1/2Cl_2 + NaOH$

In the diaphragm process, a diaphragm separates the cathode chamber from the anode chamber. Electrolyte flows under pressure from the anode chamber into the cathode chamber to prevent OH back migration into the anode chamber from the cathode side.

Mercury Amalgam Process

Mercury cell consists of a Primary cell (wherein electrolysis takes place) and a Secondary cell known as Denuders or Decomposers.

The Electrolytic cell is a carbon steel trough having a bare steel bottom or rubber-lined bottom with carbon steel cathode plate.

The anodes are hung from the top of the trough. These anodes are connected to current carrying busbars from rectifier through copper flexibles.

Mercury is passed on top of the bottom plate and this acts as a 'moving cathode'. The brine is flown through the cell. When current passes from the anode to the cathode through the brine, electrolysis takes place and NaCl is split into Na ions and Cl2 (i.e. Chlorine). Chlorine liberated from the cell is sucked by a blower and taken out for further processing. Na ions deposit over the moving mercury and form a sodium-mercury amalgam. This amalgam flows into the Secondary Cell where pure water is added. The amalgam when reacting with H2O forms NaOH and H2.

Ion Exchange Membrane Process

In this process, the lethal mercury is not used, whereas a thin synthetic membrane is used to divide the anode compartment and cathode compartment.

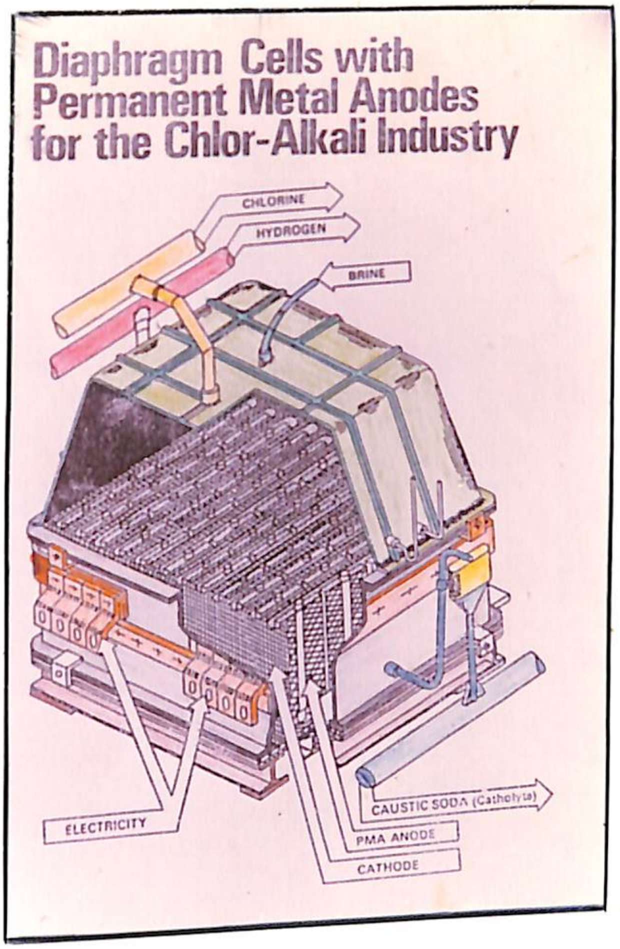
The membrane cell is made up of various anode elements and cathode elements placed one after the other and held together like a plate and frame filter press.

This process requires ultrapure brine with a hardness of less than 20 parts per billion. Therefore, a secondary brine purification system is employed, where the brine passes through a bed of resin column and is polished.

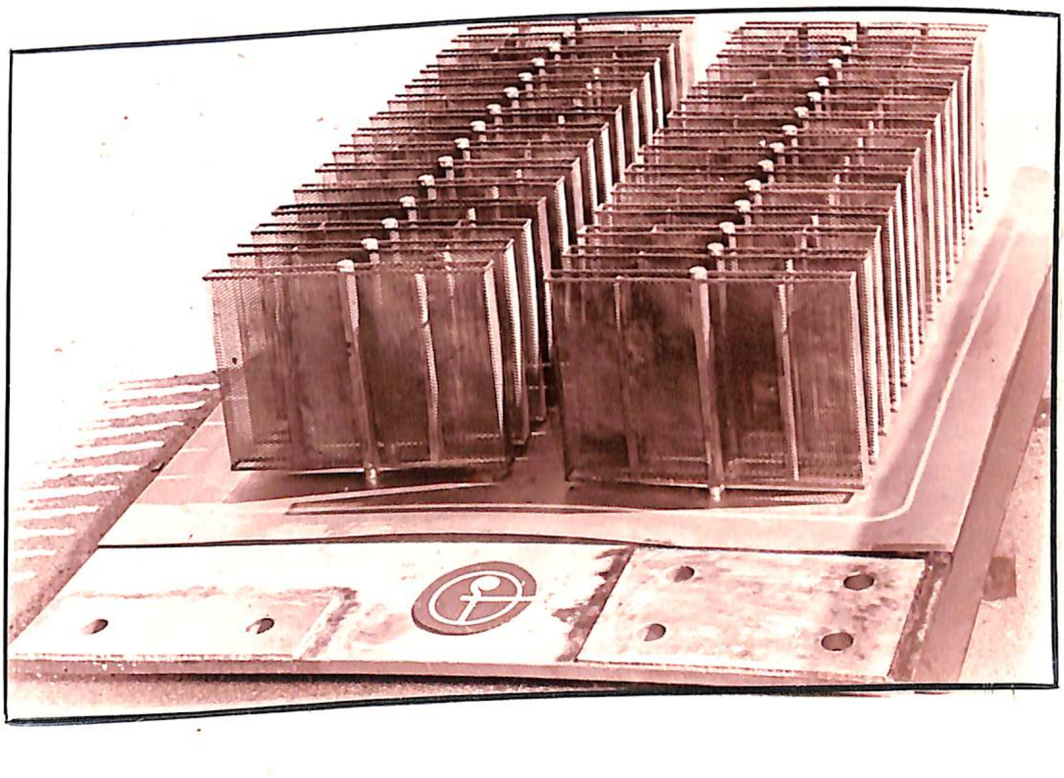
The ultrapure sodium chloride brine is fed into the anode compartment and dilute caustic is fed into the cathode compartment. These two chambers are divided by a membrane. This allows only selective Na ions to pass through from anode compartment to cathode compartment.

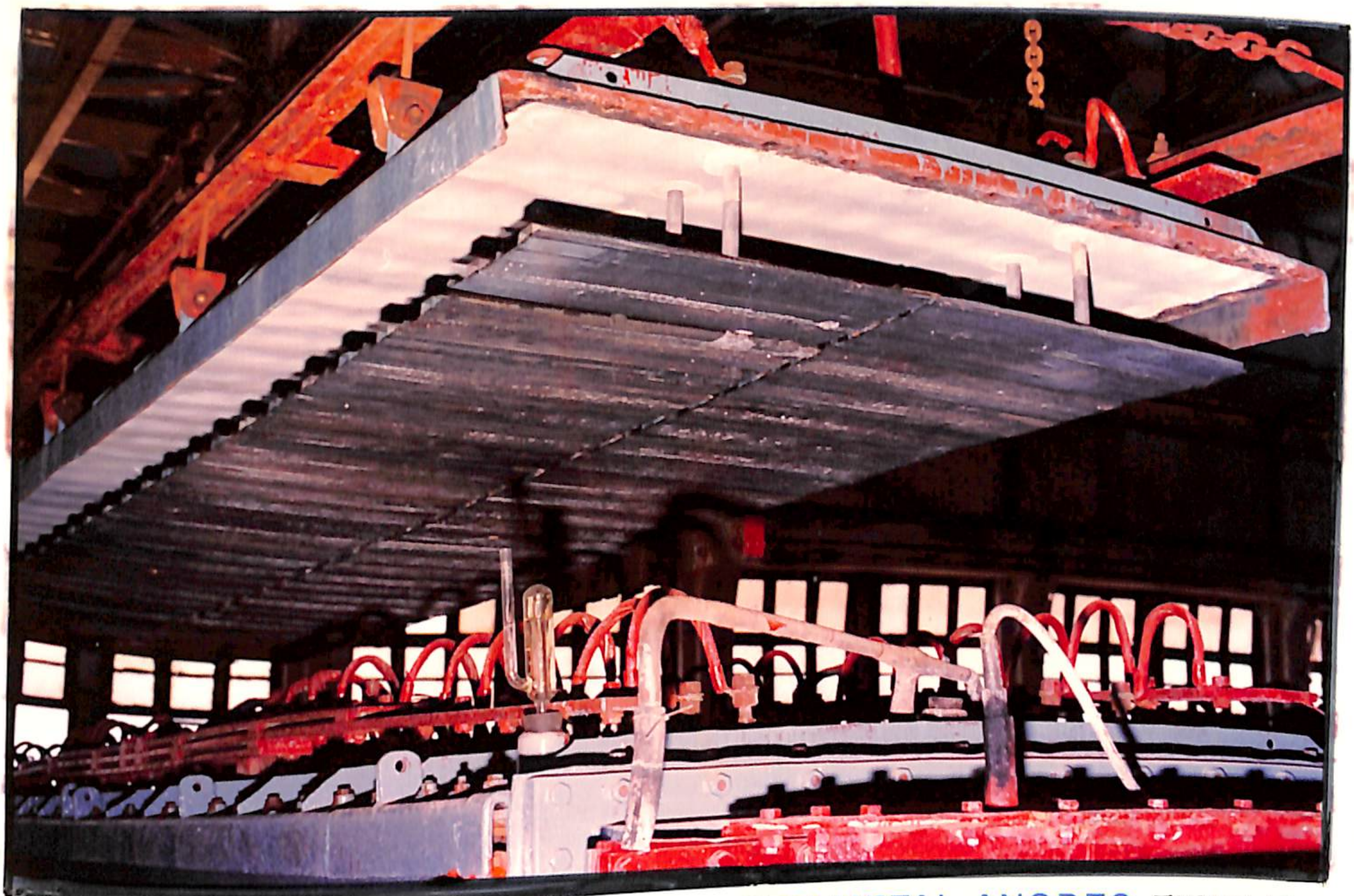
During electrolysis, NaCl is split into Na and Cl ions and Na ions pass through the membrane into cathode compartment where this reacts with the dilute NaOH and forms into increased-strength caustic soda and Hydrogen. The chlorine is released from the anode chamber. The caustic soda and hydrogen are released from the cathode chamber.

Illustrative photographs are enclosed as Fig. 3.7, 3.8, 3.9, 3.10 and 3.11.

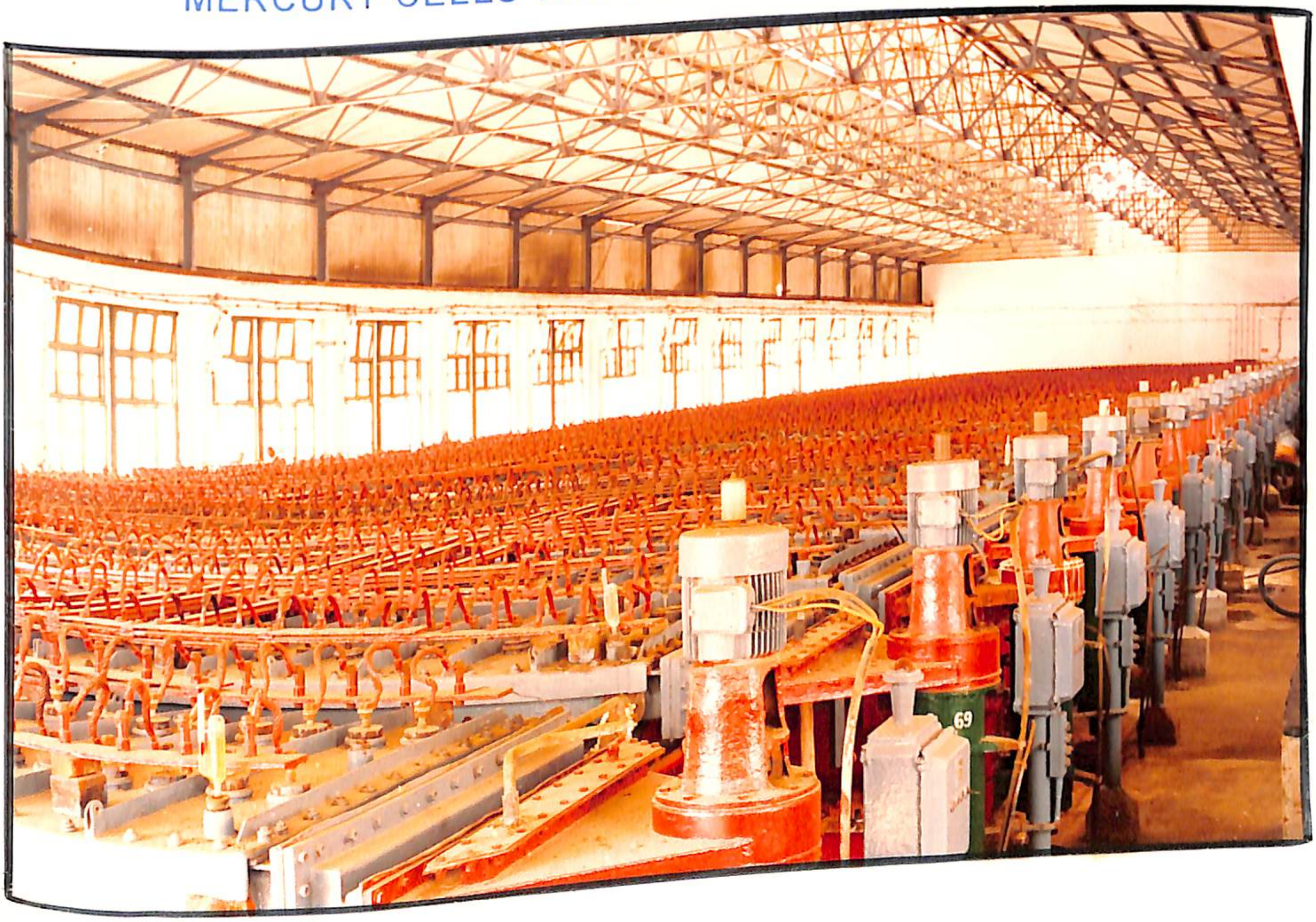


DIAPHRAGM CELLS FIG: 3.8

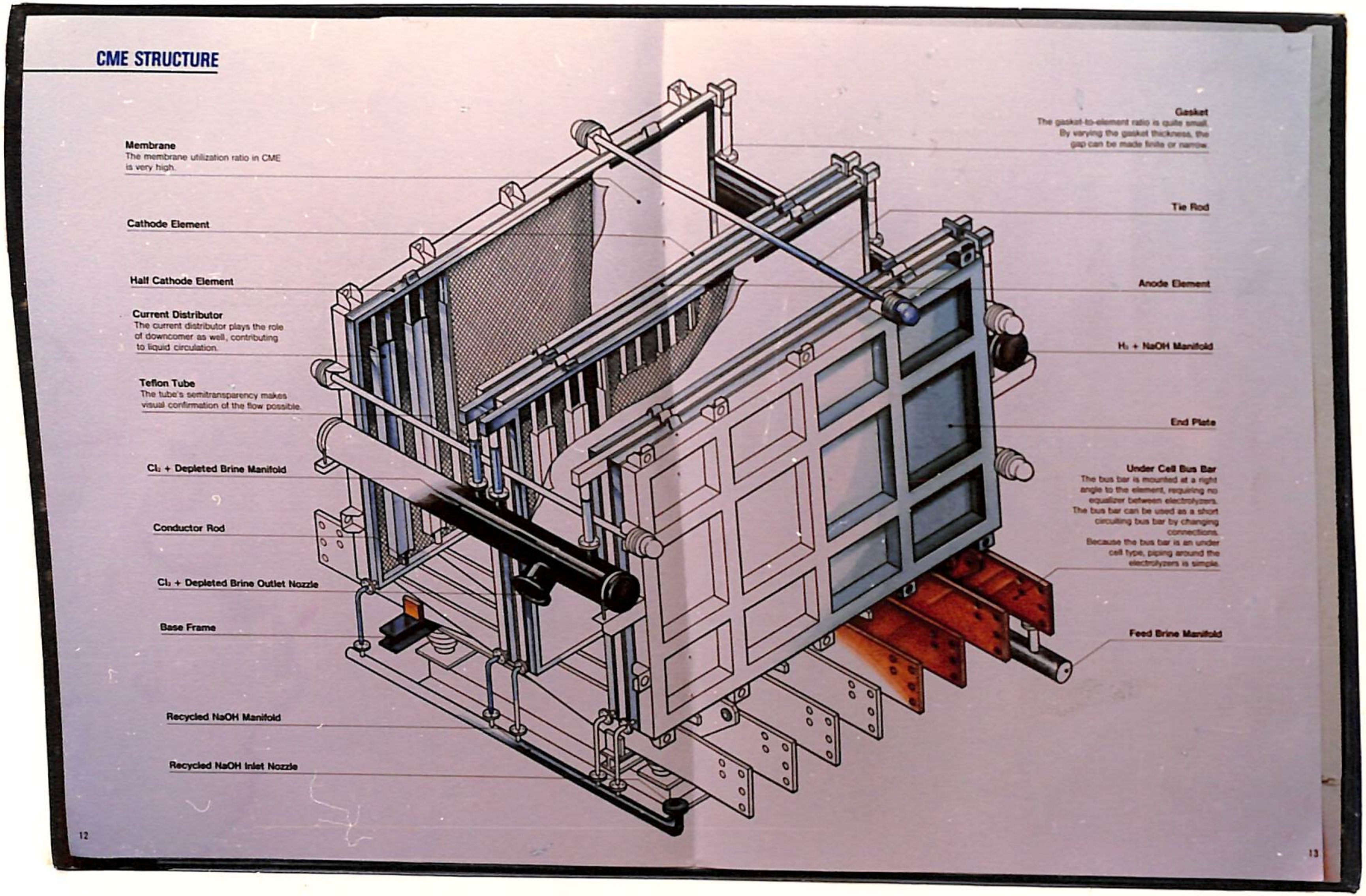




MERCURY CELLS WITH TITANIUM METAL ANODES FIG: 3.10



MERCURY CELL HOUSE



ION EXCHANGE MEMBRANE CELL
ELECTROLYSER - STRUCTURE

ION EXCHANGE MEMBRANE ELECTROLYSER

3.7 TECHNOLOGY GROWTH

Diaphragm cells

Originally, the anodes were graphite blocks and the inter-connections from copper busbars of graphite anodes were provided by pouring of lead to keep the graphite anode in position and to distribute power, and the sealing was provided by hot mastic. These cells had concrete tops. The graphite anodes had very heavy components and they were assembled one by one.

The concrete trough was used as a cell and the cathode was made of mesh or perforated plate of iron or mild steel. On the anode side, graphite was used. An asbestos fibre diaphragm was used to separate the cathode chamber from anode chamber and the electrolyte flows under pressure from the anode chamber into the cathode chamber to prevent OH- back migration into the anode chamber from cathode side.

With the advent of Titanium Metal Anodes, indigenously manufactured by Titanium Equipment and Anode Mfg. Co. Ltd. (TEAM), with the technology from Central Electrochemical Research Institute, a lot of development took place in diaphragm cell. The brine quality was improved for clearer brine to have larger benefits. Since putty was used as a jointing material for metal anodes, the mating parts of anodes, cathodes and cell covers had to be properly levelled and fitted to make a leak-proof joint. The cells required good electrical engineering practices for making proper connections. The graphite anode cells could operate with concrete tops. In the case of metallic anodes, the unnecessary source of choking of diaphragms like graphite particles, sealing compounds, organics from putty had been eliminated and hence, change-over to light fibre-glass cell cover was possible. The weight ratio of cell cover and other heavy components became 10 : 1 in changing over from graphite to metal anodes.

While the graphite anodes had very heavy components and had to be removed and assembled one by one, in case of metal anodes, it became so light that the entire assembly could be lifted-off from the circuit and maintenance could be done on a platform outside.

The introduction of metal anodes saw quick succession of developments in the cell configuration and contacts; and a permanent inter-electrode gap could be introduced. However, to obtain optimal performance, a lot of innovations were needed. The electrical contact system was originally a 3 pin system; the positive current used to go through busbar and to the cell and on to anodes to cathodes through the brine. This was through a three pin contact system to the stem threaded to the anode. This was modified by introducing current conducting from busbar through a copper flexibles connected from busbar to the top of the anode copper rod.

The next stage was lining the base with Titanium and soldering the diaphragm cell Titanium Metal Anode stem with the base.

This resulted in easy current conducting and reduction in loss of energy. The change of concrete cover to fibreglass reinforced plastic cover was made possible.

The next development by TEAM was introducing an expandable type Titanium Anode. The diaphragm is kept on the cathode. As the diaphragm gets consumed, normally the inter-electrode gap will increase. However, with the expandable type

Titanium Anode, the anode will get expanded as the diaphragm gets consumed, thus maintaining constant inter-electrode gap.

As far as diaphragm was concerned, originally diaphragms made of asbestos fibre were used in the cells.

Asbestos being highly toxic, it affected the people handling them and products were also contaminated. The disposal of used diaphragms was also detrimental to the environment. Messrs. Hooker Chemicals, Buffalo, USA, used to dump all their used diaphragms by burying them inside the earth. This resulted in a severe environmental issue and they had to face the wrath of US Government and legal consequences.

