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UNIDO

The 2nd Meeting of the Advisory Committee and the IMAAC Forum at Beijing

TECHNICAL REPORT

Sponsored and Organized by
United National Industry Development Organization
(UNIDO)

Co-Organized by
Chinese Materials Research Society (C-MRS)

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SYNOPSIS

To provide an international forum to serve the materials community for more effective management of the techno-economic aspects of sustainable development and utilization of both traditional and new materials, the 2nd Meeting of Advisory Committee and the IMAAC Forum were held on 13-18 June 1999 in Beijing. The Meeting of Advisory Committee mainly discussed the IMAAC work and plan. In the IMAAC Forum, it was first introduced for the IMAAC mission, objectives, functions, benefits from participation, funding arrangements, and invitation to participate, and so on. On behalf of Chinese Government, Prof. Dinghuan Shi, the deputy director of the department of high-tech, the Ministry of Science and Technology, PR China, attended the IMAAC Forum for a special congratulation. Ten keynote presentations had been submitted to the IMMAC Forum. It covers the development and application of various materials in China such as iron and steel, cement and ceramics, rare earths, nonferrous metals, rare metals, polymer and plastics, materials corrosion, powder metallurgy, surface technology, materials education with internet in future, ecomaterials, and so on.

Several recommendation had been submitted for IMAAC.

UNIDO

The 2nd Meeting of the Advisory Committee and IMAAC Forum

TECHNICAL REPORT

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INTRODUCTION

While preparing the feasibility study on the establishment of an International Materials Assessment and Application Centre (IMAAC), it was found that IMAAC should provide an international forum to serve the materials community for more effective management of the techno-economic aspects of sustainable development and utilization of both traditional and new materials.

Today, within the new context of UNIDO technology and investment promotion services, IMAAC and its network should be a substantive knowledge and technology resource base. As one of the international Technology Centres established or being established by UNIDO, it will play an important role in the new UNIDO Industrial Partnership Promotion Network (IPPN) as well as in the international community dealing with materials science and engineering.

Having recognized the above mentioned, the 1st Meeting of the IMAAC Advisery Committee decided to conduct its 2nd AC Meeting in conjunction with the International Conference and Exhibition organized by the International Union of Materials Research Societies (IUMRS) on 13-18 June 1999 in Beijing. It was also proposed that "IMAAC Forum" be organized within the framework of this conference in order to increase awareness about the Centre and foster the international cooperation within the framework of its programme.

At the same time, this forum is seen as a good platform to promote other International Technology Centres as well as new UNIDO Service Modules and its Industrial Partnership Promotion Network.

As a result of both meetings, the mission of IMAAC and the strategy for its establishment will be tuned in accordance with rapidly changing global economic environment, especially in the area of materials science and engineering as well as with other activities of UNIDO in investment and technology promotion.

THE 2ND MEETING OF ADVISORY COMMITTEE

The 2nd Meeting of Advisory Committee had lasted for three sessions from Monday to Wednesday at Beijing International Conference Centre. All the IMAAC Advisors had attended the AC meetings including Prof. R.C. Villas Boas, Dr. L. Fellows Filho, Dr. V. Kozharnovich, Prof. Li Hengde as well as Dr. P. Rama Rao.

The work and plan of IMAAC had been discussed from last meeting to now. Detail please refer the report from Prof. Villas Boas in appendix. Main notes from AC Meetings include:

1. At the end of May 98, IMAAC Advisory Committee was set up and met in Rio de Janeiro, Brasil, for the first time;

2. At the occasion, the objectives, mission and functions of the Centre were established and diffused throughout interested parties;

3. A pilot phase, of two years of duration, was set up, involving the following activities:

a) proposal of the operation nodes and the main hub: completed;

b) adhesion of participating organizations: 65 organizations, till end of may 99 had manifested intentions to join IMAAC;

c) the design of the hardware and software for the hub: from a sketch made by Prof. Valladares at the Rio meeting, a complete set of requirements were made and then modified, recently, by UNIDO experts;

d) acquisition and installation of the designed hard + soft for the hub: operation delayed due to organizational restructuring of UNIDO and expected to be completed by the end of October 99;

e) proposal of the profile of the operating personnel for IMAAC hub: completed and submitted for final approval by the Ministry of Science and Technology of Brazil : expected approval by the end of SEPTEMBER 99;

4. Realization of the IMAAC FORUM '99 in Beijing: an awareness

FORUM; operation completed with full adhesion of the following institutions:

a) Chinese Academy of Cement and Building Materials;

b) Institute of Corrosion and Protection of Metals of the Chinese Academy of Sciences;

c) Northwest Institute for Non-ferrous Metals Research;

d) Central South University of Technology;

e) Chinese Academy of Iron and Steel;

5. Revision of the two remaining FORUNS to be held by IMAAC during the pilot – phase:

a) the "go ahead" with the IMAAC COPPER FORUM, now scheduled to be held in conjunction with the CYTED event "Mining and Sustainable Development ", possibly in Portugal and Spain, at the end of OCTOBER 99;

b) the 'go ahead "with the IMAAC CEMENT FORUM, now scheduled to be held jointly with the Chinese Academy of Cement and Building Materials, possibly at the end of April 2000;

6. Review of possible pilot projects, under the auspices of UNIDO ongoing projects:

a) MOZAMBIQUE: the conceptual design of R&D facilities for strategic areas in Mozambique: scheduled to start by September 99;

b) MALASIA: training in technology assessment and forecasting: scheduled to start by late September 99:

c) MONTREAL PROTOCOL: assessment on materials technological issues; still under negotiations internally to UNIDO;

7. Establishment of the IMAAC BULLETIN:

a) the printing of the two first BULLETINS containing pertinent material presented at the Rio and Beijing meetings; late October 99 ;

b) next, the printing of the COPPER and CEMENT FORUM as IMAAC BULLETINS;

c) to appoint Prof. P. Rama Rao as the Editor-in-Chief of the IMAAC

BULLETIN;

8. Approval of setting up a diffusion plan, as follows:

a) to build an IMAAC HOMEPAGE at the UNIDO site: conclude in October 99;

b) to print leaflets and distributing to interested parties and events: conclusion by November 99;

9. Approval of establishing close relations between IMAAC and ICMET, both UNIDO Centers, as well as others, for projects participation and cooperation; the responsible directors of ICMET/UNIDO were invited to attend the IMAAC FORUM '99 presenting their views and missions;