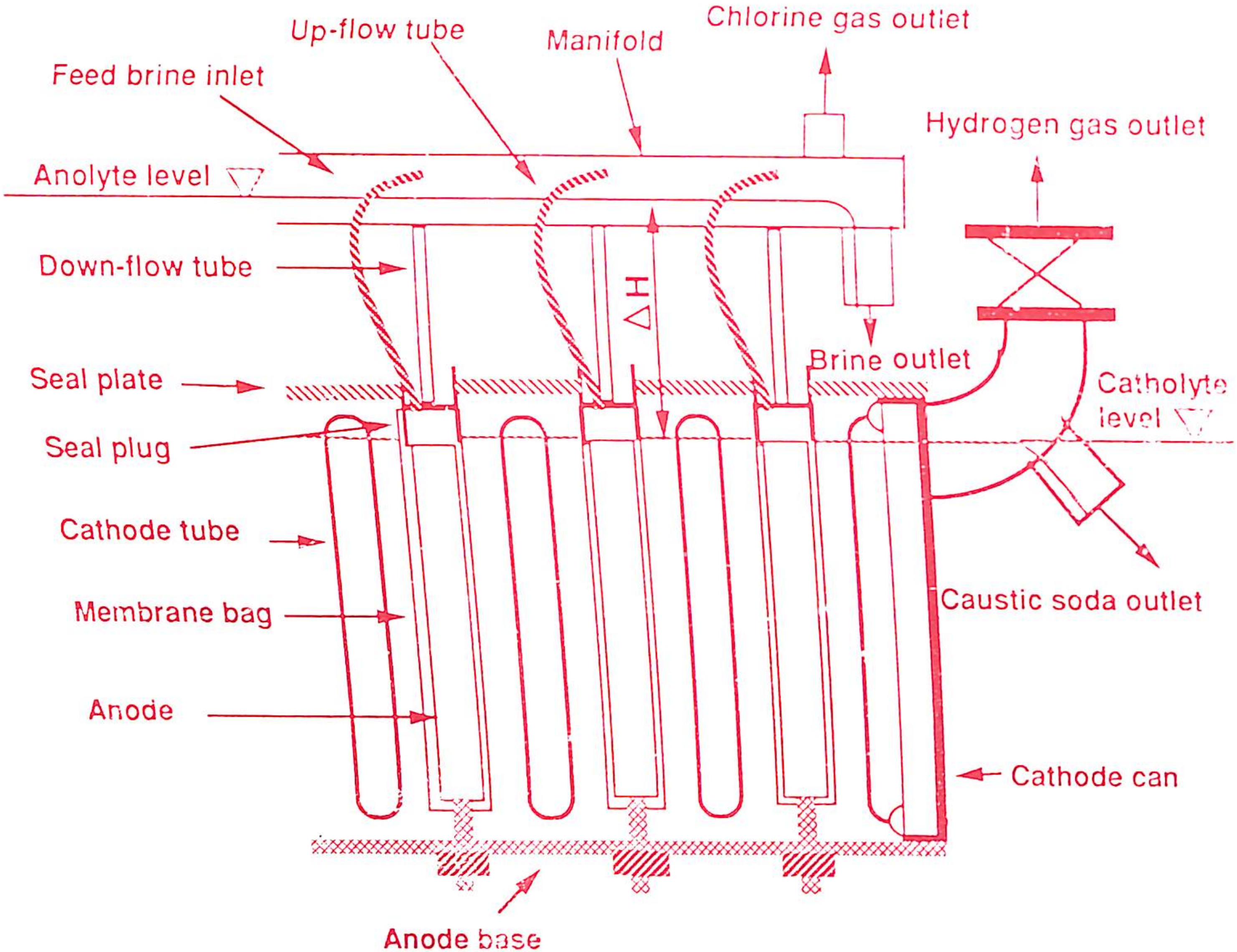
This problem was attempted to be overcome by introducing diaphragms with a mix of asbestos and polymer in the first stage and currently, the diaphragms are made of completely polymer material.

The polymer diaphragm is manufactured using expanded poly-tetra fluro ethylene (PTFE). An extrudate of PTFE is made which is then stretched at a controlled rate and elevated temperature to give a sheet of high porosity and a micro-structure characterised by nodes and frills.

This stretched material is then heated to a still higher temperature to lock the structure and produce a diaphragm which has high physical strength while maintaining good flexibility (26).

Now, a lot of Japanese diaphragm cell plants have converted their diaphragm cell plants into membrane cell plants by replacing the diaphragms with an ion exchange membrane bag. A typical schematic drawing of a Membrane Bag Cell is given in Fig. 3.12.

A comparison of operating parameters between Graphite Anode Cells and Titanium Metal Anode cells as well as with asbestos diaphragm and improved diaphragms is given in Table No.1.



MEMBRANE BAG CELL

TABLE 1

TYPICAL PERFORMANCE OF A REMODELED DIAPHRAGM CELL

	Remodeled Cell (A)	Remodeled Cell (B)	Existing Cell (Reference)
Cell Parts			
Anode	TSIA		Graphite
Cathode	Basket of Hooker Cell		Basket
Base	Ti Lined Base		Concrete
Cover	ConcretePlastic (F.R.P)		Concrete
Diaphragm	Asbestos	Improved Diaphragm	Asbestos
Performance			
Cell Voltage (V)	Approx. 3.7	Approx. 3.5	Approx. 4.1
current Efficiency (%)	94 - 96	94 - 96	94 - 96
Power Consumption (DCKWH/MT NaOH)	Av.2610	Av.2470	Av.2890
Operating Conditions			
Current Load (KA)	30	30	30
Current Density (KA/m^2)	1.63	1.63	1.63
NaOH in Cell Liq (g/l)	130	130	
Temp. (° C)	85	85	
Diaphragm Life	Approx. 6 months	12 - 24 months	2 - 3 months
Anode Life	Only Recoating	Only Recoating	Approx. 200 days

Note : Average figure during one life of diaphragm

Mercury cells

Mercury cell plants initially installed in India were of infant technology. They were Krebs cells and had concrete troughs as cells. Cathode plates made of steel were placed above the cell bottom and moving mercury acted as a cathode. Graphite blocks were used as anodes. The graphite anodes were consumable ones, with the result the inter-electrode gap would gradually increase resulting in higher cell voltage and consequent higher power consumption. The later designed mercury cells by De Nora had easy adjustment mechanism and constant adjustment of the inter-electrode gap by lowering the anodes was practised (27).

A lot of indigenous efforts were made, especially by Grasim Industries, by the team of M C Bagrodia and Ashok Parekh, with the active support of A V Birla, that the entire cell was designed and manufactured indigenously, with the need to import only mercury.

The later designs of De Nora cells had hanging type anodes making it easy to adjust individual anodes. So, it was possible to achieve a lowest possible inter-electrode gap for least resistance of brine and the lowest power consumption possible. The metal anode used for amalgam cells is characterised by excellent electrochemical properties and economy. But it has the attendant problem of occasional formation and deposit of mercury butter on the cathodic bottom plate, which can be a cause of cell performance deterioration and result in short circuiting and damages to the anodes.

To avoid this, an anode protection device was developed.

When the inter-electrode gap changes because of deposits of mercury butter on the cathode plate, there will be an increase of current flowing through the inter cell busbars connecting with the metal anode, and the voltage at the risen part of the mercury layer is lower than at other parts of the cell. The anode protection device originally developed used to detect either over current or lower voltage than the present values and in case of any deviation will lift the anode to prevent the short-circuiting. This system, however, could not exactly determine the abnormal and normal conditions of the cells. Thus, the improved version synthesised two factors, i.e. current and cell voltage as input data. The synthesised value is a determinant of abnormality to be compensated to realise stable cell operation at present.

A frame structure is placed on top of the cell in which the anodes are fixed. The anodes are connected to a motor control. Individual anodes and the busbars are connected with sensors.

When some abnormality occurs in electric current distribution in inter cell busbars and/or cell voltage distribution caused by abnormal inter-electrode gap, the anode protection device magnetic amplifier detects that condition and sends a signal to the motor control circuit to lift the anode as well as to the alarm annunciation circuit to let the operating personnel know of the abnormality. As soon as the electrical current and cell voltage return to normal level, the anodes can be lowered to the preset level.

To optimise the specific consumption of electrical energy, a good amount of mathematical modelling of reactors has been done.

Metal Anodes

During 1970s and 1980s, the effort of the industry was directed towards energy conservation and pollution control. Adoption of Titanium Metal Anode in place of the conventional graphite anodes completely revolutionised electrolytic chlor-caustic production during this period and today more than 95% of chlor-alkali units in India are operating with Titanium Metal Anodes. The essential characteristic of metal anode is that it is permanent in nature and saves power to the tune of 15% when used in place of the consumable graphite anodes.

Anode, the positive terminal of an electrolytic cell to which negatively charged ions travel, is the basic component in any electrolytic process besides the cathode. Caustic soda and chlorine are simultaneously produced by electrolysis of common salt solution in specially constructed cells and therefore categorised as chlor-alkali industry.

Whatever might be the process changes, the concept and structure of anode continue to remain constant, while it has varied in the case of cathode. In the mercury cell, the mobile mercury is the cathode. In the diaphragm cell, steel cathode with asbestos diaphragm is used. In the membrane cell, the cathode is made of nickel or stainless steel and is generally activated.

Chlorine, a highly corrosive and hazardous gas, is released at the anode. Hence, there is little choice for anode materials of construction. Precious metals being prohibitively costly for a low value product, graphite even with certain of its shortcomings like brittleness, low electrical conductivity, constituted the only anode material since the beginning of the electrolysis production of caustic soda a century back.

Constant improvements were made to offset the shortcomings of graphite. The improvements were oriented towards minimising the chlorine gas bubble effect, the erosion of the graphite, and the reduction of voltage drop.

Despite all these developments, three factors defied enduring solution:

1. The wearing away of the graphite in the harsh environment as a consequence of which the inter-electrode gap increased. Therefore, the resistance in the cell increases, and to pass the same quantity of current requires bigger potential difference. The energy efficiency goes down and power consumption increases to the extent of uneconomical operation.
2. The frequent opening of the cells for the renewal of the eroded graphite anodes, resulting in plant down time beside emission of entrained chlorine.
3. The disintegrated graphite particles carried the entrapped mercury with the resultant pollution of soil and water.

However, the escalation of power costs and greater awareness on environmental conservation, gave no choice to the eletrolytic process industry but to seek an alternative to graphite anodes.

It was in the twenties of this century, solid platinum was considered as an anode material. But the prohibitive cost in a low value product spurred the idea of application of thin coatings of platinum by electroplating over the substrates made of less expensive non-corrossive refractory metals like tungsten and tantalum. Even then the price factor was restraining and forbidding to induce any interest.

During the fifties when titanium emerged as commercially available material, the exceptional corrosion resistance of Titanium in brine of all concentrations and wet chlorine offered itself as a new material of construction for chemical industry. But the poor electrical conductivity and anodising characters disqualified it as an anode material.

In 1958, Dr Henry Bernard Beer from Holland, registered a patent with a discovery that by electroplating a noble metal like platinum or rhodium to the surface, titanium is capable of passing anodic current. However, the electroplated anode presented a high over potential of chlorine.

Simultaneous and contemporary developments on replacing electroplating with coating by thermal decomposition heralded the energy saving titanium metal anodes for chlor-alkali industry during the Sixties.

Since then, the titanium metal anodes have experienced an unprecedented application throughout the world. Today more than fifty percent of the world chlorine production and 95% of India's chlorine production is made by means of titanium metal anodes. They have found access in the classical electrolytic processes, i.e. in the diaphragm cell process and the mercury cell process, as well as the modern membrane cell technology.

The advantages of the titanium metal anodes are:

a. Dimensional stability
b. Light weight per unit area
c. Minimum gas bubble effect
d. High anodic current density upto 15 kA/sq.m.
e. Low, constant cell voltage over a long period of time
f. High current efficiency
g. High chlorine production per anode unit area
h. No CO2-contamination of the cell gas from the anode
i. Low hydrogen content in the cell gas
j. Reduced cell maintenance costs
k. Improved cell room hygiene

Though metal anode was developed and proved a boon to the chlor-alkali industry, this technology was kept as a closed-guarded secret of world monopoly and was not available to India, excepting at a very high cost in foreign exchange (28). This necessitated simultaneous development in India. Central Electrochemical Research Institute (CECRI), a laboratory of Government of India's Council of Scientific and Industrial Research took up this task, under the stewardship of the then Director, Dr H V K Udupa.

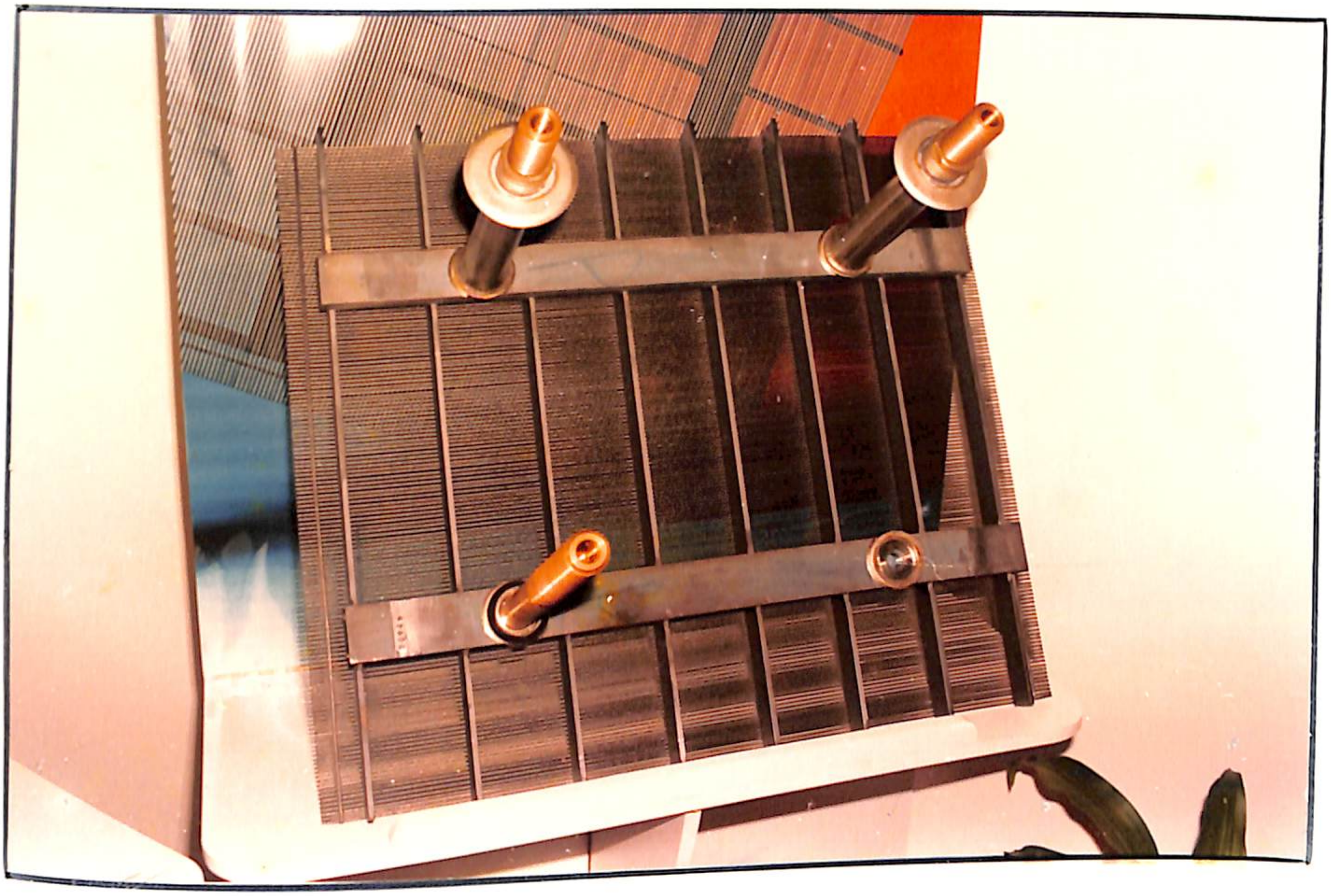
The development of metal anode called TITANIUM SUBSTRATE INSOLUBLE ANODE (TSIA) involved two parts.

First, the fabrication of the basic titanium substrate, and second activation of the same with noble metal oxides. CECRI were able to develop the coating technology, but they were stuck for want of a good fabricator of Titanium substrate.

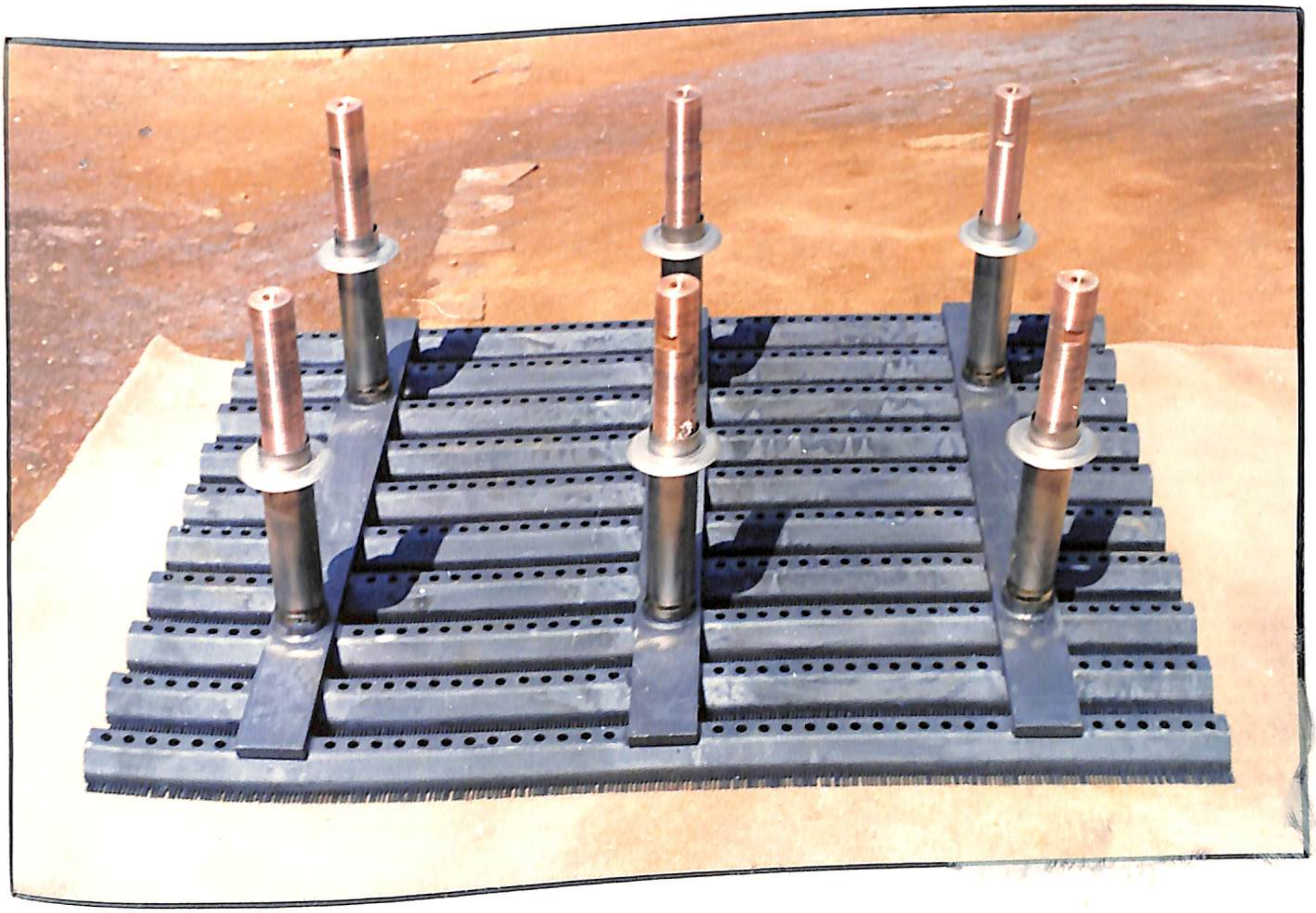
They overcame this with very active collaboration of a Madras-based Company, Messrs. Chemfab, who had developed the titanium welding technology in-house (Fig.3.13, 3.14).

A paper (29) of Dr H V K Udupa, describes the success story of indigenous development of titanium metal anode in India, and how technology management proved key factor there.

FIG. 3.15



TITANIUM METAL ANODES FOR MERCURY CELLS



SODIUM CHLORATE CELL WITH TITANIUM METAL ANODES

TITANIUM METAL ANODES FOR SODIUM CHLORATE CELL

In the author's own words as to how a technology is made a success:

Quote

The critical factors are:

A) What types of technologies are available?

Under what status, terms and conditions, these are available?

Entrepreneur who receives it and what kind of capabilities he should have, depending upon the type of technology that is available for implementation.

Insoluble Anode, an example

Managerial skill, technological background or scientific, engineering background and capability and commercial acumen.

These should be available at different extents depending upon the technology available.

B) With special reference to TSIA:

What was the status of the technology available when Mr C H Krishnamurthi Rao wanted to implement the technology. What was required was scientific background for developing the anode; and the data/details regarding coating was available with the laboratory, but the technology and expertise for making the structure on which coating is to be given was not available.

Originally, when the anode was to be tried out in a diaphragm cell, there was no problem. Because, what needed was only a titanium plate or expanded metal on which coating needed to be given.

But, when the anodes were to be made for mercury amalgam cells, it required fabrication of titanium structure. This required engineering and fabrication expertise of the structure and then only the question of coating arose.

It required an engineering skill and Mr Krishnamurthi Rao had it in abundance.

Titanium metal was new to India then and even the metallurgy was not known. How to handle it and how to fabricate was not known to anyone and only HAL had some knowledge on this. But, then it was not available for general industries. It required someone to develop the titanium fabrication technology............

Fabrication of titanium structure for anode was not a simple fabrication with good welding alone. These anodes are to work for decades in an electrolytic cell.

These structures are the current distributors; so, it required a complete understanding of the engineering behaviour, end use and the criticality of manufacturing process. This was a challenge and Mr Rao took it up very courageously.......

Cordiality between technology generators & entrepreneur: The perfect understanding of the entrepreneur with the Institute enabled quick and effective implementation of the technology. The engineering skill and commercial acumen of the entrepreneur harmoniously function with the scientific and technological skill of the scientists of CECRI.........

We feel proud that we have been able to successfully establish the metal anode industry in India, thanks to the active and able involvement of Sri CHK Rao of TEAM Co. Ltd., Madras. He left no stone unturned to ensure the commercialisation of the technology and went even a step further to use these anodes in the first ever membrane cell plant in the country, M/s Chemfab Alkalis Ltd., at Pondicherry. These anodes have also been employed with great advantage even in the production of chlorate. Mr Rao took the lead even in this by putting up a 6 tonne/day plant for making chlorates at Pondicherry. This was a trend-setting example and others followed suit and the chlorate industry has also adopted the meal anodes for commercial production of chlorates.

Unquote

Today, more than 60% of India's caustic soda production is using TSIAs of Titanium Equipment and Anode Manufacturing Co. Ltd., the collaborators and first licencees of CECRI, saving a phenomenal 350 million units of electricity every year.

Advent of membrane

While the introduction of Metal anodes helped greatly in reduction of power consumption and to some extent control of the mercury pollution, still the mercury pollution could not be solved permanently, since the process continued to use mercury as the moving cathode. Hence, the mercury used to escape through the products, atmosphere and effluent.

The 1970s were very crucial in the history of chlor-alkali industry in the world. It was this year that the Japanese Government gave a directive to all the chlor-alkali Plants in Japan to change-over to different processes which will not use mercury and a time-frame was given. This was due to the Minamata disease. The people eating fish caught from the sea around the Minamata contracted a peculiar disease. This was traced to methyl mercury from the chlor-alkali plant discharges which was swallowed by the fish and in turn got into the human system. Methyl mercury being non-biodegradable, this affected the human beings who ate such fish.

Although the industry was successful later to prove that it was not the cause still the legislation went through and all industries had to change-over. This saw the advent of Ion Exchange Membrane Process.

3.8 THE CHEMFAB ALKALIS SAGA

Titanium Equipment and Anode Manufacturing Co. Ltd. (TEAM), pioneered the Titanium Metal Anodes to caustic soda industry and enjoys more than 60% of Indian market share.

They furthered their engineering and manufacturing capabilities and expertise in exotic metals and through their R & D efforts improved upon the anode coating technique to international standards.

The Company concentrated on various aspects of energy consumption in the caustic soda industry and worked towards energy saving and increased efficiency.

But, they realised that one very important area causing great concern was the mercury pollution. In the mercury amalgam process, mercury gets discharged through air, water and sludge. Hence, they concentrated on this and brought in a Mercury Pollution Abatement Technology to control the mercury discharge into the atmosphere. Still, the problem was not totally solved.

C.H. Krishnamurthi Rao, the Chairman and Managing Director of TEAM, who travels widely and attends various seminars and conferences, developed very close contacts with leading technologists. This gave him the direct contact with the membrane cell technologists. It was early 1980 and membrane cell was a sunrise technology then.

The Membrane cells totally avoid mercury and asbestos diaphragm in the process and thus proved to be a very safe process and highly environ-friendly. Japan has been the fore-runner and by then a lot of Plants in Japan had switched over to this in view of the Japanese Government's directive to the industry to scrap mercury cells.

One other big advantage of this was that it consumes about 30% less energy than the other two processes.

Till then, the 'minimum viable capacity' of a caustic soda industry was thought to be 100 tonnes per day and many consumers could not go in for their own 'captive' plants. But, membrane cell plant also provided an opportunity to go in for smaller sized plants and this can greatly benefit setting up of 'captive' plants.

TEAM realised that the 'only answer' for tackling the twin problem of mercury pollution and power consumption was that India should switch over to this system. But, this technology being very new the industry was apprehensive about the performance of membranes in Indian conditions, where the power supply is very erratic. Being steadfast in its conviction, TEAM decided to set up its own Membrane Cell Plant - THE FIRST ONE IN INDIA; that too a small-sized one. With this, it wanted to prove to the Indian industry that not only membrane is the solution for them, but also small-size plants can be commercially viable.

TEAM took a licence for a 25 tonnes per day plant to be established at Pondicherry.

Then it scouted around for the right technology. It looked for a Technologist

- who had set up sufficient number of plants successfully
- who will technically support whole-heartedly this maiden venture in India
- who will adopt maximum possible Indian materials and Indian talents, both in engineering and in manufacturing
- who will also be willing to transfer the membrane cell technology to TEAM, so that India will have the manufacturing technology as well.

The author visited the operating plant of each technologist to ascertain for himself the correctness of the claims made by the various technologists and the various operating problems the plants had.

Finally, TEAM chose Chlorine Engineers Corp. Ltd., (a Mitsui Company), Japan, who had all the qualifications that Rao desired.

Thus, the FIRST ION EXCHANGE MEMBRANE CELL PLANT in India of CHEMFAB ALKALIS LIMITED was set up at Pondicherry and went on stream in June 1985.

Some of the important aspects of this Plant is that all the electrolyzers for this plant were made in India by TEAM, importing only critical and non-available components.

The anode coating was done in India by TEAM.

The performance of this plant was far superior. This plant witnessed an unprecedented power-trippings of 700 in the first year of operation. The plant withstood these conditions very well.

The power consumption was 30% lower. The environment is absolutely clean and more than 60% of the plant area is covered only with green.

Discharge of water and solid is very low and even that contained only salts and no toxic substances.

It proved that a 25 tpd plant can be commercially viable.

Prestigeous Institutions like Federation of Indian Chamber of Commerce and Industry and Indian Chemical Manufacturers Association have appreciated this Plant with their Awards.

Chemfab Alkalis became an eye-opener to the Government, who immediately issued a notification that "all new capacities and any expansion of capacity" in caustic soda industry "shall be based only on membrane cells".

The Government also announced import duty concessions for membrane cells.

The whole industry was curiously watching the performance of Chemfab Alkalis. It attracted Chief Executives and technical members of all the caustic soda industry, who all after visiting this Plant, were convinced that the only way out for them was membrane cells.

The success of Chemfab Alkalis resulted in setting up of another membrane cell plant in Andhra Pradesh and the other existing plants started changing over to membrane cells.

During the last 8 years, 6 plants have changed over to membrane cells, thus straightaway increasing their capacity by 30%, and the new facilities coming up are all adopting membrane cell technology.

Thus, Chemfab Alkalis is a saga of success in the annals of Indian caustic soda industry (Fig. 3.15).

INDIA'S FIRST ION EXCHANGE MEMBRANE
ELECTROLYSER CAUSTIC-CHLORINE PLANT
OF CHEMFAB ALKALIS LTD., PONDICHERRY.

3.9 CHLORINE - ENVIRONMENTAL ISSUE

Ozone Layer Depletion

It is now widely accepted that stratospheric ozone layer damage is caused by certain highly stable compounds which contain chlorine. These include chlorofluorocarbons (CFCs) used primarily as coolants in air conditioning and refrigeration, halons used in fire-fighting equipment and the multi-purpose solvents methyl chloroform (1,1,1-trichloroethane) and carbon tetrachloride. All of thse products are due to be phased out under a series of international environmental accords called the Montreal Protocol, which were adopted in 1987 (30).

The ozone layer is composed of ozone molecules (each molecule comprises three oxygen atoms) scattered thinly and at random among the other atmospheric gases in the stratosphere, which begins about 7 k.m. above the earth's surface. The ozone layer is important because it screens out some of the sun's ultraviolet (UV) radiation. Too much UV can harm human health or the environment; the thinner the ozone layer, the more UV light reaches the earth. Harmful effects of too much ultraviolet light may include: (a) skin cancer, cataracts and suppressed immune system efficiency; (b) harm to small sea creatures such as plankton, fish larvae and shrimp; (c) degradation of materials used in buildings, paints and packaging, and (d) reduced crop productivity because many plants are sensitive to UV rays.

A popular misconception is that chlorine released on earth or other chlorine-containing products may contribute to ozone layer damage. Chlorine gas is far too unstable to reach the ozone layer, some seven miles up. Studies indicate that most chlorine gas molecules from a release are broken down by sunlight into chlorine atoms very close to the earth's surface. These atoms react with other near-earth atmospheric chemicals with little or no known environmental effects.

For most chlorine-containing products, the chlorine atom is locked within a chemical matrix that does not allow it to escape. For example, polyvinyl chloride; once chlorine is processed into PVC, free chlorine gas cannot be liberated from the product.

Today, chlorine is involved in meeting the most essential needs of modern society. It has been estimated that the chlorine molecule is involved in more than half of all commercial chemistry. Chemical Engineering News magazine has described chlorine as the single material in which the production of other chemicals most depends.

Chlorine's role in purifying drinking water to guard against diseases as cholera, typhoid fever and dysentery is vitally important. In fact, drinking water chlorination is among the key public health measures responsible for increasing the expectancy in the 20th century. Chlorine-based agents also are responsible for hospital hygiene, household cleanliness and swimming pool water purity. And chlorine is the key disinfectant for sewage treatment.

Chlorine is used to manufacture plastics such as versatile polyvinyl (PVC) and polymers like polyurethane. It is used in making many organic chemicals, including solvents for dry-cleaning and metal degreasing, and in the production of crop-protection chemicals, pharmaceuticals and cosmetics.

When used in pulp and paper processing, chlorine helps produce fine stationery and book pages that are bright-white and long-lasting. And chlorine helps ensure the personal care products like disposable diapers and paper towels are strong and absorbent.

Chlorine Safety : Chlorine Shipping Containers are strong and durable. All are built from extremely durable materials to exacting Chlorine Institute guidelines. They are inspected and tested rigorously before being put into use and on a regular schedule thereafter.

Chlorine and chlorine-based products are essential to modern-day life; they are interwoven into the fabric of society. Many are indispensable. The chlor-alkali industry believes that the benefits of employing chlorine are clear and that they vastly outweigh any risks - real or perceived - that may be associated with chlorine and related products.

3.10 SUCCESS INDICATORS

Titanium Metal Anode

The introduction of Titanium Metal Anodes in 1977 has had a dramatic effect on the caustic soda industry.

The industry was on an average consuming a power of 4000 kWh/tonne of caustic soda while using the graphite anode. Caustic Soda is a power-intensive industry and 60% of the cost of production was accounted for towards the cost of energy.

So, this very high power consumption had a very severe impact on the industry.

With the introduction of Titanium Metal Anodes, the power consumption came down by 10-15%. This not only meant a huge power saving to the industry and the Nation, but also the industry could take advantage of the saved power and to this extent the industry could produce more (Fig. 3.16, 3.17, 3.18 and 3.19).

The power saved accounted for about 400 million units of electricity every year. In terms of caustic soda, this meant an additional production of app. 115,000 tonnes per annum.

Another greatest advantage this brought was that India, through Titanium Equipment and Anode Mfg. Co. Ltd., Madras, could get into the Technology Map of the world on Ion Exchange Membrane Cell Technology, much ahead of even the developed countries of the West and the North.

POWER CONSUMPTION AC kWh/T-NaOH

Graphite Vs TSIA (Diaphragm)

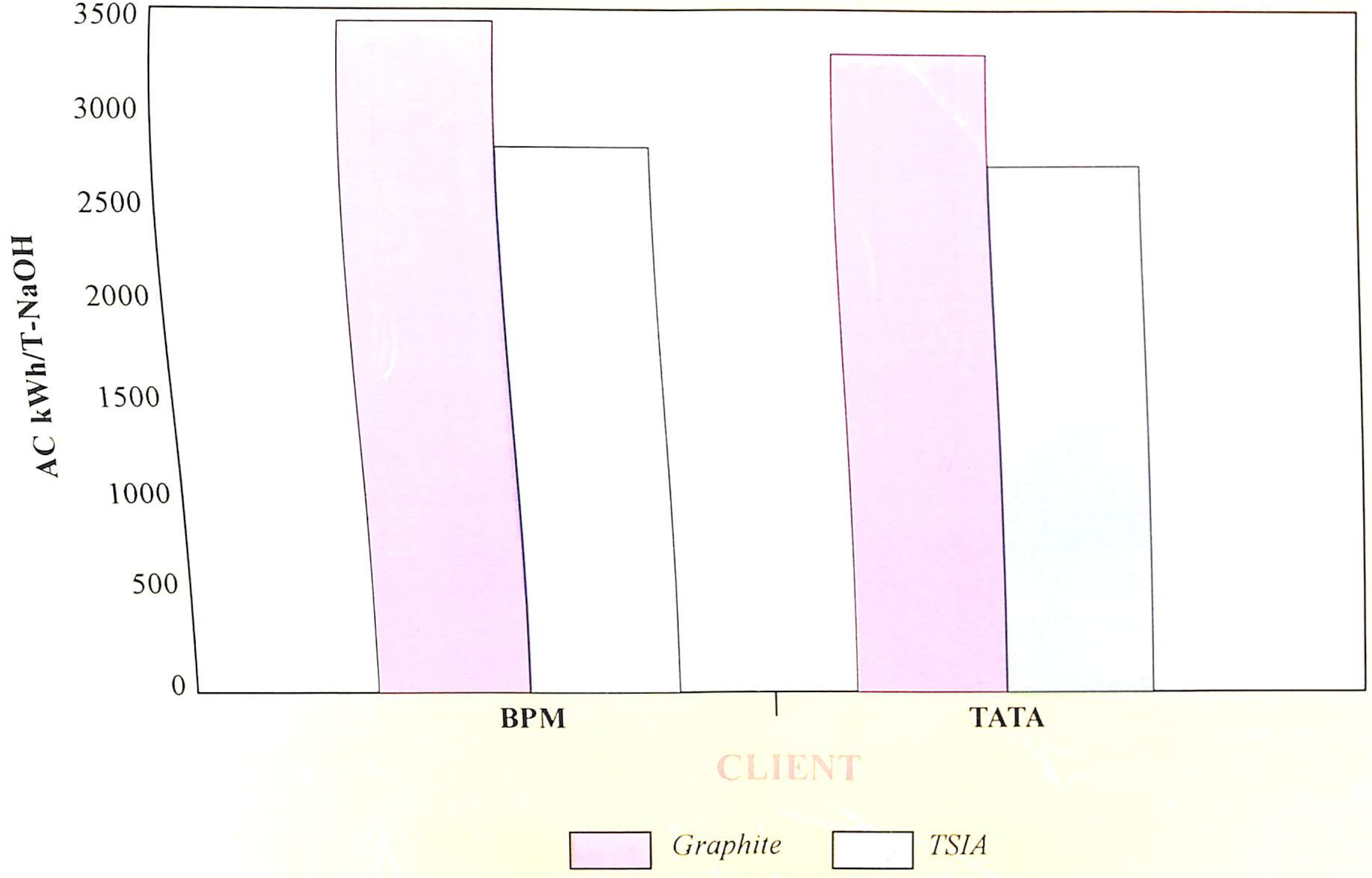
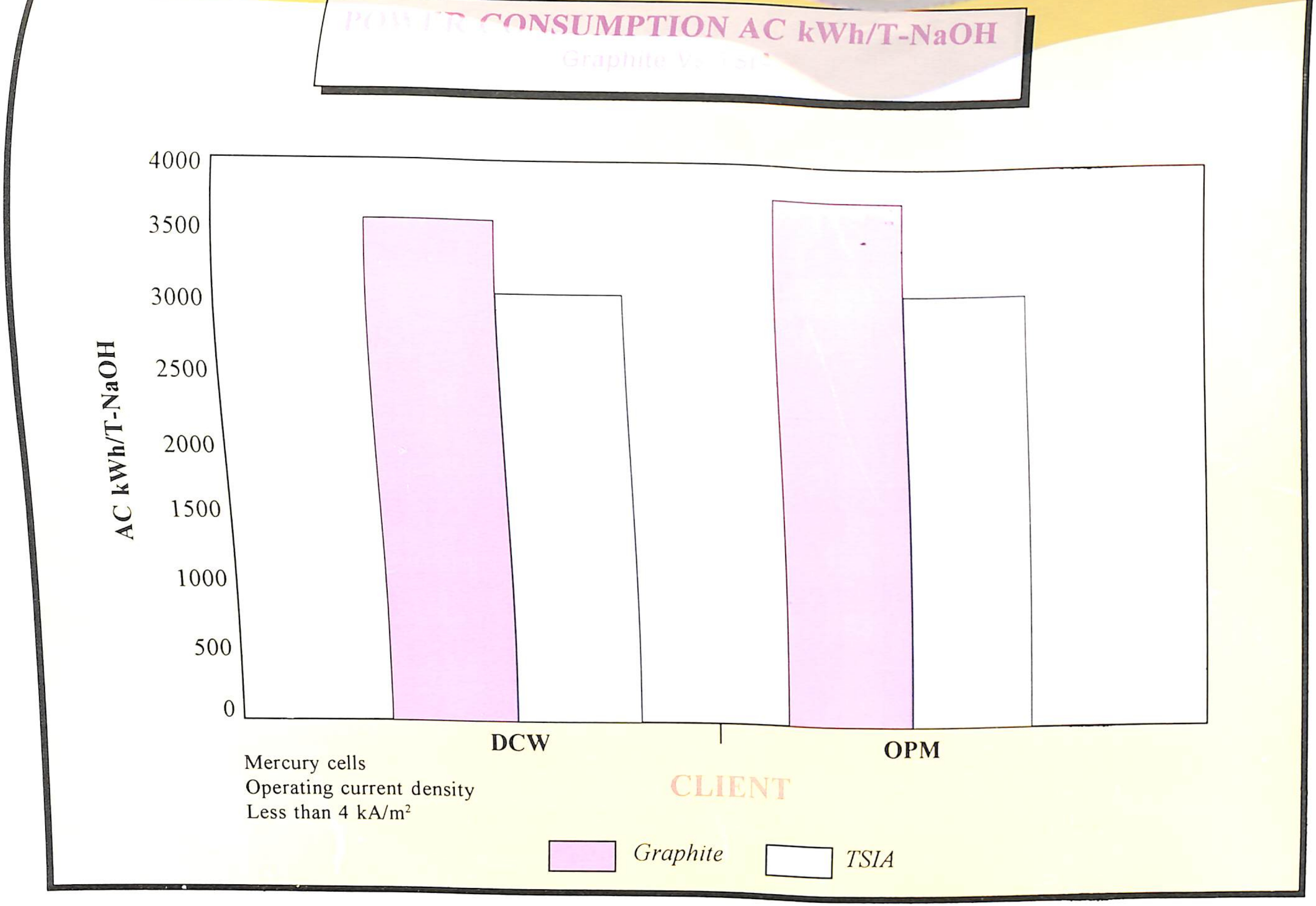
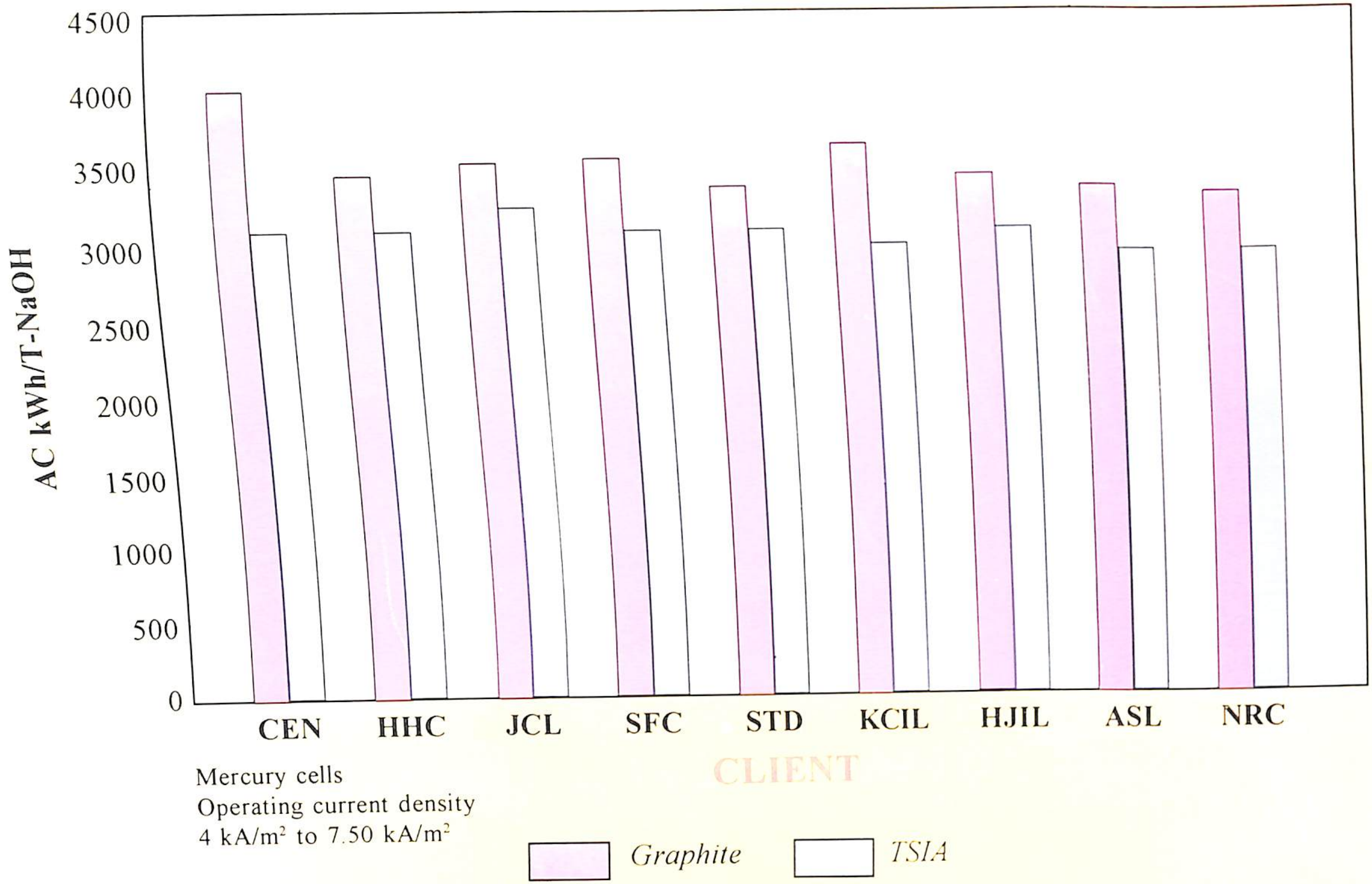