10. Approval of the release to the IMAAC hub at CETEM of USD 20 thousand to cover operational cost and general expenditures related to the decisions made;

To the following activities as approved and planned were designated the following persons :

a) Acquisition of the hardware as stated above: Vladimir Khozharnovich; up to the end of August 99;

b) Transferring of the hardware to CETEM: Vladimir and Lelio Fellows Filho; up to the end of September 99;

c) Installing of the hardware at CETEM hub: Lelio and Roberto Villas Bôas, up to the end of October 99;

d) Assigning Operational personnel to IMAAC hub: Lélio and Villas Bôas; as soon as possible: end of August 99;

e) World's Resource Assessment to be prepared by the hired personnel; Villas Bôas; up to December 99;

f) Terms of References for the COPPER and CEMENT FORUMS: Villas Bôas; for the COPPER up to the end of August 99 ; for the CEMENT up to the end of January 2000;

g) Liberation of the USD 20,000.00 for operational costs for IMAAC:

Vladimir, up to the end of August 99 ;

h) Homepage: Lélio; up to October 99;

i) Report on the IMAAC FORUM '99: Hengde Li; up to September 99;

j) IMAAC BULLETINS: P. Rama Rao; the first two up to November 99;

IMAAC FORUM '99

IMAAC Forum started on Thursday, three sessions totally. At the beginning, what is the IMAAC was introduced by the ADVISORY COMMITTEEs, included the IMAAC mission, objectives, functions, benefits from participation, funding arrangements, and invitation to participate, and so on.

On behalf of Chinese Government, Prof. Dinghuan Shi, the deputy director of the department of high-tech, the Ministry of Science and Technology, PR China, attended the IMAAC Forum for a special congratulation. By the chance, he gave also a presentation topic on the government strategy in materials development and application in China.

Ten keynote presentations had been submitted to the IMMAC Forum. It covers the development and application of various materilas in China such as iron and steel, cement and ceramics, rare earths, nonferrous metal, rare metal, polymer and plastics, materials corrosion, powder metallurgy, surface technology, materials education with internet in future, ecomaterials, and so on.

From Central Iron and Steel Research Institute, Beijing, China, Prof. Shourong Zhang gave a talk on the Issues on the Development of Steel Industry in Developing Countries. Prof. Jin Zhu from Tsinghua University presented a keynote speech on Materials Education with Internet in Future. Dr. Hailing Tu, the General Director of Beijing General Research Institute for Nonferrous Metals, introduced an application of rare earths in high-tech industry. Prof. Jingping Qu, A President of South China University of Technology, Guangzhou, demonstrated the Prospects of Plastics Processing in Developing Countries. From Northwest Institute for Nonferrous Metal Research, China, Prof. Weihong

Yin reported the role and position of rare metal materials in development of modern mankind civilization. Prof. Shixi Ouyang, the general director of China Academy of Building Materials, Beijing, presented a talk on China's cement industry – present state and strategy of development. Dr. Enhou Han from the Institute of Corrosion & Protection of Metals, Shenyang, China, introduced the Corrosion Science, Corrosion Engineering and Sustainable Development in China. Prof. Baiyun Huang, the preesident of Central South University of Technology, Changsha, China, gave a talk on the assessment and application of Powder Metallurgy Materials in developing countries. Dr. Kesong Zhou, the general director of Guangzhou Institute for Nonferrous Metal Research, China, demonstrated the current development and outlook for advanced surface technology and engineering in China. At last Dr. Duan Weng from Tsinghua University, Beijing, China, reported briefly the Environmental Impact Assessment of Materials and Ecomaterials Development in China.

Prof. Boas and Prof. Li, at last of the Forum, gave some brief comments for the IMAAC. Both mentioned the importance for the IMAAC promotion and international coorperation in materials development.

With the presence of especially invited people from the Ministry of Science and Technology of China , the General Research Institute for Nonferrous Metals, the Institute of Corrosion and Protection of Metals of the Chinese Academy of Sciences, the Central Iron and Steel research Institute, the China Building Materials Academy, the Guangzhou Research Institute of Nonferrous Metals, the South China University of Technology, the Tsinghua University, the Northwest Institute for Nonferrous Metal Research, the Advanced Technology & Materials Co. Ltd., and some three other organizations outside China, the University of Aveiro, in Portugal, the Queen Mary College of the University of London, and the Materials Science Engineering Dept. of the University of Queensland, in Australia, the IMAAC FORUM '99 was held from june 17th to june 18th at the Beijing International Convention Center (BICC).

The objectives of the FORUM, as stated during the First IMAAC ACP meeting held in Rio, were:

- the diffuse IMAAC objectives, missions and functions in the host country and other interested parties
- to attract interested organizations to be part of IMAAC nodes
- to listen to selected invited scientists and engineers from the host country in relevant topics to IMAAC's missions and objectives
- to devise alternative routes to reach associates for IMAAC

In order to accomplish with such goals the sections were so designed that the overall UNIDO new polices on investment and technology promotion were presented to the audience , followed by how does IMAAC fit within them and the accomplishments, as well as drawbacks, that IMAAC has had throughout this first year of its pilot-phase . Two presentations were held at this part:

1.-) UNIDO Investment and Technology Promotion Programme, by V. Kozharnovich .

2.-) IMAAC Objectives and Missions: Present and Future, by L. Fellows Filho.

In the sequence of the FORUM, several papers were distributed and presented, as follows:

1.-) Materials Production and the Environment, by R.C. Villas Bôas.

2.-) China's Cement Industry – Present State and Strategy of Development, by Ouyang Shixi .

3.-) The Current Development and Outlook for Advanced Surface Technology and Engineering in China, by Zhou Kesong and others.

4.-) On the Issues Concerning the Development of Steel Industry in Developing Countries, by Yin Ruiyu.

5.-) Prospect of Plastics Processing in Developing Countries, by Qu Jingping and others.

6.-) Corrosion Science, Corrosion Engineering and Sustainable Development , by En-Hou Han and others.

7.-) Application of Rare Earth in High- Tech Industry, by Tu Hailing and others.

8.-) Application for Setting up of an "International Rare Metal Material Assessment and Application Center", by Zhou Lian.

This last one being an official application to IMAAC and UNIDO to accredit the Northwest Institute for Nonferrous Metals Research (NIN) as the node for Rare Metal Material Assessment and Application within IMAAC objectives and missions.