FIG: 3.17


CONSUMPTION AC kWh/T-NaOH
Graphite
AC kWh/T-NaOH
4000
3500
3000
2500
2000
1500
1000
500
0
DCW
OPM
CLIENT
Mercury cells
Operating current density
Less than 4 kA/m²
Graphite
TSIA

POWER CONSUMPTION AC kWh/T-NaOH
ite Vs TSIA



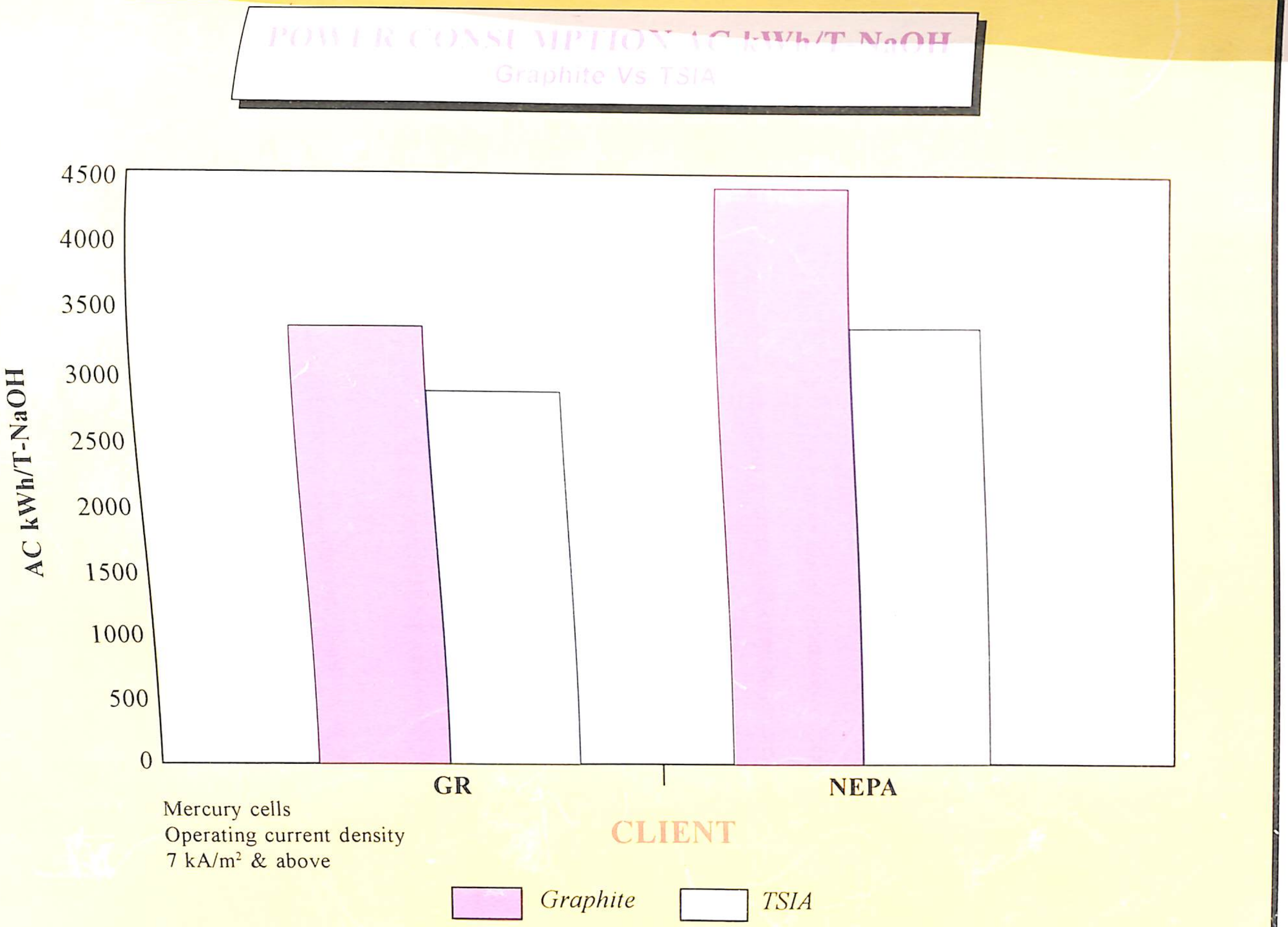

POWER CONSUMPTION AC kWh/T NaOH
Graphite Vs TSIA
AC kWh/T-NaOH
4500
4000
3500
3000
2500
2000
1500
1000
500
0
GR
NEPA
CLIENT
Mercury cells
Operating current density
7 kA/m² & above
Graphite
TSIA

FIG: 3.19

Ion Exchange Membrane Cells

Acquisition

Anticipation of the problem : Chemfab, with its long association with the caustic soda industry, as an equipment manufacturer could recognise the two major problems that always confront this industry, namely "energy" and "environment".

Anticipation of the future : The conventional processes adopted for caustic soda production were mercury-amalgam process and diaphragm process, the most widely used process in India being the former. With 34 plants operating with this process, they were holding an inventory of 2000 tonnes of mercury and every year about 200 tonnes of mercury was discharged into the environment through products, sludge and air. There was no control on the import of mercury. On the other hand, diaphragm process employed an asbestos diaphragm, which is toxic and a health hazard. Chemfab perceived that if this industry were to be baled out of this severe environmental problem, the only way is to adopt a latest state-of-art technology.

At the same time, the Japanese Government, because of the ill-famous Minimata disease, had decreed that all the Caustic Soda plants in Japan should switch-over to some technology other than mercury process. The only other technology available then was diaphragm process. This, again, involved use of health-hazardous asbestos diaphragm. These pressures led to the development of Ion Exchange Membrane Technology. This took place simultaneously in Japan and USA.

The arrival of Ion Exchange Membrane technology coincided with Chemfab's quest for a new technology for production of caustic soda/chlorine. Chemfab then got in touch with everyone all over the world, who claimed to have this technology. Chemfab was looking for a partner who had the best technology; who would extend all support to make it a success in India; who would train Chemfab's Engineers both in Japan and in India; interact closely with Indian Engineers who would perform the Detailed Engineering and most important of all, would employ the indigenous manufacture and Indian talent to the maximum extent possible. Finally, Chemfab zeroed in on 3 Companies - one in USA, one in Germany and one in Japan - who were willing to meet the requirements of Chemfab.

The many similarities between the Japanese way of working and that of Chemfab, led to a cultural alliance between Chemfab and a Japanese company. Another important aspect which weighed in favour of the Chlorine Engineers Corp. of Japan was that they were a medium sized company. In Chemfab's opinion, a mega company might not mind a failure whereas a small one would not be able to stand up to the requirement. On the contrary, a medium sized company would spare no effort to establish the success of a technology.

Assimilation

The Methodology: Chemfab along with their Japanese counterparts discussed with various caustic soda plants in India the possibility of their adopting this state-of-art technology. But, each one had an inhibition on the feasibility of adopting it in Indian conditions. Chemfab, headed by a technocrat, had the right vision and conviction that a proper technology had to succeed and decided to set up a caustic soda/chlorine based on this technology themselves.

Documentation: The collabortors were required to provide proper documents which comprised of the Know-how, Design and Basic Engineering for this Plant.

Choice of people: In order to make the technology a success in Indian conditions, Chemfab felt the need to perform Detailed Engineering in-house. This task was undertaken by an associate Engineering Company of Chemfab.

In order to assimilate the technology properly, Chemfab identified a very senior Technologist/ Engineer/ Chemist with an experience of 32 years in the field of caustic soda/chlorine and interested him with the prospect of setting up the first Ion Exchange Membrane Cell. He was aided by a team of competent technical people and inhouse engineering company to interact with the Japanese and to assimilate the technology. This team, along with a team of executing engineers took the responsibility of setting up this Plant. Thus, Chemfab Alkalis, the first ion exchange membrane cell caustic soda plant in India, was commissioned on 2nd June 1985 at Pondicherry.

Sustainability Insurance

Technological Success: This was a success story with many facets:

- The industries who were apprehensive about its adaptability after watching Chemfab's success, have found this to be a boon to the Indian caustic soda industry.

- This was an eye-opener to the Government of India, who subsequently issued directive that all the new capacities and expansion of existing capacities shall be only based on ion exchange membrane cells.
- The membrane manufacturers, who once offered a guarantee of only one year, after seeing the performance of Chemfab Alkalis, are now offering a guarantee of 3 years minimum.
- The energy saving is an exceedingly high level of 30%.
- The volume of sodium chloride brine handled is 250% less, because of the higher depletion of sodium and higher efficiency of the membrane cells.
- Chemfab could establish a caustic-chlorine production facility at a very low cost.
- Cost of production is far lower because of the very low power consumption. By using a high purity salt, the brine purification cost will be very low.
- When all the caustic soda plants change-over to membrane cells, India will be saving 1,000,000,000 units of electricity every year and there will be no mercury inventory and no mercury discharge into the atmosphere.

Technological Vigil: A team of engineers/chemists with the help of the heads of a few national laboratories always keep a close watch on the developments taking place all over the world, to enable Chemfab to keep pace with the advancements. They attend subject seminars and also organise seminars and discussions with visiting Indian and foreign experts.

On-line R & D: Chemfab has an unique concept of "on-line R & D". Many new concepts are tried out in the working plant straightaway. Four outstanding successes have been -

1. "Recovery of Barium Sulphate", a very high value added product, from the sludge, a unique process invented for the first time in the world,
2. Introduction of Reverse Osmosis for treating the raw water for feed to Demineralised Water (DM) Plant. This has tremendously reduced the load on the DM Plant, and both the Anion Exchange Resin Bed and Cation Exchange Resin Bed were removed and only the Mixed Bed is retained. There is a substantial saving in the chemical consumption.
3. "Recycling of the entire water", leading to practically "zero effluent discharge".
4. Adoption of a special Water Seal Clarifier. This helps reduction in temperature loss and helps in uniform settlement of sludge.

In view of pollutant-free high purity products, the caustic soda, chlorine and hydrogen produced in this plant lead to a lot of down-stream products with a very high value addition.

The above factors are acting as insurance for sustainability of Chemfab.

CHAPTER 4

OTHER EXPERIENCES IN TECHNOLOGY MANAGEMENT

4.1 A PROCESS AND ENGINEERING ANALYSIS OF THE BHOPAL MIC DISASTER

A Technical History of the Bhopal Plant

On the night of 2nd/3rd December 1984, a major chemical disaster occurred at the factory (Fig. 4.1) of Union Carbide (India) in Bhopal, Madhya Pradesh, when a buried stainless steel tank exploded releasing large quantities of Methyl Isocyanate (MIC). This extremely toxic chemical rapidly dispersed in the midnight air and caused horrible devastations. Panic and chaos prevailed when people young and old, men and women, adults and children stampeded to escape the attack by the toxic gas. Atleast 2500 people died, several thousand animals were suffocated to death and injuries of varying degrees were caused to over a 100,000 people. Large tracts of vegetation were damaged.

At the same time, it came to be known that a second buried tank containing large quantities of MIC existed, posing a serious hazard. While public authorities and medical specialists tried to provide relief to affected people and moved them to safer places, a task force operated parallelly to examine the contents of the second tank. Following a risk management system, the MIC present in the second tank was processed safely during 16-22 December 1984.

The Bhopal MIC leakage ranks today as the worst disaster so far in the chemical industry anywhere in the world. The Bhopal factory producing SEVIN, a proprietory formulation of the insecticide carbaryl was a subsidiary of Union Carbide Carboration (UCC), USA, a chemical giant with world-wide ramifiacations. The Union

Carbide factory in Virginia, USA also produces MIC. The technical know-how and designs for the Bhopal factory were provided by UCC. The question then arises:

- if the USA plant has been operating without any major chemical disaster, how come the technology transferred to a subsidiary resulted in such a major disaster?
- legal implications apart, it is pertinent to examine the Bhopal MIC disaster from the technology and technology management aspects. Was the technology transfer carefully done?
- was there any relaxation of safety in the designs provided to Bhopal?
- did people who handled the technology transfer exercise adequate care?
- is there reason to believe that there were serious lapses in technology management?

In this background, the present sub-chapter commences.

Properties of MIC

MIC is a highly reactive, volatile and inflammable chemical. According to the UCC brochure, MIC is usually stored and handled in stainless steel 304 and 316 equipment. Iron or steel, aluminium, zinc or galvanized iron, tin, copper or their alloys are prohibited from use.

Purified MIC will react with itself under the influence of a catalyst to form a cyclic trimer or a high molecular weight polymer. Strong bases such as sodium hydroxide, sodium methoxide and sodium acetate, certain metal chlorides such as ferric chloride and stannic chloride catalyse trimerisation. Since the reaction is quite exothermic, contamination of MIC with traces of the catalysts can cause violent reactions.

Highly purified MIC will polymerise spontaneously to a liner polymer/trimer. Water reacts exothermically to produce heat and carbon dioxide. As a result, the tank pressure will rise rapidly if MIC is contaminated with water. The reaction may begin slowly, especially if there is no agitation, but it will become violent. Aqueous sodium hydroxide solution will react with MIC quite rapidly.

MIC with the above mentioned characteristics should be considered as an explosive in addition to it being a highly toxic chemical, and places great demands on operational, maintenance and safety practices.

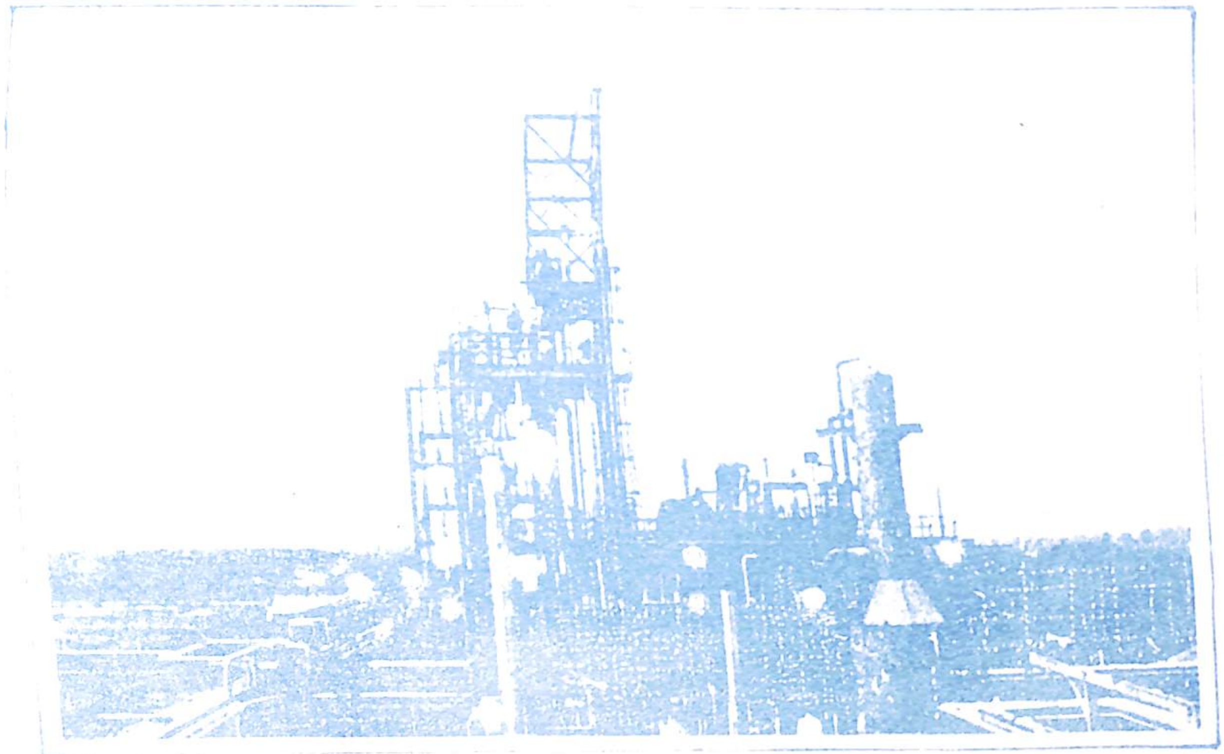
As per the UCC brochure (31), the storage temperature should be maintained below 15°C and preferably at about 0° C. The storage tank is to be equipped with dual temperature indicators that will sound an alarm and flash warning lights if the temperature of the stored material rises abnormally. The tendency of valves on storage tanks to be clogged with solids is also stated in the brochure.

The brochure further states that the cooling medium in the heat exchanger should not be one that reacts with MIC or catalyses the reactions. While chloroform is an example of a safe coolant, use of water does create a hazard.

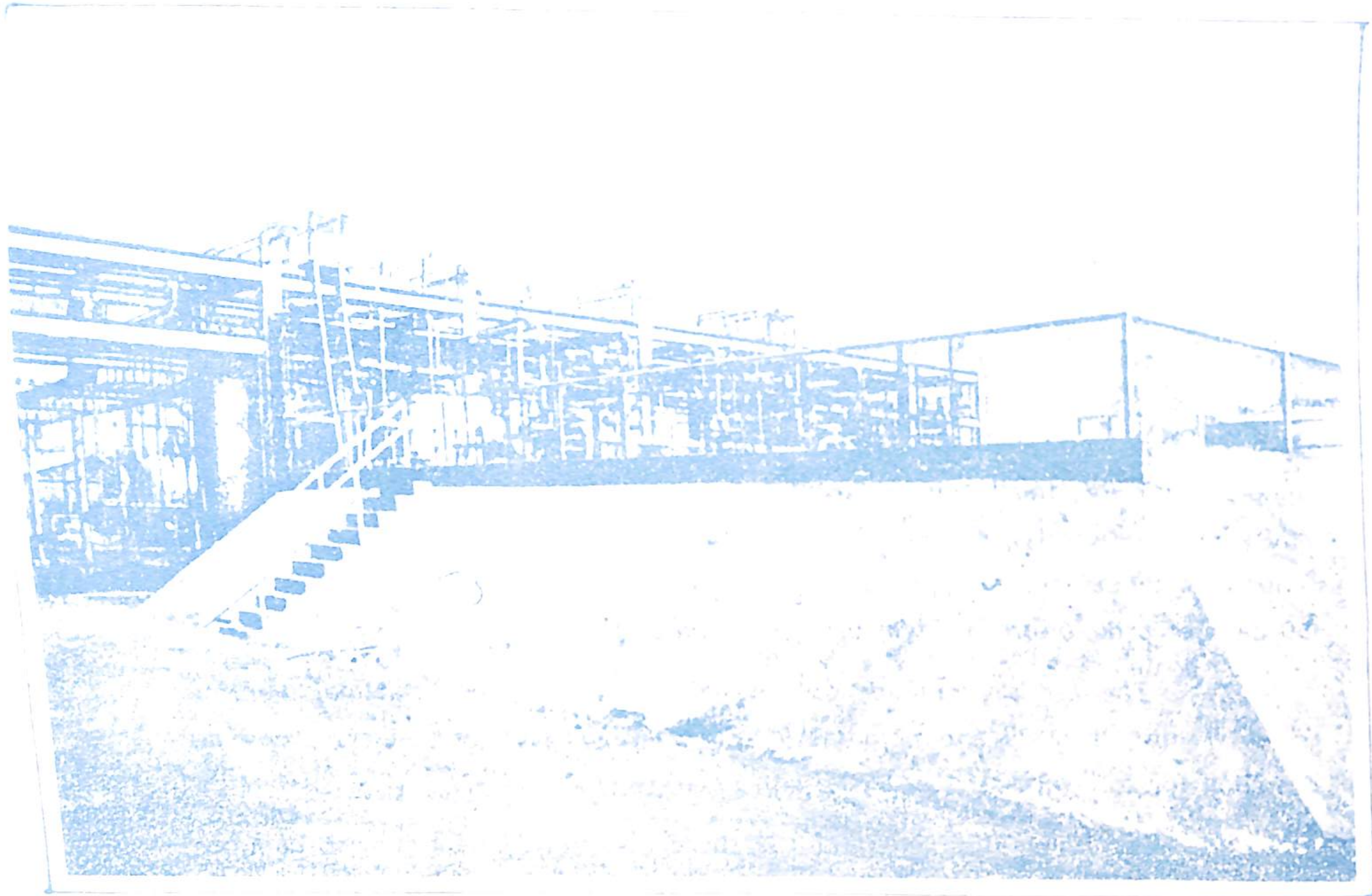
Storage Tank

The MIC storage system comprised the horizontally mounted tanks each of 15000 gallons (57 m^3) capacity and designated as E-610, E-611 and E-619 (Fig.4.2, 4.3). Two of these were used for storing the produced MIC while the third was used for temporary holding of off-specification material. The two tanks together could store 90 mT of MIC, the daily equivalent for fomulation being 3 mT.