Also, the paper by P. Rama Rao, entitled "Approach to an Integrated Mineral-Material-Product Development "was distributed to the participants, although not presented, since Prof. Rama Rao rather allowed the time he will utilize for the exposition to other Chinese participants not listed above (for instance, the Vice Minister of S&T of China and an enterpreneur from ATM Co. Ltd.).

The relevant points raised throughout the FORUM were:

1.-) lack of clearness from the part of the attendees of what in fact is IMAAC, how it works, and how can you join it;

2.-) the eagerness on the part of the interested entities, previously contacted by Prof. Hengde Li, in joining IMAAC, as soon as the questions regarding IMAAC – see above - were answered;

3.-) the views raised by all of the expositors on cost internalization of the environment as a crucial question to the materials engineer and scientist;

4.-) the very interesting particularities of the Steel and Cement industries in the developing world that were posed by Drs. Yin Ruiyu and Ouyang Shixi, when analyzing the Chinese case-study;

5.-) the decision , by the ACP, of confirming the CEMENT FORUM and to held it jointly with the Chinese Academy of Cement and Building Materials ;

6.-) to consider the papers presented , and/or distributed, in the FORUM as worth of publishing in a IMAAC BULLETIN;

7.-) the absolute place of these FORUMS within the activities of a bigger Conference , as the IUMRS one, in order to attract interested parties to IMAAC , in accordance to Hengde LI and Ariel Valladares when they proposed it in Rio, back in 1998.

CONCLUSION

The ACP decided:

1.-) to publish the IMAAC FORUM '99 in a IMAAC BULLETIN which Editor-in-Chief was designated to be Prof. Dr. P. Rama-Rao;

2.-) for that matter, Prof. Dr. Hengde Li , will convey to him all relevant writings that were eventually missing during the oral presentations;

3.-) that the IMAAC CEMENT FORUM will be held in 2000, probably by April, in a joint effort between IMAAC and the China Academy of Cement and Building Materials;

4.-) for that purpose, the International Coordinator, Dr. Vladimir Khozarnovich was entitled to negotiate directly with that Academy, with the help of Prof. Dr. Hengde Li;

5.-) to adopt for the next IMAAC FORUNS say the COPPER and the CEMENT, specific "TERMS OF REFERENCES "in order to enhance and enlarge the participation of interested entities;

6.-) for that matter Villas Bôas was assigned responsible;

RECOMMENDATION

1. The Beijing IMAAC Forum has been proved to be very succssful and useful in advancing the course of IMAAC project. It is recommended that future IMAAC forums will be oganised, either for any specific subjects such as cement, iron and steels, or for comprehensive reviews on important materials developments..
2. Broad and intensive interests have been reflected from the proceedings of the Beijing IMAAC Forum. Many research centres and universities in China expressed their concern in joining IMAAC network as nodes of the whole system. It is recommended that some procedures should be prepared to examine and approve their applications. And the pace of IMAAC project should be accelerated.
3. To facilitate the IMAAC development the CETEM hub should be quickly established and a global network can then be realized.
4. Governmental supports are always important in order to accomplish this kind of international poject. It is hoped that UNIDO could exert its influence in this respect to encourage the relevent govrnmental agencies to participate and support IMAAC activities.

APPENDIX

A, The Program of AC Meeting and IMAAC Forum

B, Papers of AC Meeting

C, Papers of IMAAC Forum

D, Participant Lists

Appendix A

The Program of AC Meeting and IMAAC Forum

PROGRAM

June 13 – 18, 1999 Beijing, China

http://www.chimeb.edu.cn

June 17, Thursday, IMAAC Forum Session A 8:30 ~ 12:30 Room 2001

Chairmen: Prof. Heng-de LI Tsinghua University, Beijing, China

Chairmen: Dr. R. C. Villas Boas CETEM, Rio de Janeiro, Brazil

Opening Statement

Prof. H.-D. Li C-MRS, Beijing, China

An Introduction for IMAAC

Dr. V. Kozharnovich UNIDO, Vienna, Austria

An Introduction for IMAAC

Dr. L. Fellows Filho Ministry of Science and technology of Brazil

Cafe Break

An Introduction for IMAAC

Dr. P. R. Rao Atomic Energy regulatory, Mumbai, India

An Introduction for IMAAC

Dr. R. C. Villas Boas CETEM, Rio de Janeiro, Brazil

Discussion

June 17, Thursday, IMAAC Forum Session B 14:30 ~ 18:00 Room 2001

Chairmen: Dr. L. Fellows Filho, Ministry of Science and technology of Brazil

Chairmen: Dr. V. Kozharnovich UNIDO, Vienna, Austria

The Issues on the Development of Steel Industry in Developing Countries

Dr. R.-Y.. Yin Central Iron and Steel Research Institute, Beijing, China

Materials Education with Internet in Future

Prof. J. Zhu Tsinghua University, Beijing, China

Rare Earths in China

Dr. H.-L. Tu Beijing, China

Cafe Break

Prospects of Plastics Processing in Developing Countries
Prof. J.-P. Qu, Southchina University of Technology, Guangzhou, China
The Research and Application of Rare Metals
Prof. W.-H. Yin Northwest Institute for Nonferrous Metal Research, China
Discussion

June 18, Friday, IMAAC Forum Session C 8:30 ~ 12:30 Room 2001

Chairmen: Dr. P. R. Rao Atomic Energy regulatory, Mumbai, India
Chairmen: Dr. L. Fellows Filho, Ministry of Science and technology of Brazil
State & Prospects of Chinese Cement
Prof. S.-X. Ouyang, China Academy of Building Materials, Beijing, China
Corrosion Science, Corrosion Engineering and Sustainable Development
Dr. E.-H. Han, Institute of Corrosion & Protection of Metals, Shenyang,
Powder Metallurgy Materials Assessment and Application in Developing Countries
Prof. B.-Y. Huang, Central South University of Technology, Changsha
Cafe Break
Surface Engineering
Dr. K.-S. Zhou Guangzhou Institute for Nonferrous Metal Research, China
Environmental Impact Assessment of Materials and Ecomaterials Development
Dr. D. Weng Tsinghua University, Beijing, China
Discussion

June 18, Friday, IMAAC Forum Session D 14:30 ~ 18:00 Room 2001

The Meeting of the Advisory Committee (AC)