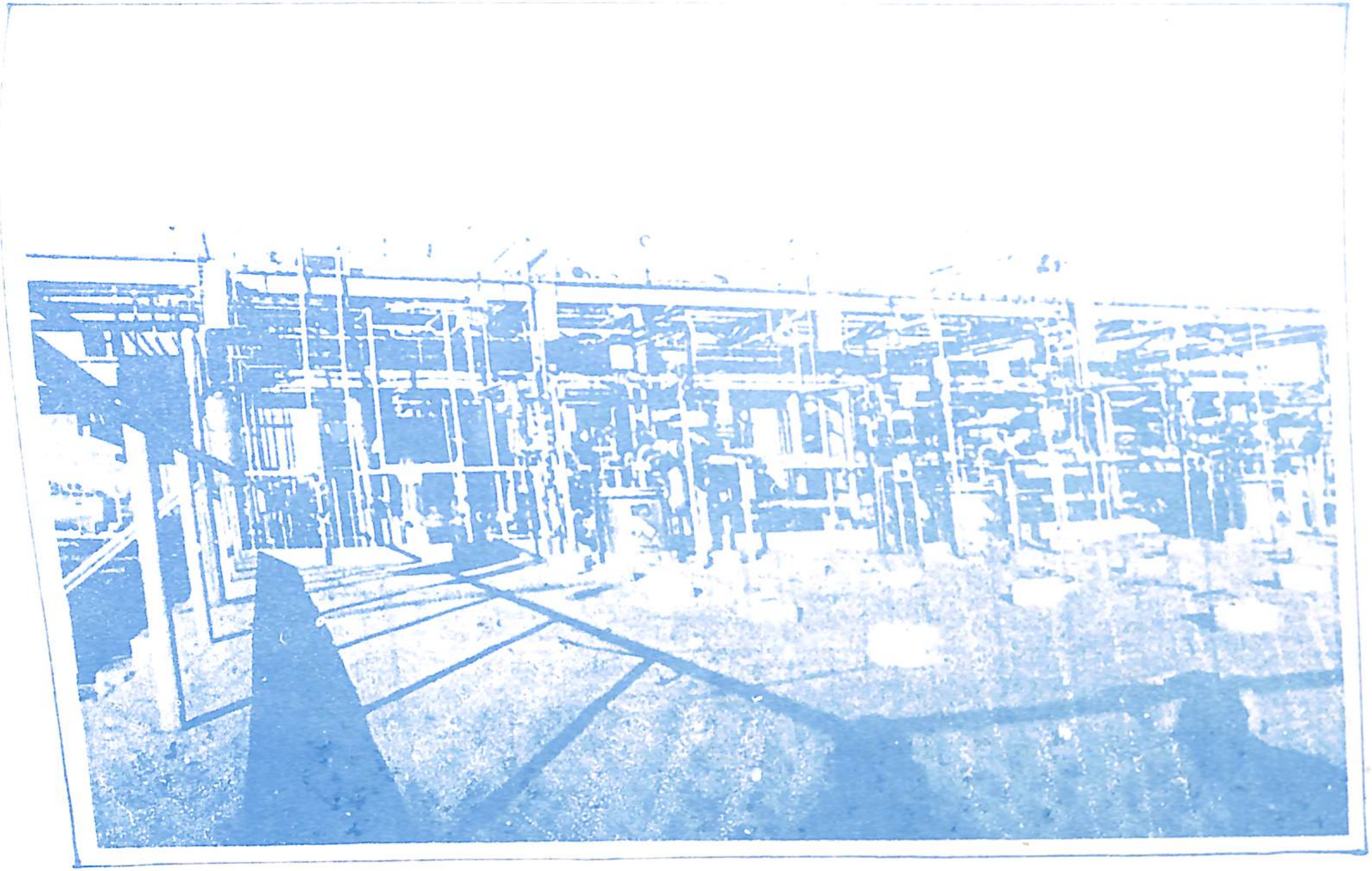
A schematic layout of the common headers and the instrumentation and control system of the individual tanks is reproduced in Fig.4.4.



MIC PLANT

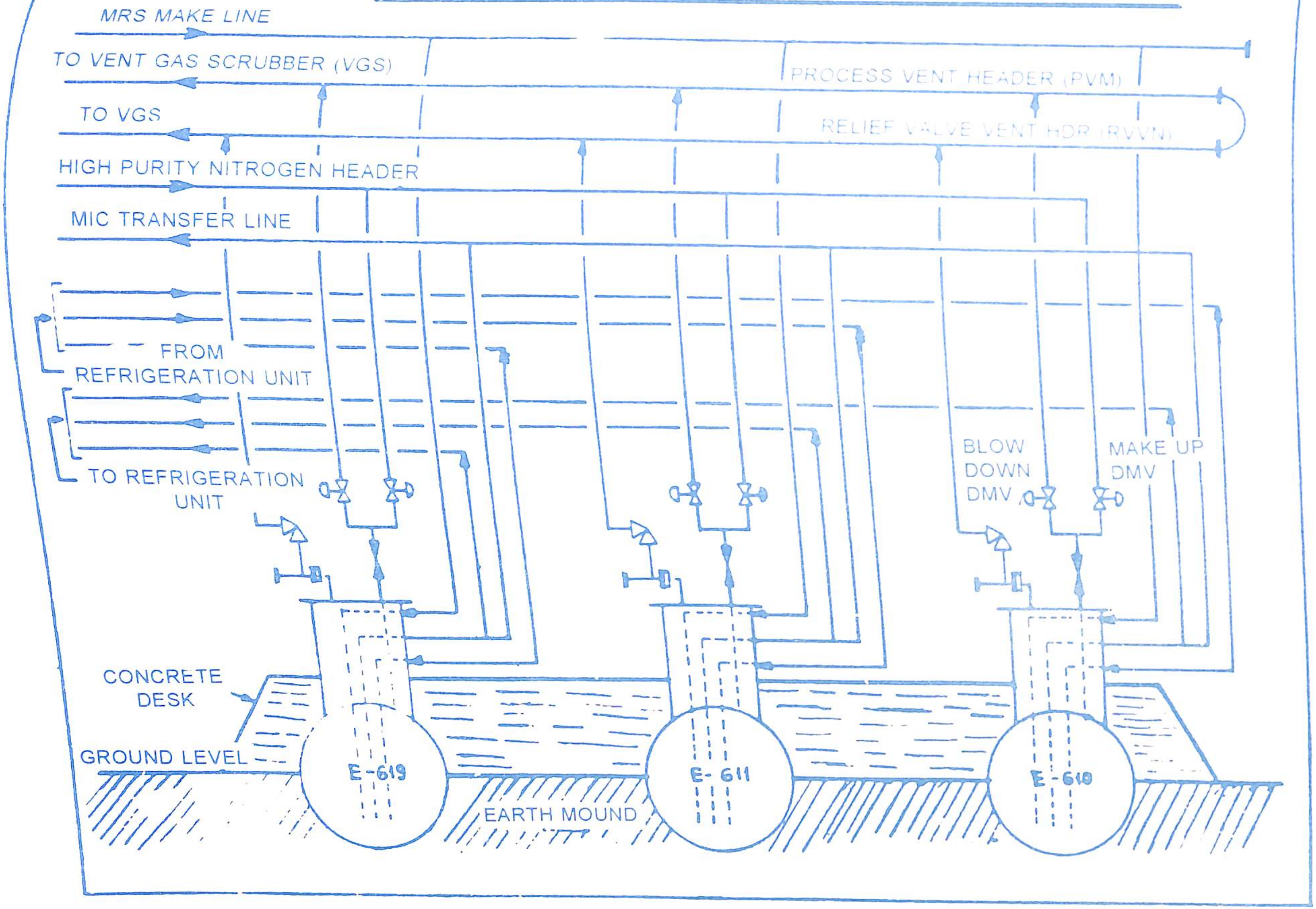


VIEW OF MOUNDED MIC STORAGE TANKS FROM GROUND LEVEL



VIEW OF TOP OF MIC STORAGE TANKS

SCHEMATIC LAYOUT OF COMMON HEADERS OF MIC STORAGE TANKS



The highly toxic and explosive nature of MIC requires that the storage system and its related instrumentation/control be of high reliability.

Inspection of MIC storage tanks is difficult, since they are buried. The ill-fated tank 610 was reportedly cleaned and inspected in 1982. Varying quantities of MIC from production runs at different periods had been filled into tank 610. Similarly, varying quantities of MIC had been removed at different periods.

Commercially produced MIC contains hydrolysable chloride in the form of phosgene and methyl carbamoyl chloride(MCC). Ingress of even a small quantity of water (of the order of 40-50 ml per tonne of MIC) will lead to the reaction of water with the hydrolysable chloride to provide hydrogen chloride and with a little more of water, aqueous hydrochloric acid. This leads to corrosion of stainless steel, the material of construction of the storage tank, leading to the formation of ferric chloride which can catalyse the violet runaway reaction.

The Sevin unit could process of the order of 3 to 4 tonnes of MIC per day. The inventory of MIC in the two storage tanks was the order of 90 tonnes, equivalent to nearly 30 days production.

It is normal plant practice to have intermediate batch tanks to hold production from a single shift or for a day. The product collected in these tanks is analysed, its quality ensured and then it is transferred to the bulk storage tank.

Such a facility of batch tanks had not been provided. MIC was directly fed to the bulk storage tanks from production without any batch tank.

Alternatively, an on-line analyser could have monitored continuously the quality of MIC before it entered the storage tank. An alarm could have been provided to alert the operator regarding off-quality MIC and enable him to take quick action to prevent contamination of the bulk storage tank with off-quality material. There was no provision for such an on-line analyser/alarm system.

Water is used as the cooling medium in the multi-tubular MRS overhead condenser. Water circulated in the shell side is at a higher pressure than the pressure of MIC inside the tubes. Even a pin hole in any of the tubes could lead to a quantity of water entering the MIC make line which is taken directly to the bulk storage tank.

Nitrogen

MIC is kept under positive pressure of nitrogen which is supplied by a carbon steel header common to all the storage tanks. There is a strainer in the hydrogen line. Subsequent to the strainer the pipe is of carbon steel and leads to make up DMV which also has a body of carbon steel. Similarly, the blow down DMV is also of carbon steel body. These carbon steel parts may be exposed to MIC vapours and get corroded, providing a source of contaminant which can enter the MIC storage tank.

The level in MIC tank is measured by purging of nitrogen. The header supplying this nitrogen is made of carbon steel and the connection from the manifold to the level instrument is by a copper tube. There is no strainer or filter in this line which can prevent entry of rust or metallic particle entering the tank along with nitrogen.

Instrumentation and Control System

The pressure in the MIC tank increases rapidly if MIC is contaminated with water. No high pressure alarm was installed to alert the operator about the build-up of pressure.

There is a graphite rupture disc between the tank and the safety valve. This graphite rupture disc may break because of pressure surges even under normal conditions. There was no provision for an alarm to ring the operator if a rupture disc broke.

For the storage of a lethal chemical such as MIC, two instruments in parallel (one for control/indication and another for alarm) are normally provided. No such provision existed. For example, quite often the level readings had not been recorded, reportedly because the level system used to be out of order very often due to choking problems. In fact, after the event since the only level monitoring system provided for tank 611 was not functioning, it was not possible to ascertain the exact quantity of MIC in that tank. An additional level measuring system would have helped in such a situation.

Ingress of contaminants or water can start a reaction with MIC which will begin slowly and produce a rise in temperature of the tank contents. However, the range of the temperature transmitter provided was only -25°C to +25°C, with a high alarm setting at +11°C. The contents of the tank were being stored at ambient temperature, which in Bhopal varies approximately from +15°C to +40°C. The temperature of MIC in the storage tanks for most part of the year was higher than the high temperature alarm setting, i.e. +11°C. Indeed the temperature of material in the tank was higher than the maximum of the range of the temperature transmitter, i.e. +25°C.

In such circumstances the actual temperature was not known and the transmitter was of no value. Further, provision of "rate of rise in temperature" alarm would have alerted the operator's attention to the start of such a reaction. No such provision existed.

Refrigeration

There is only one common compressor and chiller system for all the three MIC storage tanks. For such a hazardous material as MIC, where maintaining it at a low temperature is considered very important, a spare compressor and chiller system would have ensured proper chilling even when the main compressor and chiller system was under repairs or maintenance. The lack of a spare compressor and chiller ranks as a major lapse.

Vent Gas Scrubber

The VGS is designed to neutralise a maximum of about 3.5 tonnes (7700 lb) of MIC at a maximum rate of about 9.6 tonne/hr (21200 lb/hr) in a vapour form.

The accumulator volume of 80m^3 (21000 gal) is filled with the recommended 10% caustic solution to neutralise a maximum of about 16 tonnes of MIC. Also, operation of VGS at temperatures above 70°C for extended periods is not recommended since absorption will be poorer and the heat of neutralisation is not completely removed by the cooler in the VGS system.

With the caustic make up pump capacity at 95 lpm (25 gpm) of 20% caustic solution, additional MIC that can be neutralised is also limited to about 2 tonne/hr.

An Analysis of the Event

Taking together the background and circumstances, the study of the properties of the materials, examination of tank residue, simulated experiments on conditions for formation of various chemical entities, critical examination of relevant features of design all considered together provides a basis for outlining the factors which led to the event. The following picture emerges (32).

- MIC readily undergoes chemical reactions with explosive violence, producing a large amount of heat, and allowing a large portion of stored liquid MIC to vapourise. This is inherent to the nature of the material. Neither the precise conditions under which such run-away reactions could be initiated in MIC nor its manner of prevention are well known.
- A much larger than necessary quantity of MIC was stored in underground tanks which have many inlets and outlets that can permit entry of contaminants which can set off explosive reactions.
- Reports indicate that a reaction was initiated and the temperature rose rapidly. There was no 'rate of rise in temperature' alarm to indicate the rising temperature which would have alerted the operator to an early detection of a run-away reaction.
- Any emergency dumping of liquid MIC into the VGS would not have been feasible because the alkali available in the accumulator was

grossly insufficient. Calculations show that even if the normal design load for VGS is taken into consideration, the VGS is inadequate to neutralise a discharge of 28 tonnes of vaporized MIC in about 2 hours. It would also have led to an abnormal tempeature rise in the VGS.

- Therefore, neither the liquid nor the gaseous disposal system was capable of handling the surge of release which occurred.
- From the examination of the tank residue and from the conditions of formation of the residue, it can be surmised that the temperature reached in the bulk storage tank may have been around 250°C. Information from the mechanical examination of the tank indicate that the pressure may have reached 11 to 13 kg/cm^2g with the corresponding temperatures in the range of 200 to 350°C.
- The chemical analysis of the tank residue clearly shows the evidence of entry of approximately 500 kg. (110 lb) of water. The fact that the tank 610 was not under pressure of nitrogen for approximately two months prior to the accident also indicates that conditions existed for entry of contaminants such as metallic impurities through the high pressure nitrogen line. Such impurities have a catalytic effect on the possible reactions MIC can undergo.
- The hydrolysis of MIC with about 500 kg. (1100 lb) of water by itself and in the absence of other contaminants is not expected to lead to thermal run-away conditions. The presence of this quantity of water would have possibly resulted in reaction with about three to four tonnes of MIC, generation of carbon dioxide, breaking of the rupture

grossly insufficient. Calculations show that even if the normal design load for VGS is taken into consideration, the VGS is inadequate to neutralise a discharge of 28 tonnes of vaporized MIC in about 2 hours. It would also have led to an abnormal tempeature rise in the VGS.

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- The chemical analysis of the tank residue clearly shows the evidence of entry of approximately 500 kg. (110 lb) of water. The fact that the tank 610 was not under pressure of nitrogen for approximately two months prior to the accident also indicates that conditions existed for entry of contaminants such as metallic impurities through the high pressure nitrogen line. Such impurities have a catalytic effect on the possible reactions MIC can undergo.
- The hydrolysis of MIC with about 500 kg. (1100 lb) of water by itself and in the absence of other contaminants is not expected to lead to thermal run-away conditions. The presence of this quantity of water would have possibly resulted in reaction with about three to four tonnes of MIC, generation of carbon dioxide, breaking of the rupture

disc and release of CO_2. Such emissions would be expected to cease once the water has been consumed.

- The presence of trace amount of metallic contaminants derived from the material of the tank or its attachments or from extraneous sources, may not necessarily initiate a violent reaction under dry conditions. Small amounts of local trimerisation may take place, as observed throughout the pipelines and plant. However, the ingress of water, would provide for active species of initiator to be generated and distributed in the liquid.
- All these considered together imply that ripe conditions for the initiation of a run-away trimerisation reaction already existed in tank 610 on the day of the event; and that entry of water would have generated active initiators and the hydrolysis of MIC would have provided the necessary heat also for the trimerisation reaction to take off with explosive violence. The carbon dioxide evolved upon hydrolysis would then provide the necessary mixing leading to even more rapid chemical reactions. The storage tank thus equalled the conditions of a well mixed tank reactor, supplied with heat.
- Once initiated, the trimerisation reaction rapidly led to a temperature increase leading to levels as high as 250°C with auto catalytic and auto-thermal features. At these high temperatures, secondary chemical transformation occurred leading to the complex mixture of products actually found in the tank 610 residue.
- It is estimated that 500 kg (1100 lb) of water could have entered the tank 610 either from the MRS condenser (through condenser tube

leaks) or through RVVH/PVH lines. The detection of some sodium in the tank residues is also significant. The observed sodium levels are substantially higher than what would have normally been present due to the entry of 500 kg (1100 lb) of water (below 0.5 ppm)

- It appears that water entry through RVVH/PVH lines is quite likely. It has been reported that around 9.30 PM on 2nd December, 1984, an operator was clearing a possible choke of the RVVH lines downstream of phosgene stripping still filters by water flushing. Presumably the 6" isolation valve on the RVVH was closed but a slip blind had not been inserted. Under these conditions when the filter lines are choked, water could enter into the RVVH, if the 6" isolation valve had not been tightly shut or passing.
- There is also the possibility that alkaline water could have backed up from the VGS accumulator into the RVVH and PVH under certain conditions. Several litres of alkaline water was drained from the RVVH/PVH lines in the MIC structure in May 1985, lending credence to such a possibility.
- RVVH/PVH lines are made of carbon steel. Back up water or alkali through these lines increase the possibility of metal contaminants entering the tank, especially in the absence of positive nitrogen pressure.
- The water that entered RVVH at the time of water flushing along with backed up alkali solution from the VGS already present could find its way into the tank 610 through the RVVH/PVH lines via the blow down DMV or through the SRV and RD.

- Possibilities for intrusion of water, alkali and metal contaminants into tank 610 thus existed from 22nd October, 1984 and into tank 611 as well during 30th November to 1st December 1984, when there was negligible positive nitrogen pressure in these tanks.
- It was reported that trimerisation of MIC to solid material in small quantities and consequent choking of lines leading to tank was a frequent occurrence. What is surprising is that this seems to have been well accepted by the plant operating staff. Similarly, cleaning and purging with water of lines associated with the storage tanks was also accepted as a routine procedure. The hazards presented by ingress of water or other contaminants was not appreciated and the tank 610 was allowed to stay without positive nitrogen pressure from 22nd October to 2nd December 1984.

According to the UCC brochure MIC can react with water to produce DMU and TMB. The heat generated would be related to the quantity of water. The brochure also mentions metallic contaminants could lead to violent reactions of MIC which has the unique combination of properties of explosive reactivity, ready volatility and high inhalation toxicity. It seems possible that small amounts of water in presence of trace amounts of metallic contaminants could set off explosive reactions and leakage not containable in the inadequate VGS system.