SCHEDULE

Date	Day	Time	Location	Content
13 June	Sun.	18:00~22:00	Hall No.1	Reception
14 June	Mon.	9:00~12:30	Hall No.1	Plenary IUMRS-ICAM'99
		14:30~18:00	Room 2001	IMAAC AC Meeting
		18:30~21:30		AC Activity
15 June	Tue.	8:30~12:30	Hall No.1	Plenary IUMRS-ICAM'99
		14:30~18:00	Room 2001	IMAAC AC Meeting
		19:00~22:00		IUMRS Entertainment
16 June	Wen.	8:30~12:30	Hall No.1	Plenary IUMRS-ICAM'99
		14:30~18:00	Room 2001	IMAAC AC Meeting
		18:30~21:30		AC Activity
17 June	Thu.	8:30~12:30	Room 2001	IMAAC Forum Session A
		14:30~18:00	Room 2001	IMAAC Forum Session B
		19:00~22:00		IUMRS Banquet
18 June	Fri.	8:30~12:30	Room 2001	IMAAC Forum Session C
		14:30~18:00	Room 2001	AC Meeting

Co-Chairmen: Prof. Heng-de LI
Secretary: Dr. Duan WENG & Mr. Xiaodong WU
Interpreter: Miss Jin TANG & Miss Yu LIN
Phone: +86-10-6278-5775
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V. Kozharnovich
IPC/ITP

UNIDO Investment and Technology Promotion Programme
(Technology Component)

I. Technology and Investment in the New Global Economic Context

The rapid economic growth worldwide has been achieved by countries which have adopted technology as the engine of growth. Furthermore, the new context of globalization, free trade agreements, deregulation and other factors is critically enhancing the role placed by technological innovations in both economic growth and the competitiveness of business.

Taking into account the new global competitive environment, top management of the technology-based companies regards technological leadership today as a key prerequisite for the companies' success and growth. In the future, competitive pressure on firms is expected even to increase as a result of growing competition in the world markets and in the context of GATT commitments.

Therefore, technological innovation and new technologies are now at the core of the strategies of successful industrial firms of any size in any country. But the technology transfer process and application of new technologies at the industrial scale go alongside with industrial investment which, in particular private investment, is a key determinant of economic development and employment creation.

Today, the establishment of a conducive investment climate for promotion of innovations, the generation of matching national investments and the improving the institutional capacity constituting the infrastructure and business environment for the absorption and utilization of technology and investment in industry are clearly seen as a key requirement for industrial competitiveness. But there is a need for an integrated wide-ranging investment and technology promotion approach that would not only attract and retain the inflows of investment and technology but will also make the optimum use of them for the domestic economy.

II. Challenges of Industry

Technology-related companies face distinct challenges through having to focus resources on emerging technological innovations and market opportunities. These companies need to be innovative both in determining potential opportunities and in their reactive response to market changes or competitor action. Although flexibility is probably inherent for small companies, larger companies need to retain this ability to reconfigure and accommodate temporary activities, and to retain the spirit of entrepreneurs to sustain the flow of innovative ideas.

Today, industry, and SMEs in particular, are facing an increasing number of new challenges:

- global competition is getting fiercer;
- cooperation and strategic alliances are now essential;

- flexibility is becoming increasingly necessary in order to adjust to changing costumer demands;
- quality requirements are higher than ever.

Technological innovation plays a central part in facing these challenges. Ensuring constant technological improvements in the enterprise is the cornerstone for both survival and success. But the process of successful dissemination and transfer of technology and the investment promotion depends on the absorption capacity of enterprises, particularly the SMEs. No matter how good the dissemination and transfer mechanisms are, the actual exploitation of a new technology is preconditioned by the absorption capacity of an enterprise.

It is mainly the responsibility of the firm to ensure the development of this capacity, but the local research and technology institutes (RTIs) can assist and facilitate the process in several ways. It must be a major objective for RTIs to assist the industry in building up the absorption capacity. When this is achieved, the enterprise will be looking for new ways to improve its business through investment and technology mechanisms and seek RTIs' help for this.

III. Needs in Research/Industry Partnerships

It is evident that production cannot be managed in isolation from research and technology. Market increasingly demands that firms be able to meet the recent challenges and be competitive in the new rapidly changing global economic environment. Some of the more evident phenomena recently emerging are:

- increasing importance of knowledge intensive industries;
- inter-functional closeness between R&D, manufacturing, marketing and customer services (time compression);
- increasing globalization of production;
- technology alliances and networking between companies, R&D and technology institutes and universities;
- long and expensive development of a new product and short product life cycle;
- increasing importance of the role of R&D in the globalization process;
- advances in organizational techniques, lower communication costs, the emergence of new sources of intermediate products, intensive cost-reducing pressure etc. - all have tended to make more cross-border sub-contracting and collaboration.

For SMEs in particular, other main reasons for research/industry business partnerships in the new economic context are:

- no one SME can afford to have a research unit in its structure due to high cost of research;
- SMEs cannot manage all of new technologies involved in multidisciplinary by its nature innovation projects and RTIs can provide this knowledge;
- SMEs are also normally short of R&D facilities and new technological know-how, whereas RTIs generally possess these in abundance;
- SMEs need an objective partner in monitoring technological advances, testing, standards, etc.

These phenomena signify that enterprises, to be competitive, have to gain significant production benefits by having close links with research and development and effective mechanisms from the sales, marketing and production functions to the R&D, universities and other technical departments. Therefore, the research/industry interface and partnership become a key criteria in competitive performance and survival.

IV. Problems and new Role of R&D and Technology Institutes

Today, the research and technology institutes perceive themselves to be the knowledge resource base and most important instruments for implementing technological change within areas in which they have their core competence. Their primary objective is to enhance the technological competitiveness of the SMEs by implementing new technology. The two most common RTIs roles were identified as technology gap filling and the role of taking part in SME research and innovation projects.

The other functions of RTIs are recognized as trouble shooting, providing links to other research and support institutions, and assisting SMEs in analyzing and managing innovations. It should be noted however, that other sources of technology are considered important too; for instance, equipment suppliers are considered to be the second most significant contributors to this process.

Research and technology institutes can typically offer such services and, thus, are considered as strategic partners of industry and assets for enhanced competitiveness. However, they themselves are facing new challenges as well. The level of basic government spending on research and development is decreasing in most countries and RTIs have to adapt to a new situation where mainly undertaking research activities is not sufficient. They have to develop closer links with their target industry both in research collaboration and the effective transfer of technology and know-how.

Today, they are typically inward-oriented and technology supply-driven. In many cases, they do not have incentives or adequate management and marketing systems to respond effectively to the demands of both public and private industries in the fast changing global economic environment. The capabilities and organizational characteristics of such RTIs are increasingly out of step with the requirements of the new situation faced by the countries in the late 1990s, namely: privatization, the strong pace of technological advances and innovations on account of new technologies, globalization and the opening up of the economy, and the need to enhance the competitiveness of industry.

Therefore, strong misgivings about the relevance and performance of the research and technology institutes are increasingly being voiced in government and industrial circles of many countries. There is a concern about the need to revitalize, restructure and re-orient the existing institutes so that they become industry demand-driven, market-oriented and commercially sustainable, providing the important technological contribution to economic development. The changes in the R&D establishment are required to adjust the restructuring process in the countries to the global economic context.

These new requirements have also placed new key demands on research providers and managers, in particular:

- sharper business competency;
- proficiency in translating technological innovation into commercial advantage;

- maintaining state-of-the-art R&D resources to remain an effective partner;
- proactive management of the interface between proprietary commercial and private/public research.

Therefore, in the process of revitalization of research and technology institutes, it is necessary not only to examine their role within the National Innovation System and to harmonize their strategy and work programmes to the needs of industry and markets. It is also very important to strengthen the managerial skills and marketing mechanisms, change the culture of work and link industrial research to actual investments.

UNIDO's RESPONSE

V. UNIDO Programme on Revitalization of Research and Technology Institutes and Strengthening Their Links With Industry

Today, UNIDO is the only multi-lateral organization offering an integrated package of services to strengthen National Innovation Systems through the revitalization of research and technology institutes (RTIs) so that they become market-oriented and industry demand-driven providing the technology support services to enterprises, particularly to SMEs. It is an integral part of the UNIDO overall investment and technology promotion programme to build up institutional capacity in developing countries for sustained economic growth, industrial competitiveness, and public/private sector partnerships.

The main aim of the programme is to bridge the gap between technological developments and their commercial industrial applications, thereby enhancing the absorptive capacity of developing countries for new technologies and investments. Its strategic goal is to improve the industrial competitiveness and investment climate in the countries through promoting technological innovations, building up private/public sector partnerships, strengthening technological capacity, and fostering international cooperation.

Particularly, UNIDO has developed the Guidelines on Revitalization of Research and Technology Institutes which aim at improving the effectiveness and performance of an institute and are associated with certain specific techniques that have gained prominence in recent years. The revitalization/restructuring of any organization is a multi-dimensional and multi-disciplinary challenge and is especially important for RTI because the role it can span both public and private sector interest and concern infrastructure development, national programmes and new business projects.

In addition, UNIDO and its International Centre for Science and High Technology (ICS) have also developed a Programme of Support Services to assist the RTIs to improve their performance and impact on socio-economic development of a country in the new global economic and a country specific industrial context. The programme focuses on the government funded/sponsored institutes many of which are now suffering from the crisis of under-funding, disconnection from industry, loss of key personnel and weak international linkages.

The programme consists of various types of services in support to R&D revitalization process. It includes the introduction of new management and marketing tools, policy advice, R&D funding, project management, benchmarking, training, networking, linking the technology promotion to investment mechanisms, and building up business partnerships. The programme also aims at developing new strategy for R&D and Technology Institutes to enhance their competitiveness and ensure the sustained growth.

Within the framework of this programme, UNIDO is actively cooperate with the Science and Technology Policy Research Unit (SPRU of the Sussex University, England; the Research Unit on R&D Management of the Manchester Business School, England; the University of Rome, Italy; the International Development Group (IDG) from England, and other national, regional and international institutions concerned.

VI. Managing the Technological Change

It should also be taken into account that the process of technological innovations has also been changing, and this greatly impacts on its management. Increasingly, technological innovation requires the fusion of multiple technological disciplines, deeper and deeper technical skills, early availability of market knowledge, and tools and methodologies. This increases the need of firms, especially SMEs, to access external sources of technical knowledge and information (markets, customers, technology suppliers, etc.), and to rely on their support and technological collaboration. They also need additional investment and technology support services and training in order to meet the new challenges.

In providing its services, UNIDO adopts a two-fold approach. On the one hand, it focuses on the macro-economic environment and the capacity building needs of the principal institutions involved in investment and technology promotion. On the other hand, it addresses the issues that are of key importance and relevance at the various phases of the investment and technology promotion cycle and their absorption at the industrial scale.

Through advisory services and training programmes, UNIDO building up the capacity in such areas as the development of the promotion strategy of a country, preparation of a portfolio of business opportunities in the field of investment and technology linking, technology transfer and negotiations, technology management, building up strategic business alliances, promotion of international projects and matchmaking, sub-contracting exchange, etc. To enhance the impact and achieve the objectives, UNIDO responds to the problems in an integrated manner providing a package of services, which include the appropriate tools and methodologies.

VII. Establishment and Networking of UNIDO International Technology Centres

With globalization and increase in the international competition, technological advances have been recognized as a key issue for sustainable industrial development in developing countries. Since the 1980s, UNIDO has been repeatedly called upon by its governing bodies to accelerate international cooperation in the technological area, including the establishment of international technology centres and networks.

UNIDO has responded to these demands and specific requests of both industrialized and developing countries and developed a substantial programme to support the establishment and operation of a number of centres in various technological areas. The programme on Centres is derived from and underpinned with information and analysis from UNIDO's ongoing regular programmes.

The ITCs provide UNIDO with visibility in specific technology areas and have now become a UNIDO trademark since the Organization is recognized as the only UN agency having this unique tool for promotion of international collaboration and encouraging industrial investments in the area of new technologies.

These Centres provide a mechanism for building up awareness on technological advances and innovations, linking the technology promotion with investment opportunities and creating new industries through international collaboration, business partnerships and strategic alliances. They also act as the bridge for cooperation between developing countries themselves and between them and industrialized countries.

Within the new context of international competitiveness, the International Technology Centres and their networks have in addition become an important worldwide knowledge and technology resource base and a bridge between the research community and the commercialization of technologies at the industrial scale.

The Centres are fully financed from extra-budgetary contributions, but play an important complementary role to UNIDO programme of work in the various technology areas. In fact, the UNIDO programme draws support from the centres and, therefore to some extent, they are providing additional resources to programmes under the UNIDO regular budget.