- It defies reasons why such large amounts of toxic MIC was allowed to be stored. The quantities stored were quite disproportionate to the capacity of further conversion of MIC in downstream unit. If 42 tonnes of MIC had been stored in 210 stainless steel drums of 200 litre capacity each or even in 42 drums of 1 tonne capacity each, as alternative to a single tank, there would be no possibility of a massive leakage and effects of even such a leakage could be minimised by spray of water or alkali.

- The events of 2nd/3rd December, 1984 arose primarily from these facilities and accepted practices (33-35).

Concluding Remarks

From this analysis, it appears that the factors that led to the toxic gas leakage and its heavy toll already existed in the combined properties of very high reactivity, volatility and inhalation toxicity of MIC. The unnecessary storage of large quantities of such a chemical for inordinately long periods as well as insufficient caution in design, in choice of materials of construction and in provision of measuring and alarm instruments, together with the inadequate controls on systems of storage and on quality of stored materials as well as lack of necessary facilities for quick effective disposal of material exhibiting instability, led to the accident.

Combination of conditions for the devastating accident were inherent and extant. When dealing with potentially hazardous process technologies risk assessment should be an ongoing concern to eliminate all possible flaws and strengthen safety. This calls for responsibilities and actions at all levels, top management, middle management and operator levels. Advance actions on these lines could have avoided or minimised the damage that occurred in Bhopal on the night of 2nd December 1984.

4.2 FAILURE ANALYSIS OF TECHNOLOGY MANAGEMENT IN MAGNESIUM METAL PRODUCTION

Production of Magnesium Metal by a Public Sector Undertaking

Features

Licensed capacity	:	600 tonnes per annum
Raw material	:	Sea bitterns
Know how supply	:	A CSIR Laboratory.
Technical Consultant	:	A leading Indian Consulting Engg. Company (CC)

Applications of Magnesium

Magnesium is a strategic metal. It has varied applications. viz:

a. Aeronautical industry - as an alloy for Aerospace - Rocket application.

b. Aluminium industry, for making alloys.

c. Nuclear fuel for making granules as fuel mix.

d. Titanium production - for Magnesium reduction.

India is importing about 3000 tonnes of Magnesium metal and a Public Sector Undertaking (PSU) ventured a project for production of Magnesium metal, promoted by a State Financing Corporation (SFC)

Chronology of the Project

1979	:	Tamilnadu Minerals and Magnesites (TMM) signs the agreement with a CSIR Laboratory for promoting a project to manufacture Magnesium metal from sea bitterns.
1984	:	Appointment of CC as the detailed Engineering Consultant.
1984	:	Project was transferrd to another Public Sector Undertaking.
1987	:	SFC took back the project.
1987	:	SFC formed PSU as a Strategic Company. - project escalation, missing links, etc sorted out.
1989 Sep	:	Project was completed. Total investment in the project : Rs.10 crores.
1989 Oct	:	Trial production started with alternative raw feed from Nuclear Fuel Complex. Operated only two cells out of 14.
1991	:	Bitterns plant was commisioned.
1993 Jan	:	the plant was closed due to unviable operation.

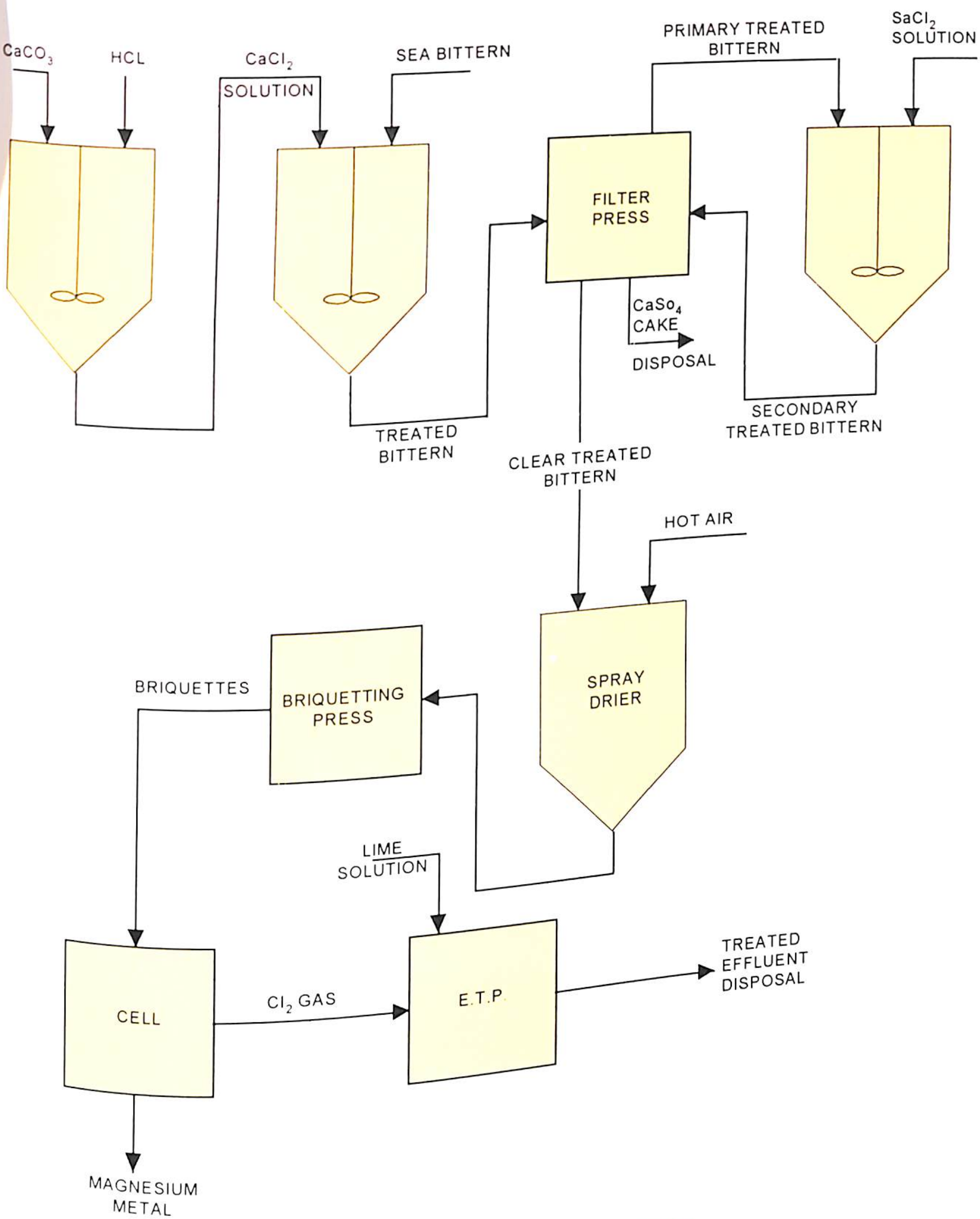
Total number of people employed : 170

Monthly commitment of Rs. 9.75 lakhs is being spent by SFC even today.

Description of the Process

Process Flow sheet is in Fig. 4.6.

FLOW CHART



PROCESS FLOW CHART FOR
PRODUCTION OF MAGNESIUM METAL

Sea bitterns are treated with hydrochloric acid and mixed with calcium carbonate to produce calcium chloride. Sulphate is eliminated as calcium sulphate (gypsum).

The treated bitterns is enriched in Magnesium chloride to about 350 gpl. This solution is spray-dried and Magnesium chloride (hydrous) with 15% moisture is obtained which is then briquetted. This is the feed for the cell which produces Magnesium metal and chlorine is also released simultaneously in the process.

Magnesium metal floats on the surface of the electrolyte. This is taken out in ladles manually and cast manually. The cell operating temperature is 700 ° C.

When the product was tapped it contained a lot of impurities including salt and hence had to be remelted to remove all the impurities to get purer magnesium. Chlorine is scrubbed with lime solution and discharged into the sea.

Problems in Operation

1. The raw material which was originally planned was hydrous Magnesium chloride which was not ready and hence an alternative raw material was procured from Nuclear Fuel Complex (NFC).
2. The quantity available was sufficient only to feed 2 cells against 14 cells required.
3. When the original hydrous Magnesium chloride feed manufactured from bitterns was used, the production efficiency was very low. The yield per cell was hardly 30% of what the process owners specified.

The Company had to depend on anhydrous Magnesium chloride from NFC to sustain the production.

4. There were a lot of equipment problems with - spray drier, briquetting machine, effluent treatment plant etc.
5. In the cells, the electrode life was very short and the cathodes were not functioning.
6. There was too much of sludge accumulation inside the cell.
7. Excess power consumption.
8. Formation of Magnesium hydroxide/ Magnesium chloride due to presence of Magnesium oxide and moisture.
9. The operation was difficult when attempts were made to run the cell using the spray dried material.
10. When the bittern route Magnesium chloride was followed, there were fuming of anodes, erosion and sludge formation and hence the plant had to be stopped, to revert back to NFC feed.
11. It was established that the cells must have pure feed of Magnesium chloride with water content of below l% and less than 1% of Magnesium oxide.
12. The design of the cell did not have provision for chlorine separation during the production and it was concluded that the cell design was wrongly conceived.
13. On the process side, after running the plant for 3 years, it was found that bittern is not able to generate anhydrous magnesium chloride, which is the suitable feed, even though the original specification of the process owner allowed 15% moisture.

14. As the laboratory had conducted experiments only at the lab scale for a short period, they could not be of much help in solving the problem on a continuous commercial scale.

15. Consultants were of no use as they had merely scaled up the designs given by the Process Owner.

Now, the Plant, with a huge liability, has been referred to BIFR, to declare it as a sick unit (37).

Case Analysis

i. Here is a case, where all the complications have contributed together to the failure of the Technology as well as Technology Management.

ii. On the technology side, the laboratory should have evolved a proper cell with correct material of construction and should have made a Pilot Plant before going in for a commercial scale.

The advantage of going in for an electrolysis process is that in the pilot plant itself commercial size electrolyser can be designed and operated continuously to get the practical experience and optimum parameters of operation as if running a commercial plant.commercial size electrolyzer can be designed and operated continuously to get the practical experience and optimum parameters of operation as if running a commercial plant.

Once this is done, it is only a question of multiplying the number of cells/modules instead of scaling up.

iii. On Process Owner's side, they just took for granted the bench scale results without making a proper size of the cell.

iv. While giving the Technology to the Engineering Company to upscale all the parameters that were necessary, a number of important things were not looked into properly by the Process Owner. For example:

a. material of construction of anode and cathode.

b. exact specification for upgrading the base magnesium chloride from bitterns.

c. current density

d. side effects of electrolysis

e. sludge formation

f. chlorine disposal

g. product quality

h. practical handling methods of end product in molten form in 700 degC.

v. A systematic job by a responsible process owner should have been to ask the same consultancy company to manufacture one electrolyser out of the 14, and run it in a commercial way, to analyse all the problems that could arise, sort out and optimise the best results to get the product acceptable to the Process owner, Consultant, Buyer of the technology and the End User.

vi. This is a clear case where the Consultant also failed in his responsibility by upscaling the technology without proper concept of the process. He should have brought to the notice of the owner of the plant the anamolies that the process owner had in the process and should have more cautiously designed the upscaled version.

vii. From the side of the owner of the plant, had it been a private participated Company, a lot of details would have been gone into, before signing up of the agreement, taking over of the process and appointment of the Consultant. The contract signed also does not hold responsible either the Process Owner or the Consultant who encouraged the entire investments resulting recurring losses for the owner.

viii. From the owners side, there was no professional approach - to understand the capability of the lab, while transferring the indigenous CSIR developed technology into a commercial scale and to excercise sufficient care, in selecting and evaluating the technology.

ix. From the Institution side, lack of responsibility is evident. There was no proper appraisal of the process prior to release. Because of the big name of the Consultant, CSIR Laboratory and State Financing institution were involved - cleared the project and sanctioned the loan.

Had there been a proper technology management at the Process Owners' level by systematic upgradation and optimisation of the cell size and the operation, and had the Consultant done a systematic and stepwise scaling up without sacrificing the prescribed concept, this plant would not have failed.

Conclusion

From the foregoing, it becomes clear that this is a case of gross negligence in technology acquisition; on the part of the inventor it was a gross negligence in development; on the part of the Institute to transfer the technology when it was

4.3 TITANIUM WELDING TECHNOLOGY AND TEAM

Introduction

Titanium is the ninth most abundant element in the earth's crust and is in the fourth place as an industrial metal following iron, aluminium and magnesium. Titanium has nearly half (4.5) the specific gravity of copper, is equivalent to steel in strength but light, higher in corrosion resistance than stainless steel and far more heat resistant than aluminium, all of which give the metal a distinct uniqueness.

Rev.W.Gregor of England discovered this wonder metal Titanium by isolating its oxide from a black magnetic sand in 1790.

M.H.Klaprath, a German, confirmed in 1975 rutile ore consisted the same oxide and he named the new element as Titanium, borrowing the name from Greek mythology.

In 1910, an American, M.A. Hunter, isolated Titanium metal from Titanium tetrachloride by sodium reduction and thus the metal came into existence.

The industrial application of Titanium came when W.J.Kroll, Luxembourgian Chemist, established the process of Titanium production by magnesium reduction in the year 1946.

How Titanium metal is made

The ore rutile is treated with chlorine to make Titanium tetrachloride and metallic magnesium or sodium is used to produce Titanium in a spongy state.

The process using magnesium for reduction is called Kroll process and that of using sodium is called Hunter process.

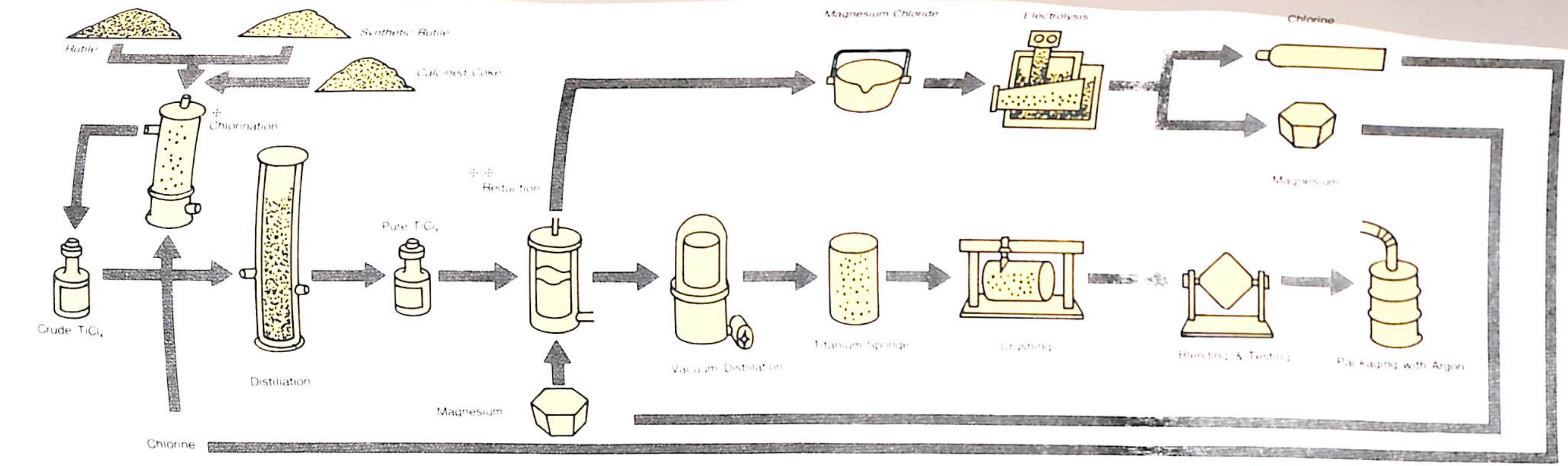
Titanium sponge is melted in vacuum furnace to produce ingots including alloy production.

The ingot is rolled into plates and rods with other mill sections.

Typical production flowchart for Titanium Sponge and typical production flowchart for mill products and castings are shown in Fig. 4.6, 4.7.

TYPICAL PRODUCTION FLOWCHART FOR TITANIUM SPONGE

FIG: 4·6

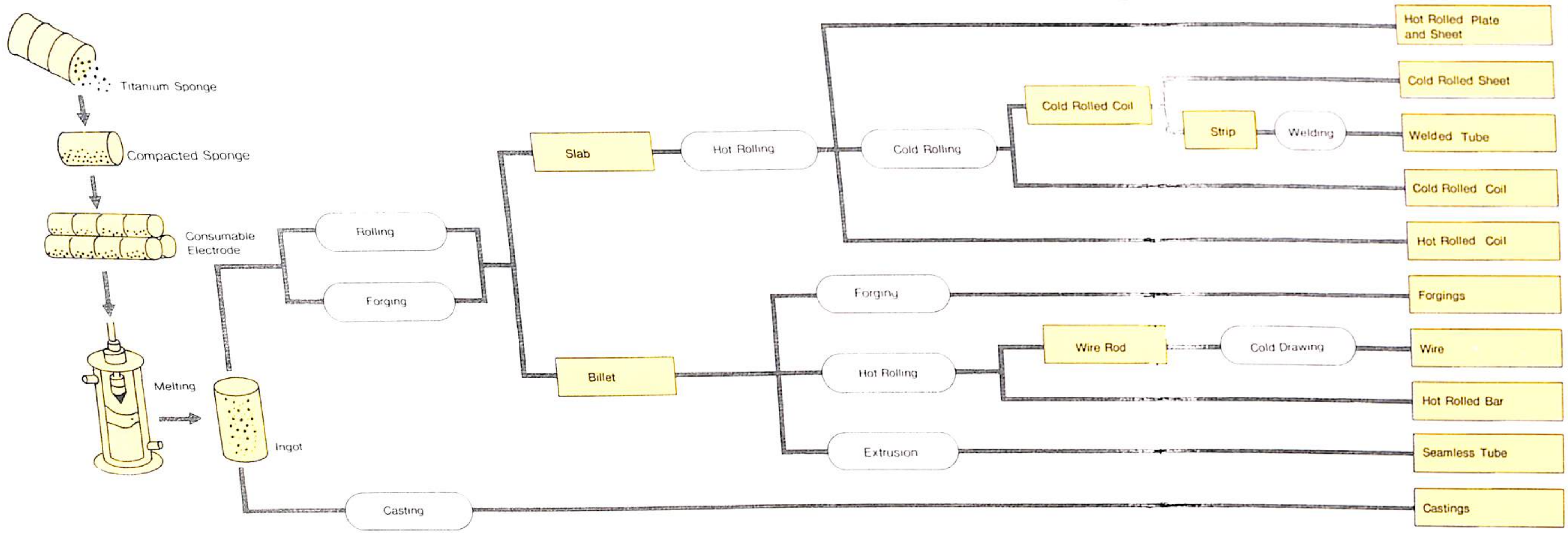


$$^{*}TiO_2 + 2Cl_2 + C \rightarrow TiCl_4 + CO_2$$

$$^{**}TiCl_4 + 2Mg \rightarrow Ti + 2MgCl_2$$

PRODUCTION FLOWCHART FOR TITANIUM MILL PRODUCTS AND CASTINGS

FIG: 4·7



Furnaces with non-consumable electrodes are also in use.

Resources and production capacity of Titanium

Titanium is the ninth most abundant metal in the earth's crust. The ore is available in Brazil, India, Canada, Norway, South Africa and Australia.

The main ores of Titanium are rutile and ilmenite. They exist in the beach areas in the form of sand deposits and the volume is estimated to be 300 million tons. The life of Titanium resources is estimated to be as long as 10000 years and there will be no exhaustion in any foreseeable future.

World production capacity of Titanium Sponge is given in Fig. 4.8 Production of Titanium mill products by application is given in Fig. 4.9.

Design features

In view of the lightness, corrosion resistence and strength, for a vessel compared to carbon steel or stainless for a given application, titanium will be cheaper in the long range because of its long life and down time in maintenance.

The physical properties of the metal are given in Table 2 and the corrosion resistance properties in Table 3.