Each International Centre has an active network consisting of industrial R&D institutes, universities, professional and industrial associations working in the same subject area and having their own networks of partners with strong links to industry. These surrounding the Centres networks provide the opportunity to ensure that the work programmes of ITCs continuously reflect the industrial needs of the countries.

Taking this into account, the International Technology Centres with their networks and sub-networks, as a substantive technology resource base, play an important role in UNIDO Industrial Partnership Promotion Network (IPPN). They are intended to provide the decision-makers in the countries, and in UNIDO as well, with the high value information on the technology and investment trends and help them develop the policy and business strategy taking into account the global and country's specific contexts.

It is also important to note that support and finance for UNIDO Technology Centres comes from extra-budgetary contributions of a wide range of countries, both developed and developing. An interesting new aspect is the interest from existing international centres of excellence and other international organizations to join and collaborate with UNIDO International Technology Centres (e.g. ICMET established cooperative links with VAMAS - similar cooperative programme of the G-7 countries). In addition, some leading industrial groups expressed the interest in establishing international cooperation with UNIDO Centres as well, e.g. Samsung Electronics.

1. INTERNATIONAL CENTRE FOR SCIENCE AND HIGH TECHNOLOGY (ICS), Trieste, Italy

A UNIDO autonomous institution whose action - is concentrating on its specificity with an annual budget of approximately US$4,5 Million. The areas of competence mandated to ICS are covering a wide spectrum of new technologies, particularly:

- pure and applied chemistry;
- earth environment and marine sciences and technologies;
- high technology and new materials;
- institutional, management, interdisciplinary and networking activities.

The main activities of ICS aim at building up national capacity in technology promotion, commercialization, transfer and management and include:

- expert group meetings, seminars and workshops on technology development and commercialization issues;
- training courses on technology management and strategic business alliances;
- study tours and fellowships;
- short-term consultancy services;
- monitoring technological advances and dissemination of information through publications;
- establishing and strengthening the links between the research community and industry;
- networking.

At present, UNIDO and ICS are reviewing the strategy in terms of strengthening the role of the Centre and harmonization of its programmes in the transfer of know-how and technology and building up technological capacity in the developing countries taking into account the new Service Modules of UNIDO and global economic environment.

2. INTERNATIONAL CENTRE FOR MATERIALS EVALUATION TECHNOLOGY (ICMET), Taejon, the Republic of Korea

At present, ICMET is implementing its Pilot Activities Phase focusing mainly on capacity-building activities through training and carrying out collaborative programmes to harmonize testing and evaluation methodologies in selected areas of new materials. In the context of new Service Modules of UNIDO, it develops the strategy for its further promotion and establishment. The main aim in 1999 will be to implement the new strategy, to harmonize the activities of ICMET with the investment component, to develop a new work programme and mobilize additional funds for the operational phase.

The mission of ICMET is to develop international guidelines, codes of practice, and standards on testing and characterization of new materials which can be accepted across national boundaries. The development, verification and application of common (for both producers and users) methodologies for materials testing and evaluation speed up the application of new materials at the market place and promote further development of new products and processes, thus encouraging new industrial investment.

Thus the main role of ICMET is to bridge the gap between research and development organizations, innovative enterprises and the market place in the developing countries in order to stimulate the diffusion of new materials and processing technologies and their application in materials related sectors of industry. ICMET is also to bridge the gap and foster the collaboration and partnerships between developed and developing countries in this vital for industrial development area.

At present, ICMET has already established links with VAMAS Programme (similar G-7 countries' collaborative programme to which the developing countries have received now the access via ICMET). ISO has also expressed the interest to cooperate with ICMET and to work out a relevant agreement on this matter. The year 1999 will be the year of consolidation and strengthening of these cooperative relations. It is also planned to expand the activities to other regions and further develop the ICMET network.

3. *INTERNATIONAL MATERIALS ASSESSMENT AND APPLICATION CENTRE (IMAAC), Rio de Janeiro, Brazil*

IMAAC started its Pilot Activities Phase in May 1998 and has already established an initial network consisting of 14 R&D and technology centres, universities and national authorities dealing with materials related issues in 12 countries (Argentina, Brazil, Canada, Chile, China, Germany, India, Italy, Mexico, Portugal, Puerto Rica, and United Kingdom).

The mission of IMAAC is to provide an international forum to serve the materials community for more effective management and utilization of traditional as well as new materials taking into account their techno-economic aspects and impact on sustainable industrial development. It will function as a proactive institution in building up awareness in industries and governments in the face of technology trends having an impact on development of national materials and human resources within the rapidly changing global economic environment.

Based on that, IMAAC will assist developing economies to absorb and apply rapidly emerging knowledge of materials and to enable them to cope with the demands of competitive global markets as well as meeting quality and environmental standards. It will also help the entrepreneurs and investors to look for new businesses and partnerships.

In 1999, IMAAC will focus on further promotion, development of its network, harmonization of the work programme with other UNIDO International Technology Centres and Service Modules, especially in the area of investment and technology promotion, and will develop the strategy for the years to come. Particularly, it plans to conduct a "Materials Forum '99" within the framework of the International Conference and Exhibition to be organized by the International Union of Materials Research Societies in June 1999 in China. This forum is seen as a good platform to promote IMAAC and other International Technology Centres as well as new UNIDO Service Modules.

4. *INTERNATIONAL CENTRE FOR ADVANCEMENT IN MANUFACTURING TECHNOLOGY (ICAMT), Bangalore, India*

The Pilot Activities Programme of ICAMT is planned to start in April 1999.

The main aim of ICAMT will be to enhance technological performance in manufacturing, productivity, and quality of goods and competitiveness of developing countries through the transfer of advances in manufacturing technologies and techniques. The centre will provide a wide range of services including individual project engineering, training courses, demonstrations, and assistance in selecting and using technologies, software and equipment. The establishment of ICAMT will help develop a strategy and policy and encourage new investments into manufacturing industry, promote the creation of joint ventures, South-South and North-South cooperation, and facilitate the building up business partnerships.

ICAMT will provide small manufacturers with an extensive selection of state-of-the-art systems with which they can gain hands-on experience and allows them to make intelligent decisions on the system selection that it best suited for their application. It will also act as the UNIDO resource base in manufacturing technologies and as a partner of UNIDO sub-regional, field and Investment Promotion Services Offices, as well as other members of its partnerships' network.