FIG. 4.8

WORLD PRODUCTION CAPACITY OF TITANIUM SPONGE

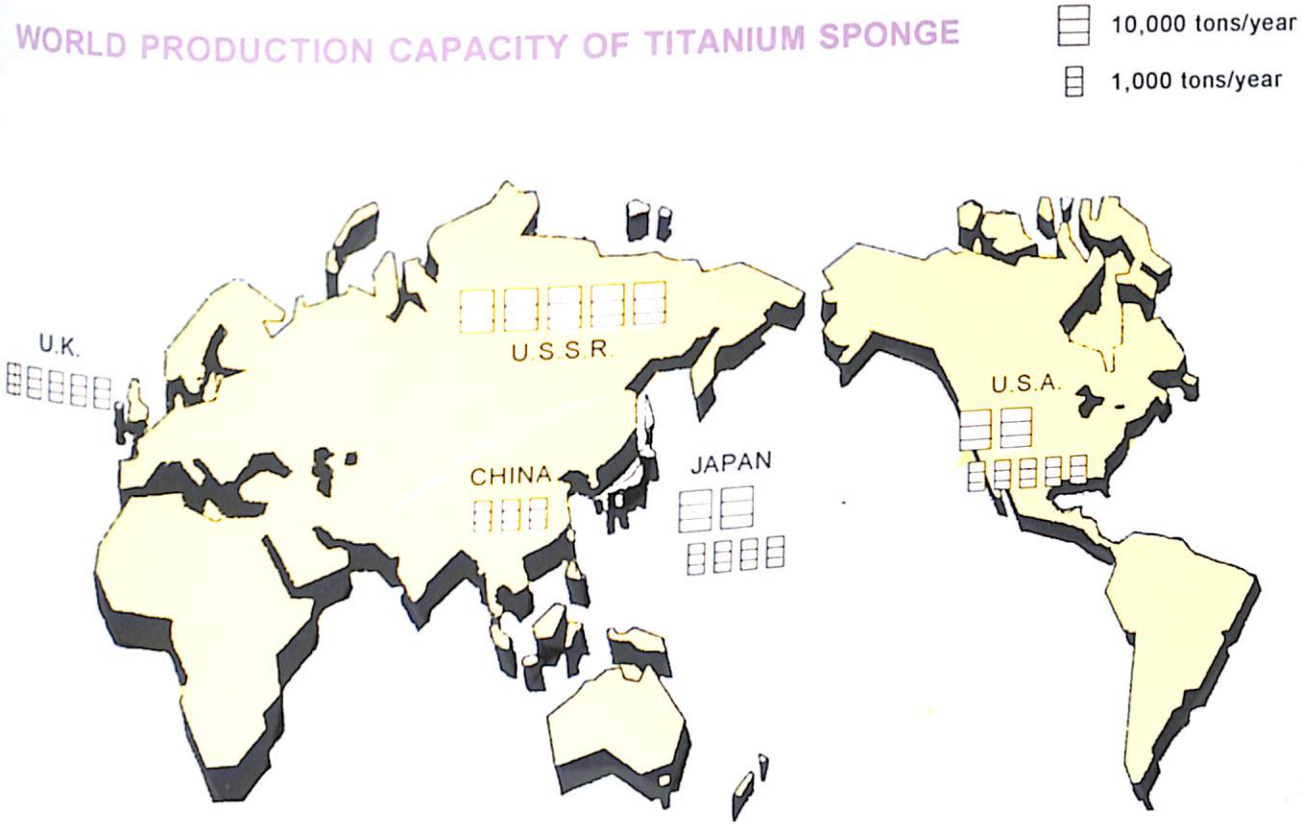
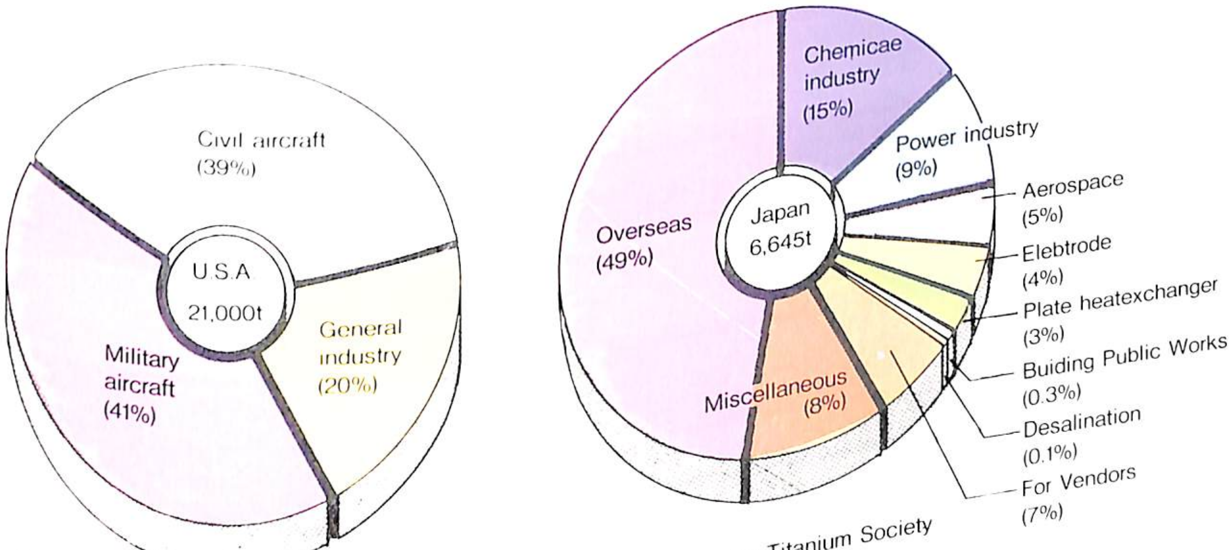


FIG. 4.9



Source: Estimates by The U.S. Bureau of mines based on contracts with Titanium Industry

Sourse: Japan Titanium Society

TABLE : 2.0

Physical Properties

Special features of the physical properties off commercially pure titanium are as follows:

1) A high melting point at 1,668°C (slightly higher than that of iron)
2) A low specific gravity of 4.5 (about 60% of iron and 170% of aluminum)
3) A low coefficient of thermal expansion at 8.4×10^{-5}/°C (about 1/2 that of 18-8 stainless steel and 1/3 that of aluminum).
4) A low thermal conductivity at 0.041 cal/cm²/sec/°C/cm (about the same as that of 18-8 stainless steel).
5) A large electrical resistance at 55 μΩ-cm (comparatively larger than that of metals besides 18-8 stainless steel).
6) It is non-magnetic with a permeability of 1.0001.
7) Its crystal structure at temperatures below the transformation point (885°C) is a close-packed hexagonal lattice; at temperatures above the transformation point, it is a body centrered cubic lattice.
8) A low young's modulus at 10,850 kgf/mm² (about 50% that of iron and about 150% that of aluminum).

Material	Atomic No.	Atomic weight	Specific Gravity	Melting Point (°C)	Coefficient of Thermal Expansion (/°C)	Specific Heat (cal/gr/°C)	Thermal Conductivity (cal/cm² sec/°C/cm)	Electrical Resistance (μΩ-cm)	Electrical Conductivity (% IACS)	Young's Modulus (kgf/mm²)	Poisson's Ratio
Titanium	22	47.90	4.5	1,668	8.4×10^{-6}	0.124	0.041	55	3.1	10,850	0.34
Iron	26	55.85	7.9	1,530	12×10^{-6}	0.11	0.15	9.7	18	21,000	0.31
18.8 Stainless Steel (AISI 304)	-	-	7.9	1,400 to 1,420	17×10^{-6}	0.12	0.039	72	2.4	20,400	0.3
Aluminum	13	26.97	2.7	660	23×10^{-6}	0.21	0.49	2.7	64	7,050	0.33
Aluminum Alloy (75S-T6)	-	-	2.8	476 to 638	23×10^{-6}	0.23	0.29	5.8	30	7,300	0.33
Magnesium	12	24.32	1.7	650	25×10^{-6}	0.24	0.38	4.3	40	4,570	0.35
Nickel	28	58.69	8.9	1,453	15×10^{-6}	0.11	0.22	9.5	18	21,000	0.30
Hastelloy C	-	-	8.9	1,305	11.3×10^{-6}	0.092	0.03	130	1.3	20,860	
Copper	29	63.57	8.9	1,083	17×10^{-6}	0.092	0.92	1.724	100	11,000	0.34

(Notes) 18-8 Stainless Steel: Cr(18%) - Ni(8%)-Fe(Bal.) 75S-T6: Extra super duralumin {Cu(1.6%)-Mg(2.5%)-Cr(0.3%)-Zn(5.6%)-Al(Bal.)], quenched and tempered. Hastelloy C:58Ni-17Mo-14Cr-6Fe-5W

Physical properties other than those above:

Crystal Structure
- α Titanium (885°C or lower):Close-packed hexagonal lattice — a = 2.9504Å C=4.68333Å c/a 1.587
- β Titanium (885°C or higher) : Body-centered cubic lattice — a = 3.3065Å

Heat of fusion : 14.5 cal/g   Permeability rate: 1.0001

Corrosion Resistance

A. Corrosion Resistance in General

Corrosive	Concentration (%)	Temperature (°C)	Corrosion resistance: Titanium	Corrosion resistance: 18-8 Stainless steel	Corrosion resistance: Hastelloy C
Hydrochloric acid HCL	10	24	○	x	●
	30	24	x	x	●
	10	80	x	-	○
	30	80	x	-	▲
Sulfuric acid H_2SO_4	10	24	▲	-	●
	50	24	x	x	●
	10	100	x	-	●
	50	100	x	-	●
Nitric acid HNO_3	10	24	●	●	●
	50	24	●	●	-
	10	100	●	●	▲
	50	100	●	○	-
Aqua regia HCl-HNO_3	HCl:HNO_3 3:1	24	●	x	▲
		100	○	-	-
Chromic acid H_2CrO_4	5	24	●	-	●
Hydrogen fluoride HF	5	30	x	x	▲
Phosphoric acid H_3PO_4	10(Aerated)	24	○	●	●
	50(Aerated)	24	▲	●	●
	10(Aerated)	100	x	●	●
	50(Aerated)	100	x	○	●
Ferric chloride $FeCl_3$	10	24	●	x	●
	30	24	●	x	●
	10	100	●	-	x
	30	100	●	-	x
Cupric chloride $CuCl_2$	10	24	○	x	○
	30	24	○	x	○
	10	100	○	-	-
	30	100	○	-	-
Sodium chloride NaCl	10	24	●	○	○
	40	24	●	○	○
	10	100	●*	○*	○
	40	100	●*	○*	○
Calcium chloride $CaCl_2$	10	24	●	●	●
	50	24	●	○	●
	10	100	●*	-	●
	50	100	●*	x	●
Ammonium chloride NH_4Cl	10	24	●	▲	●
	40	24	●	-	●
	10	100	●*	-	●
	40	100	●*	-	●
Magnesium chloride $MgCl_2$	10	24	●	▲	●
	40	24	●	○	●
	10	100	●*	▲*	●
	40	100	●*	-	●
Ferrous sulfate $FeSO_4$	10	24	●	○	○
	50	24	●	○	○
	10	100	●	○	○
	50	100	●	-	○

Corrosive	Concentration (%)	Temperature (°C)	Corrosion resistance: Titanium	Corrosion resistance: 18-8 Stainless steel	Corrosion resistance: Hastelloy C
Ammonia NH_3	10	24	●	●	●
	30	24	●	●	●
	10	80	●	○	○
	30	80	●	○	●
Sodium hydroxide NaOH	10	24	●	●	●
	50	24	●	●	-
	10	100	●	●	●
	50	100	○	○	●
Sodium carbonate Na_2CO_3	10	24	●	●	●
	30	24	-	-	-
	10	100	●	●	●
	30	100	●	●	●
Hydrogen sulfide H_2S	Dry Gas	24	●	▲	●
	Wet Gas	24	●	○	○
Chlorine Cl_2	Dry Gas	24	x	-	●
	Wet Gas	24	●	-	▲
	Dry Gas	100	-	●	○
	Wet Gas	90	●	-	▲
Sulfur dioxide SO_2	Dry Gas	30 to 60	●	-	-
	Wet Gas	30 to 90	●	-	-
Seawater	High Flow Speed	24	●	-	-
	Stagnant sea water	100	●*	-	●
Acetic acid CH_3COOH	10	24	●	●	●
	60	24	●	●	●
	10	100	●	●	●
	60	100	●	○	●
Formic acid HCOOH	10	24	○	○	●
	50	24	○	○	●
	10	100	○	x	●
	30	100	x	x	●
Lactic acid $CH_3CH(OH)COOH$	10	24	●	○	○
	50	24	●	○	●
	10	100	●	○	○
	50	100	●	x	○
Oxalic acid $(COOH)_2$	10	24	○	○	○
	20	52	x	-	○
	50	24	-	○	○
	10	100	-	-	○
	50	100	-	x	○
Citric acid $C_6H_8O_7$	10	24	●	○	●
	50	24	●	○	●
	10	100	●	○	●
	50	100	x	x	●

(Notes)
* Local corrosion such as pitting corrosion may occur.
●:< 0.051 ○:<0.508 ▲:0.508 to 1.27 x:>1.27 mm/year

Applications

Due to light weight, high strength, anticorrosion, cryogenic property, super conductivity, short radioactivity (half life), magnetic insensitivity, non-toxicity to living tissues, fashionability, hydrogen absorption, sharp memory, the applications are many and varied such as:-

- Aerospace - body structure, engine parts;
- Petrochemical - heat exchanger, reactor, electrode;
- Automobile - Connecting rod, valve, suspsnsion spring
- Thermal/Nuclear Power - condenser, turbine blade
- Construction & Civil Engineering
- roof, bridge cable, piping
- Marine development - marine riser for floating platform, bathyscaphe, desalinator
- Cryogenic equipment - MHD power generation, superconductive generator
- Radioactive Waste disposal - canister,transport container
- Precision machine - computer
- Medical treatment, food - artificial bone, heart valve, heart pacemaker, microsurgery, heat exchanger for fermentation
- Sport - Golf club, tennis rackets, bicycles
- Accessory - frame of spectacles, watches, cameras, tie-clips
- Energy - Hydrogen automobile, waste heat utilisation
- Residential - sensors, motors

Titanium finds application in many strategic areas too. Titanium is a treasure house for future, and its development is a major mission for people living in the 20th century. In the field of ocean development, the role of titanium is expanding endlessly in such areas as in deep-sea exploration vessels, deep-sea mineral sampling ships, sea differential temperature power generation, sea wave activated power generation, sea bridges, marine farms, offshore airports and offshore oil field development.

Titanium - Opening up the future

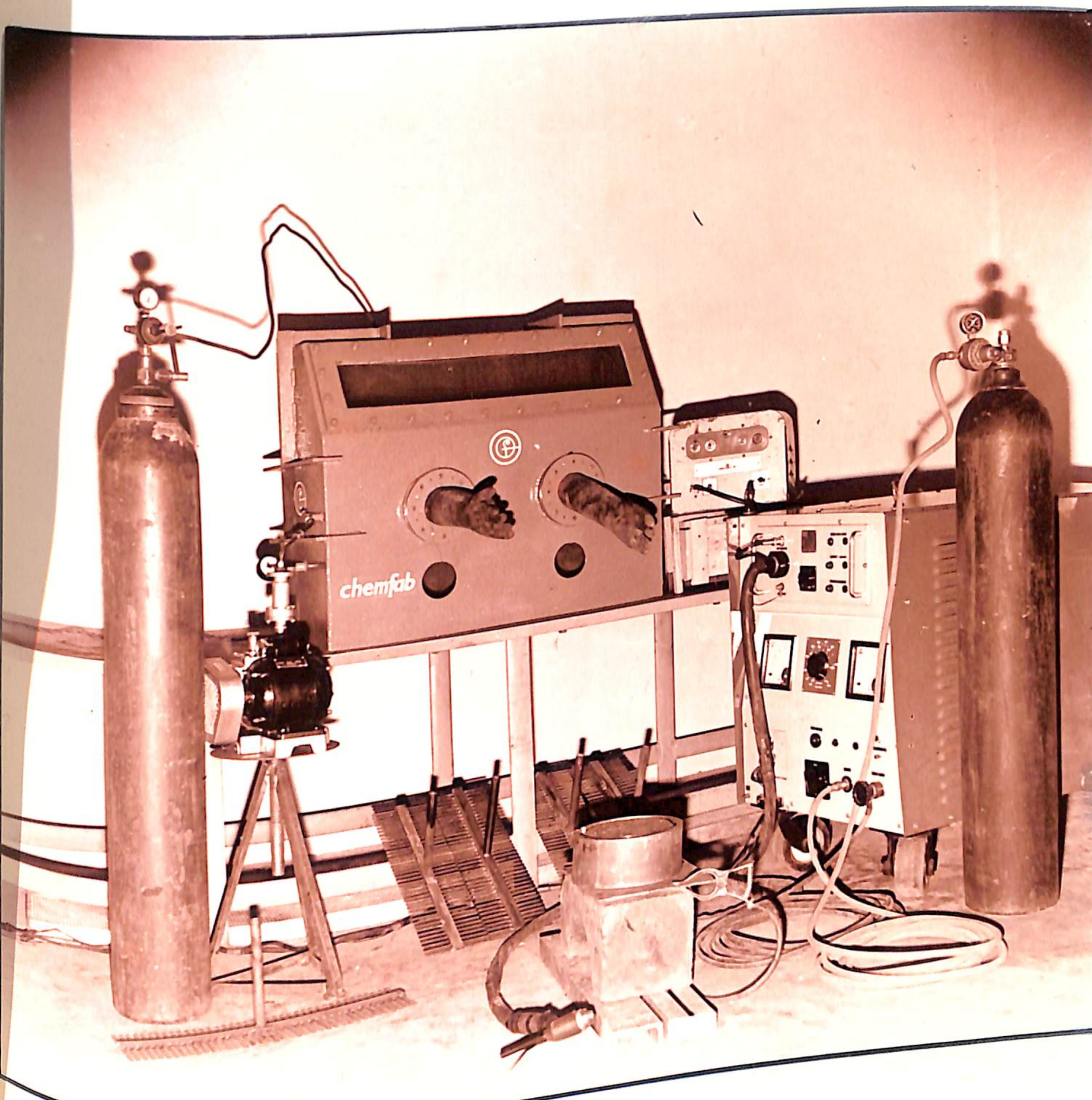
With three very valuable major properties - high corrosion resistance, lightness and strength - field of activities of titanium has been expanding on land and sea and in the sky, and now, it is entering a new phase of vast ubiquitous applications with its further functional properties; superconductivity, hydrogen absorption, and shape memory.

The Evolution of TEAM

In India, the first ever commercial application of titanium was taken up by Chemfab, Madras in the year 1967. Until then 100% of the titanium equipment were being imported.

It all started with T.I. Cycles having a huge stock of damaged titanium anode baskets procured at a very high cost from UK and not being able to get them repaired indigenously. An opportunity was given to Chemfab by T.I Cycles to try the repair work on titanium baskets, and this turned out to be an eye-opener for the titanium industry in India.

Chemfab tried to do the welding work with the available information and with an argon arc welding set. To start with, they landed up with very high oxidization and a purple white powder. Later, Chemfab developed a glove box (Fig. 4.10) where argon gas was filled in and later on a welding with an acceptable strength of titanium could be achieved which was good enough for that purpose. As the customer was satisfied on this performance, Chemfab got the chance to repair all the 200 baskets. By then various parameters could be stablised for welding titanium. The cost of repair work was quite remunerative to Chemfab athough this was only small portion compared to the imported cost of the basket This gave the opportunity for Chemfab to get to know the metal more intimately (Fig. 4.11).



GLOVE BOX FOR TITANIUM WELDING

Chemfab imported a few sheets of commercial grade titanium to attempt a trial and error method of welding and to establish various parameters. In understanding the properties of the metal and the practical way to handle it, several scientific organisations like Bhabha Atomic Research Centre (BARC), Defence Metallurgical Research Laboratory (DMRL), National Aeronautical Laboratory (NAL), were helpful. In fact, Chemfab could establish a clean room for welding purpose only with the unhesitating help of senior officials of BARC. This came out from the participation in an open Seminar in 1967 in the Indian Metallurgical Association, which was widely attended by all the manufacturers and BARC, DMRL scientists.

The various experiments with the accent on the following, conducted by Chemfab, established a very good acceptable welding :

1. proper edge preparation
2. tools and tackles used for edge preparation
3. degreasing and surface preparation for welding
4. using of correct grade of argon gas.
5. the importance of dew point in argon gas
6. shielding in the welding by argon gas through -
    a) welding torch
    b) back up shield
    c) shield from the atmosphere in the welding area
    d) natural cooling area of the heat affected zone in the argon atmosphere
7. Indigenous development of uniform argon gas-distributor and the selection of metal and the fixtures thereof.
8. Development of special fixtures for back up shield.

9. Development of a clean room to National Aeronautics and Space Administration (NASA) standards where air quality, volume of air by laminar flow, cleanliness and avoiding all ferrous contamination are all taken care of (Fig. 4.12).

FIG: 4.12

CLEAN ROOM TO NASA STANDARDS
AT TEAM, FOR TITANIUM WELDING

These successful developmental efforts gave the impetus to Chemfab to participate in the International Titanium Conference held in Moscow in 1976. This presented an excellent opportunity for Chemfab to get exposed to various applications of titanium and the thrust titanium was getting in the world. Therefore, Chemfab decided to start an exclusive company for manufacturing titanium fabrications and thus the new company Titanium Equipment and Anode Manufacturing Company Limited (TEAM) was formed with a horizontal transfer of technology from Chemfab. An industrial licence was obtained for titanium manufacture and to manufacture various other components. It was a gigantic task to convince the Central Government to give a separate licence, apparently due to inadequate knowledge and appreciation of the importance of this metal in the technical wing of the Government at that time. Chemfab familiarised the Directorate General of Technical Development, on titanium and its importance for the industry and the backwardness India suffered at that time in this area.

The Growth of TEAM

After successfully obtaining the licence, a very active collaboration began with one of the laboratories of Council of Scientific and Industrial Research (CSIR) resulting in a major breakthrough in the manufacture of titanium electrode and the first titanium electrode in the country was made. What started as a humble beginning with the cooperation of Central Electrochemical Research Institute (CECRI), a unit of CSIR in 1977 developed in a big way later on to manufacture membrane cell electrolyzers.