VIII. Plan of Action

The Plan of Action is based on the overall strategy for the Investment and Technology Promotion Service Module, e.g. to consolidate the strategies of all components, develop the operational approaches, to adjust the programmes to the new realities and implement all this into practice. Particularly, it is planned to implement the following:

- to harmonize the work programmes of all International Technology Centres and to provide synergy between their activities, the Service Module on Investment and Technology Promotion and other UNIDO programmes and projects on the complementary basis;
- to expand and strengthen the networks of the ITCs;
- to integrate the ITCs and their networks with UNIDO's Industrial Partnership Promotion Network (IPPN);
- to strengthen the building up awareness functions of ITCs and other networked R&D and technology centres in order to act as an Advisory Board for UNIDO, policy makers, entrepreneurs and investors and help them formulate and implement the policy and strategy in the area of investment and technology promotion, taking into account the trends in changing global economic and competitive environment;
- to promote UNIDO ITCs as "Centres of Excellence" in promotion of technological advances and innovations in the area of their core competence, building up business partnerships and networking for sustainable industrial development.

MATERIALS PRODUCTION AND THE ENVIRONMENT

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Abstract
Materials play a fundamental role in developing a nation and in maintaining or increasing its share in the word's economy.
However, any material to be produced has in its transformation cycle, at least one extracting, processing, fabrication and manufacturing step in which releases of substances, gases, liquids, or solids, occur to the environment.
This paper addresses some environmental problems associated to the extracting and processing of some non-fuel-non-ferrous commodities that are of major interest to the hydrometallurgist in an attempt to design environmentally sound products.

1 Introduction

The production and utilization of material in general, and as consequence those of ores and metals, obey, within a given framework of industrial development, the economic cycles that are in effect in a certain time period. These cycles have been well-discussed in the literature[1][2][3][4] and might reflect a world, a local or a geopolitical trend.

As the selection of a given set of materials depends upon the predominant cycle in the industrialized countries, these determine, to a greater or lesser extend, the consumption pattern of a given commodity, inducing the market to adapt itself to such a new reality.

In materials based industries two general strategies arise: there is a search for materials that suit an available technology, and the development of technology for an available material.

The recycled materials, which magnitude of use of the industries varies from economy to economy, need, as a general rule, lower capital and energy expenditures and more manpower than that of the primary processing. Also, they require lower pollution control costs than the primary ores. Such a recycling is more intense as the sophistication of the economy increases, since viable quantities of recycled materials must be available in order to reutilize them.

However, as important as they are in the world's economy, materials to be produced promote changes in the environment: they require energy to be processed, land to be installed, disposal sites to receive tailings or disposals, give off gases and dusts, and require water and earth movings. In fact, since early times such environmental impacts have been recognized and some actions and concerns arouse. here and there, to minimize them or at least leaving them within a tolerable acceptable limit.

Such acceptability, of course, changes from time to time, as social pressures increases, forcing legislative decisions that promote technological alternatives which, in turn, reflect on the economy.

As regarding to the environment, two major questions are receiving worldwide attention: what are the effects linked to the production, disposal and use of materials, and what are their availability in a foreseen future?[5].

This paper tries to focus on the first of these issues, reviewing some of the facts and figures of the environmental impacts caused by a limited range of commodities, withing the non-fuel-non-ferrous industries.

2 The average metal recoveries and the production steps

For any material to be produced there are corresponding **steps** in which **discards** are also produced. These **discards** might be of two broad cathegories: **losses** and **effluents**. **Losses** are those discards readly identified to the main material produced, i.e., parts of that material that are left behind throughout the production steps. **Effluents** are the discards coming from these same steps and that are inherent to the applied technology within each production step, but not necessarily identified to the main material.

2.1 The average metal recoveries

In order to systemize the analysis of the environmental impacts of the discards an attempt is going to be made in quantifying such average metal losses.

No universal claims are made on the exposed reasonings, but they migh help to point-out the emergency of the facts and impacts.

It is well recognized that ore recoveries, from mining to final metal product varies from country to country, from economy to economy, as a function of technology, skill, regulatory laws, finantial capability, etc...; so are the environmenal impacts caused by primary and secondary metals production.

Therefore, **recoveries** and **losses** figures from metal to metal and even for the same metal from country to country, even when apparently similar technologies are used, do vary substantially due to the so called "particularities" of the mining world: the cut-off-grade and the compromise between grade versus recovery optimal combination, making each orebody unique in its physical and economic characteristics.

Other things being equal, the lower the grade or the poorer the quality of the ore, the higher will be the cost of recovery of the valuable products. To the extent that there is a choice of the grade of the ore to be mined, there is also a choice of the total tonnage and of the total product recovered; the lower the permissible grade, the higher the tonnage. Therefore, the fixing of the cuttoff grade in deposits of irregular grade-distribution may require several computations of alternative tonnages and grades on the basis of different assumptions as to mineable limits.

Equally important with grade is the workability of the ore which is measured by the cost of physical removal of the rock. Other factors, such as accessibility from mine openings, thickness and regularity of the ore zone, hardness and toughness of the ore, presence of interfering structures, such as faults, weak ground, et allia, all must be evaluated when the decision on which ore must be taken should be made.

Variations in the grade in the workability of an ore body, may go side by side, or they may partly compensate each other. Ores of many different grades and many different costs, but sufficiently similar in other qualities to be amenable to the same treatment process may be mine or blended to profitable recovery of otherwise para marginal ore.

Complete removal of all available ore from mine, or complete extraction of all available ore is never achieved. Cost per unit recovered rise almost continuosly and usually with increasing steeps as attempts are made to increase the percent extracted. In the short run, with the recovery plant given, the percent extraction of metal will depend, to some extent, on the grade of the ore itself; the mining method usually limits the recovery of the ore in the mine[6] [7].

As well as the utilized processing technology. For **gold leaching**, for example, the recovery figures are those shown in Table 1.

Table 1. Gold leaching recoveries[8].

OPERATION	PARTICLE SIZE	METTALURGICAL RECOVERY	COSTS
Agitation	< 0,1mm	90 - 95% > 20h	↑IN ↑OP
Vat	< 10mm	70 - 80% 3 to 4h	↑IN
Heap	> 10mm	40 - 60% 3 to 4w	↓IN ↓OP

IN = investment costs
OP = operational costs

h = hour
w = week

Lets have a look on some select mineral commodities, as regarding recoveries and grades, as shown in Table 2.