Initially, TEAM faced the probelm of market acceptability, since any manufacture out of Titanium was an import substitution. Hence, though not actually needed, just to get the market acceptability, it became necessary to get a tie up and the same was obtained through a collaboration agreement for designs & drawings of equipment. However, there was not much training needed as by then Chemfab had made a perfect welding procedure manually.

The following are various specialised areas -

Pumps, Blowers, Pipes Lines, Heat Exchangers, Pressure Vessels,

Seperation tanks, Valves, Anode elements, Anode coating etc.

Technology Upgradation: The technology upgradation was possible mainly due to the Lloyds Registrar of Shipping, a third party world inspection Inspectorate. TEAM's name was established in the year 1980, when for first time in the country, TEAM made Palladium Support Pipe Lines in the Gramaxone Plant of Associated Chemical Co. of India Ltd (ACCI). This was done in the clean room of TEAM. This paved the way for TEAM to get an entry into the world market as titanium fabricator.

Exposure to Technologies - New and Future: As a Corporate philosophy, TEAM is always keen to give exposure to its personnel and Engineers. Accordingly a team of Engineers and welders was deputed to study the titanium fabrication industry in one of the Japanese companies under an arrangement. By this arrangement, the Japanese company qualifies the welders.

Having had a look at various equipment and art of technology followed, the TEAM group who visited Japan found out that the productivity level in India was far lower when compared to Japan and they made a very detailed study interacting with the various workmen and upgraded their technology to keep pace up with the latest developments. This exposure gave rise to automation by selecting a computer aided spot welding machine exclusively for the purpose of manufacturing ion exchange membrane cells. The machine was totally computer controlled where six types of electrolyzers can be tackled for the titanium element welding for the manufacture of electrolyzers. The principle is to pass DC current through specially selected electro-tips where the programming could be made for -

a) vertical movement

b) cross movement

c) type of welding

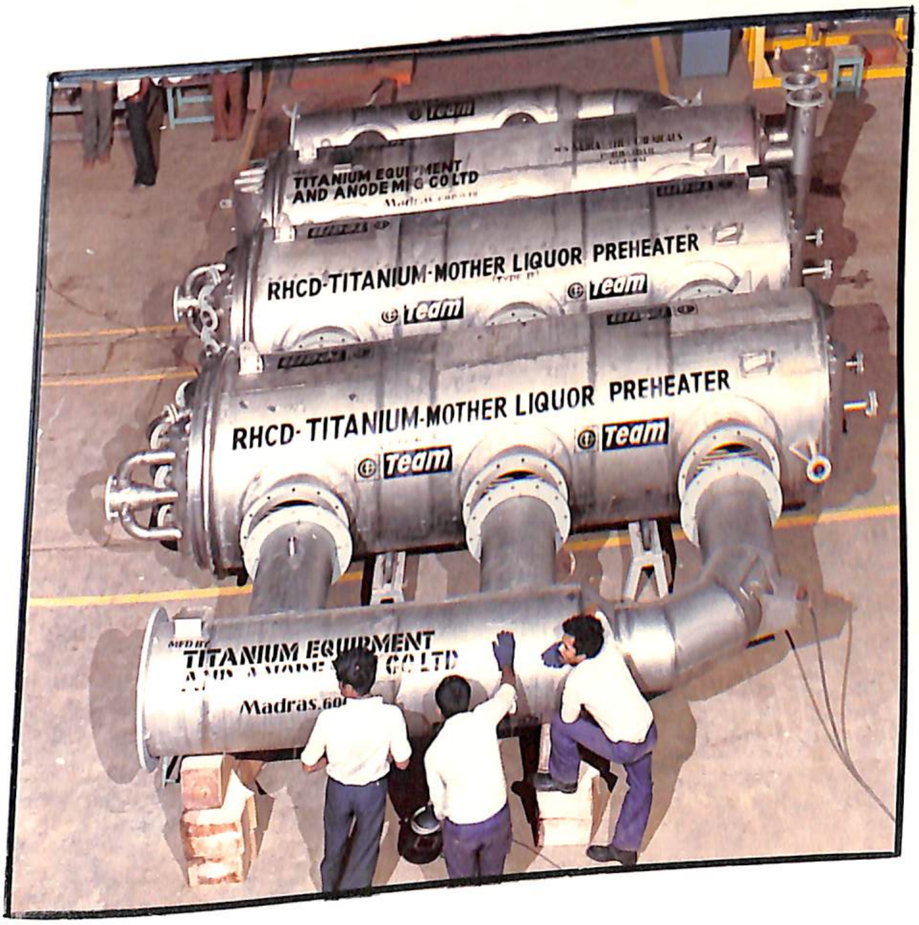
d) adjustment of current

By setting parameters for each type of electrolyzer, the production rate was increased four times than normal hand welding and this also resulted in consistency in welding quality. As most of the work being done on titanium welding is tailor made, TEAM prefers to do as much as possible a position welding by proper manipulation and selecting proper gadgets for argon gas shielding.

Certain alloys require argon helium mixture for shielding and cooling which is also being adopted. The latest art of science is laser welding. This will be employed for the purpose of producing components for super conductivity, hydrogen absorbtion. Shape memory is on the anvil which. TEAM is fully geared up to absorb these technologies and face the future with confidence and assurance, for the betterment of the industry (Fig 4.13, 4.14).

FIG. 4.15

TITANIUM PRESSURE VESSEL



TITANIUM HEAT EXCHANGERS

TITANIUM TOWER FOR PETRO-CHEMICAL INDUSTRIES

TITANIUM GAS BOTTLE FOR SPACE TECHNOLOGY

4.4 FRAUNHOFFER GESELLSCHAFT

For a successful technology implementation, upgradation is required. This upgradation is possible only by way of research and development and constant search for new technologies and diversification.

One method of implementation of the above can be achieved through.

A. Enhanced R & D efforts

B. Recognised Government Laboratories

C. Outside agencies in the form of developed companies exclusively doing this business.

Fraunhoffer Gesselschaft (FhG) is one such C-Category company founded in 1949 in Munich with the main aim to contribute to the reconstruction of Germany after the second world war. This company employs 7,700 people and has 46 research institutes in 14 German locations (Fig. 4.15).

It also maintains a research centre in USA. The total value of the research is nearly DM 940 Million. Most of the private companies utilise their services.

Yet another speciality of this company is to help loss making companies in solving their problem and turning them to green companies.

As a strategy to sustain competitiveness through technical innovation, FhG's research is oriented towards short and medium businesses.

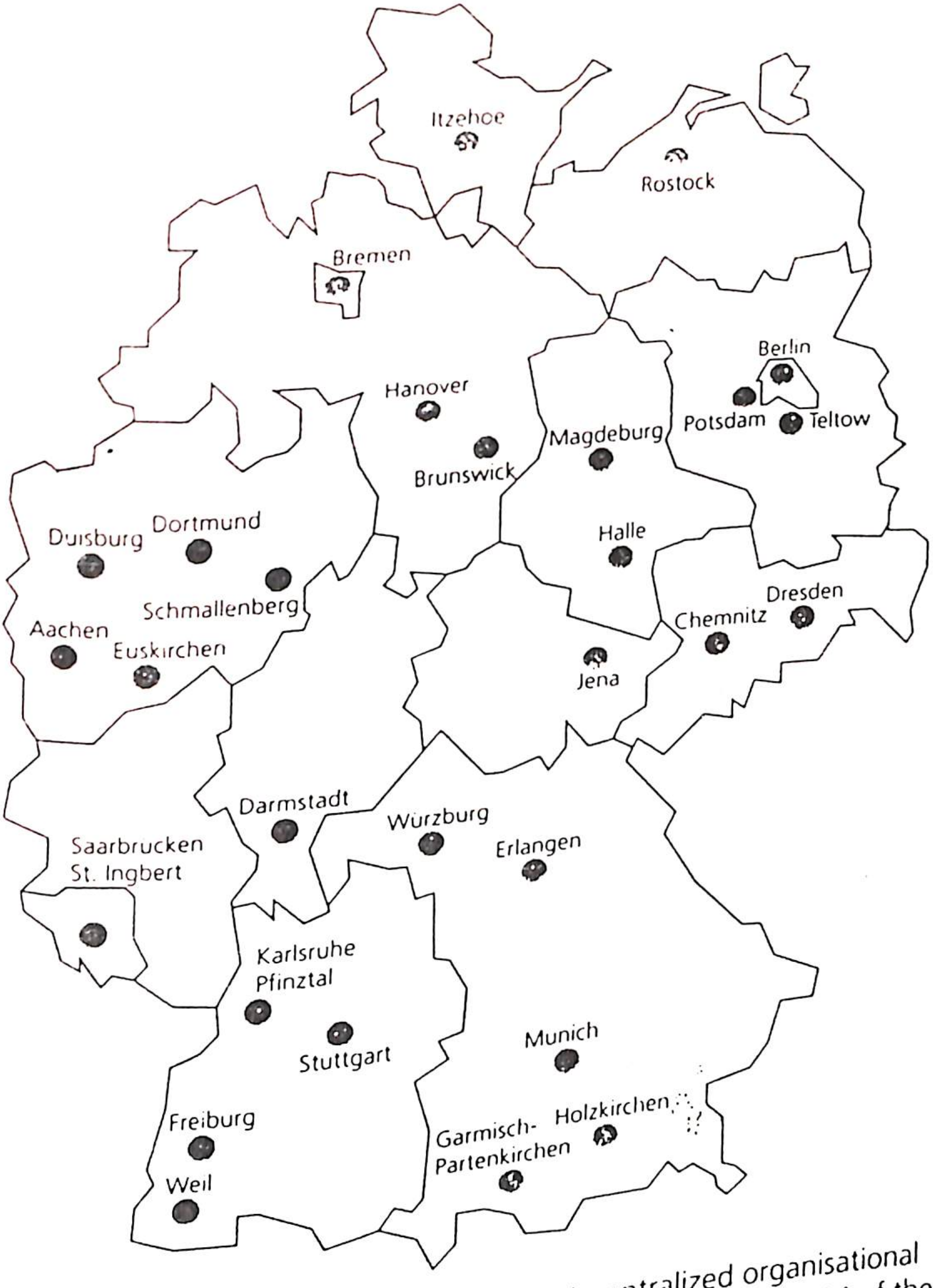
The success of FhG is mainly due to heavy emphasis it places on its people who are its more valuable asset. FhG offers latest management tools to technology projects identifying trends in technology and relying on the basic research, sourcing the technology to compete with internationals and implementing the technologies which will have practical applications - right technology at the right time - for example robot, for automation in automobile industry, computer aided control technology where precision and speed are required.

To achieve technological success, over and above R&D efforts, the technology should find practical applications. Turning research results into industrial use is very important.

Resource pool towards development would mean shared and reduced cost and lesser risk.

FhG is an example which demonstrates that efficiency and creativeness of an enterprise depend on the people it employs. A technological company has to depend on professional experience and leadership qualities of its scientists and engineers.

The locations of the Institutes of the Fraunhofer-Gesellschaft



The Fraunhofer-Gesellschaft maintains a decentralized organisational structure. 46 research establishments in 31 towns located in 14 of the German *Länder* provide their respective regional Industries with services. The head office is in Munich.

CHAPTER 5

CONCLUSIONS

5.1 ANALYSIS OF CASES PRESENTED AND IDENTIFICAGION OF MAJOR CRITICAL ISSUES & FACTORS INFLUENCING MANAGEMENT OF TECHNOLOGY

The cases and studies presented in the preceding chapters clearly bring out that a major and critical criterion in an industrial venture is "**Informed judgement and care in technology acquisition.**"

In the case of Bhopal, a multinational company was involved and it was taken for granted that the multinational would have taken all the acquisition care that were necessary.

In the case of magnesium metal, the necessary care had not been exercised in the technology development stage itself and the technology was sold in a premature condition to the project promoter.

Therefore, in both the cases informed judgement was not exercised and enough care was not taken in the acquisition and they had to meet with failure.

In the case of titanium welding technology, it was based on in-house development with hands-on job practice. The development was done in a systematic manner based on results achieved at each stage of the development. It was given the same rigorous treatment and care, as is developed for transfer to an outsider.

In the case of membrane cell technology, the choice was between many multinational companies from USA, Japan, UK and Europe. To make informed judgement, data were collected globally, systematically, from each one of the proposed technology suppliers and subjected to rigorous in depth analysis. The above analysis was not only on the soundness of technology, but also for using the indigenous talents and the intellectual property of the Indian company having exposure in critical equipment manufacture.

The global share of market for the chlor-alkali plants based on ion exchange membrane process is:

American technologies	-	5%
European technologies	-	40%
Japanese technologies	-	40%
UK technologists	-	5%

The fact that the Japanese control 40% of the global market today in the membrane technology vindicates the choice of Japan as the source. Though European source also accounts for 40% today, there has been one failure and that company which used their technology had to wind up; USA is not able to go ahead beyond 5% of the market with their technology. Therefore, Japan comes out on the top as the best technology source and this corroborates sound judgement exercised in the technology acquisition for the project.

This also accounts for the fact that the Japanese do not market a technology commercially unless they have gone through a complete cycle of proof of each and every component and the process. It is very difficult to point out any Japanese technology which had failed on 'technology acquisition' basis.

Technically, and more morally, the cultural characteristics of Japanese are unquestionable. Actually, this is part of their value systems. In other words, the values of life makes their culture more important, meaningful and attractive.

Moreover, the Japanese cultural alliance blended very well and made it a success.

Yet another Japanese success indicator is customer-service orientation. On the other hand, the Americans concentrate on the legalities, and the Europeans on contractual obligations.

A second important issue that emerges from this research as major and critical is **Technology assimilation**. Successful assimilation of technology depends on the **choice of the people**, their intellectual capabilities, team spirit and a good leadership of the people. Choice of the people thus becoming a critical factor. In the case of Bhopal, even though the choice of Indian people may have been correct, because of the multinational company's (MNC) style of operation, the Indian intellectual property was not made use of - in the case of MNC any change in the process or sizing of the equipment has to have the approval of the MNC headquarters in various disciplinary departments. This not only takes a long time, but in the normal course they never approve changes because of their monolithic nature and because of the differential treatment given to foreign technologists by the Indian government authorities, MNC could get the project through.

In the case of membrane cell, training of the people was meticulous - right from qualification, education, operational training, safety training, maintenance training and exposure to plants outside the country and a good interaction through various seminars and workshops.

In the case of Magnesium, the quality or the intellectual power of the laboratory was not properly utilised to form a team to develop this into a full-fledged technology. In India, where there are very many eminent scientists who cannot accept failures, and laboratories who will accept any challenges, it was a wrong choice in the selection of the institutional intellectual power for this particular project. It was also the easy going attitude of the financial institutions and the State Government's investing company and the taking-it-for- granted attitude of the big name consultant, there was lack of necessary care which led to failure in the assimilation.

Whereas in the case of Titanium, success was because of the people who were involved - right from welders to engineers who worked in unison as a team to make the venture a success. Similarly, in the case of membrane cell technology, it is the choice of correct process owner, the consultants, the Indian intellectual power (especially in the area of indigenisation and implementation of the project), proper training to the people in operation of the plant, which collectively made the project a success.

In case of Magnesium had there been greater care at the time of assimilation and proper methodology evolved to study the performance of the cell, the project could have been stopped at that stage itself and further losses avoided.

In the case of Bhopal, the question of assimilation did not arise because of the MNCs style of functioning and the lack of adequate utilisation of Indian skills.

Clearly the choice of people determined success as well as failure.

In the process of assimilation, it is very critical and important to have proper documentation. This will fix the various accountability of individuals, teams and the organisations for successful assimilation of the technology.

Had there been a proper documentation on the contractual obligations in the case of Magnesium with the Consultant, with the Process Owner and with the Financial institutions, such accountability could have been fixed.

In the case of Bhopal, it involving a MNC company and a subsidiary, it appears that much seriousness was not attached to this factor.

During assimilation, Safety audit is very essential especially for hazardous chemicals like MIC or Chlorine. Although safety audit was carried out at Bhopal, the findings of the audit were not followed and action taken. In the case of membrane cell plant, although safety audit was not mandatory, a reputed national laboratory - Central Leather Research Institute - was appointed to conduct the safety audit and their recommendations were meticulously implemented.

The third factor that emerges as major and critical is **sustainability insurance**, in the context of technological change.

Vital elements of this sustainability are:

Technology Vigil: The technology chosen should have an adaptability for upgradation/changes to cope with the technology improvements with multiproducts.

In case of Titanium, the welding technology was upgraded stage by stage from the outdated glove box welding to computerised semi-automatic welding.

In case of membrane plant, it is adaptable for any new development

a. in polymer technology with improved ion exchange membranes,

b. of new cathode coatings/anode coatings for further energy saving,

c. for any new material of construction to improve corrosion resistance.

In insuring sustainability, the most critical factor would be adaptability for change and improvements in the process and hardware.

Constant improvement in efficiency of operation, reduction in power consumption, reduction in raw material and chemical consumption could easily bring down the cost of production giving a competitive edge to the company's products.

At the membrane cell plant, on-line R & D has become a way of life. There has been continuous developmental work on waste utilisation, energy recovery, water recycling, high value addition. Special benefits arose in

a) lower water consumption

b) quality of salt

c) recovery of Barium Sulphate from the waste sludge

5.2 THIS STUDY IN THE INDIAN CONTEXT

Following the new foreign trade policy and restructuring of the Indian economy, a sea of changes have taken place starting from 1992 onwards. The devaluation of rupee did help improve exports. The rupee denominated, Russian trade collapsed and new debt servicing arrangements took over with expectation of resumption. There was a clear change, system manipulation yielding to market development. The average level of export from India in the past five years is US $ 18 Billion, only 6% of the national GDP (less than 0.5% of the total world trade). Chinese exports of manufactured goods and services has crossed US $ 100 billion, through the trading hub of Hongkong. It is easy for India now to maintain atleast a 15% annual growth of export which would not only take care of the debt service in the next 3 years, but will positively improve to stimulate domestic economy. With efficiency and productivity being upgraded by selective and efficient technology management backed by the excellent scientific and technological research capability already available in India, there is a strong avenue for services export - after the patent laws are suitably adjusted. India has to compete for its share of the market with China and other South East Asian countries who have more exposure and grip in the present situation. Better economic performance in the G-7 countries has brought in radical changes in their national priorities and policies leading to sustained economic growth.

The G-15 is clearly shifting the political sphere to economic sphere and definite signs of improved South-South relations is perceivable.

The conclusion of GATT negotiations has enlarged the volume of global business to about US $ 300 billion a year and a reasonable portion of this can be tapped by the Indian strength of intellectual power and R & D base and technology management skill.

The GATT concept of managed trade by selecting a number of limited targets creating a Government-Industry-research team effort will help negotiate the country's competitive advantages and would take place at the enterprise level. This is the precise way how productivity and competitiveness drove Japan to its present world status in many sectors, automobiles and electronics providing examples. Outstanding example of similar achievement in India where the Government, intellectual power and the research system acted in tandem is the selection of technology and competent management of Indian Space Research Organisation.

Thus, India has the basic required intellectual manpower and the R & D infrastructure to acquire and assimilate technologies from world over.

Till the New Economic Reform arrived, the Indian industry had been protected by the Government by various incentives at very high cost, which in a way helped attain a high intellectual manpower strength in the world.

Now, a situation has come where a change has to be accepted if India has to exist globally in the changed world scenario.

Because of the protection afforded by the Government, many companies were earning high profits and could manage to sell in the domestic market, irrespective of any gaps in the quality. The Financial Institutions and Banks had a very good time in building up their own resources by charging a very high cost on finance, which was passed on the customer.

The customer has now become more and more knowledgeable. He knows the importance and value of quality. Customers are equally conscious of cost. Hence, in today's changed scenario, an Indian customer would automatically look for the best quality product at the cheapest price from any part of the world.

The Indian Government cannot any more afford incentives and has to look for proper revenue to liquidate its international borrowings and achieve a strong economy. This is possible only with a systematic industrialisation and systematic management of the change.

Hence, it becomes extremely important for the existing industries to understand the current situation and rise to the occasion of the change. Whether it is development of a new gadget or a new commercial technology, success would depend critically on the way the entire process is managed.

The big change is in the form of economic revolution and opening up with an aim to get a better share in the world for Indian manufactured goods and services. Government has allowed huge foreign investments into the country in the form of equity and in the form of loan to reduce the liabilities, and in the form of new investments and substantial expansions in the core and non-core sectors.

The interest rate on the foreign exchange thus received is hardly 30% of the present interest charges prevalent with Indian financial institutions.

The best way to operate and manage the present change would be to

a. look for proper technology and marketing tie-up with world renowned companies;

b. allow equity for them in the Indian business, to enable establish a credibility in the world market and for profit-sharing.

c. look for updating the quality standards through in-house R & D as well as inputs from foreign collaborators; exercise great vigil in technology acquisition and assimilation;

d. look for the world market

e. take advantage of the cheaper cost of conversion and intellectual power in India for the mutual benefit of the collaborator and the Indian company.

f. avail the lesser cost of finance, to enable produce at a cheaper cost.

India has fortunately built up a very strong R & D base. India is in a similar situation to what Japan was two to three decades ago. Though not economically sound there was building up of the infrastructure. Now, Japan is fully benefiting from the infrastructure developed over decades. Similarly, India should now take full advantage of the infrastructure built all these decades since independence.

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