It can be readly seen that the problem associated to earth moving and tailing disposal is quite a severe one, since from the grade of the ore up to the production of a salable concentrate, the mass of the produced concentrate, as related to that of the ore total (MC) and the mass recovery itself (MR) are, of course, far from the sustainable target of total utilization, for the aforementioned reasons.

Table 2. Selected mineral commodities recovery/grade

ORE	RECOVERY	GRADE	COMPANY
Nb_2O_5 (3,0%) piroclore	MC = 3,3% Ore MR = 66%	60% Nb_2O_5 Conc.	CBMM (9)
TiO_2 (1,5%) ilmenite	MC = 2,2% Ore MR = 81%	55% TiO_2 Conc.	RIB (9)
Cr_2O_3 (17%) chromite	MC = 28% Ore MR = 65%	37% - 46% Cr_2O_3 Conc.	FERBASA (9)
WO_3 (0,5%) scheelite	MC = 0,49% Ore MR = 74%	75% WO_3 Conc.	TUNGSTÊNIO (9)
Sn (1,3%) cassiterite	MC = 1,9% Ore MR = 69,1%	48% Sn Conc.	RENISON (10)
Ta_2O_2 (0,16%) tantalite	MC = 0,22 Ore MR = 70%	49% Ta_2O_5 Conc.	BERNIC (10)

As already pointed out MC stands for the mass of produced concentrate, as related to that of the ore total, in percent, and MR is the mass recovery, i.e., the recovered amount of the valuable commodity as related to the original amount in the ore.

A very illustrating example of recovery, grade, mass recovery, earth moving, generated by-products is the production of phosphate fertilizers, from volcanic rock, that besides the usual earth-moving and disposal problems associated to the production of the concentrate, it generates five times the mass of gypsum as that of the concentrate, P_2O_5 based, when such a concentrate reacts with sulphuric acid to produce the fertilizer.

2.2 The Production Steps

Lets describe such **production steps** and their **discards**, for the purposes of this presentation, identifying **four** steps, namely **extracting**, **processing**, **fabricating** and **manufacturing**, as follows:

- **extracting step**, i.e., the mining and beneficiation of the ore to a commercial concentrate. The **losses** are dependent upon the mining method (open pit, cut-and-fill, room-and-pillar, etc...) and beneficiation techniques (gravity separation, flotation, etc...); the **effluents** generated are CO_x NO_x from machinery and equipment, process waters and contaminated freatic waters, particulate material, and earth moving disposals/rearrangements;
- **processing step**, i.e., the extractive metallurgy or chemical operations to convert a concentrate into a metal; **losses** are depend upon the chosen technologies and skills involved (pyro, hydro and/or electro), and the **effluents** generated are gases (CO_X, NO_X, SO_X), liquids (heavy metals contamined waters) and solids (sediments, and heavy metals dusts);
- **fabrication step**, i.e., those operations devoted to produce rods, bars, sheets, etc...; the losses are scrap materials resulting from those operations, denominated "home

scrap"[11] endlessly recirculated, without any net loss of metal; the **effluents** are waste waters and industrial gases;

- **manufacturing step**, i.e., the application of mechanical operations for the shaping of metals by machining, stamping and forging, other than those of the fabrication step; the **losses** are parts of metal resulting from such mechanical treatments that does not produce the aimed product, being denominated "new scrap" or "prompt scrap" [11][13][14][12], which recycling is well organized and efficient[12][13]; the **effluents** are water vapors and industrial gases.

The utilized average metal recoveries figures from ore to metal, involving the **extracting** and **processing** steps are those of HASIALIS[15] and for the **manufacturing** step that of MAR[14]. It is acknowledged that this last figure is well obsolete for the U.S. where it was obtained in 1954(!); however in other parts of the world such figure might be still reasonably valid. As for those of HASIALIS they are average figures, and large departures from these figures, for a given particular case, do exist.

The **production steps**, as indicated, are all illustrated in Figure 1. Such a flowchart, or Sankey diagram, helps to seek solutions related to the **discards** involved in each production step. A similar chart might be attempted in terms of overall mass flows (MC's), if defined for each production step, resulting in more impacting figures, since earthmovings, then, would be included.

Tunneling into **each** of the aforementioned **four** production steps, a clear picture, hopefully, will then be achieved. Lets try that!

For this, some explanations are needed to follow Figures 1 the remaining Figures of the text:

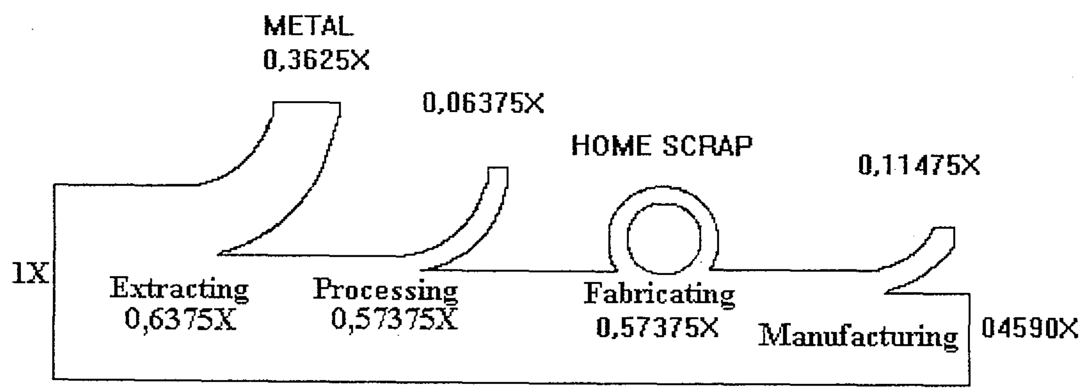

Figure 1. The production steps

X = the metal content of the *"in situ"* ore

L_E = is the **loss** in metal resulting in the extracting step, and is equivalent to 0,3625 X.

P_E = is the **product** in metal originated from the extracting step, and is equivalent to 0,6375 X.

L_P = is the **loss** in metal resulting from processing, and is equivalent to 0.0637^{5} X.
P_P = is the **product** in metal resulting from processing and is equivalent to $0{,}5737^{5}$ X.
L_F = is the **loss** metal resulting from fabrication and is equivalent to O X (endless recirculated).
P_F = is the **product** in metal resulting from fabrication, and is equivalent to P_P.
L_M = is the **loss** in metal resulting from manufacturing, and is equivalent to $0{,}1147^{5}$ X.
P_M = is the product in metal resulting from manufacturing.
E_i = is the **effluent**, generated in each stage.

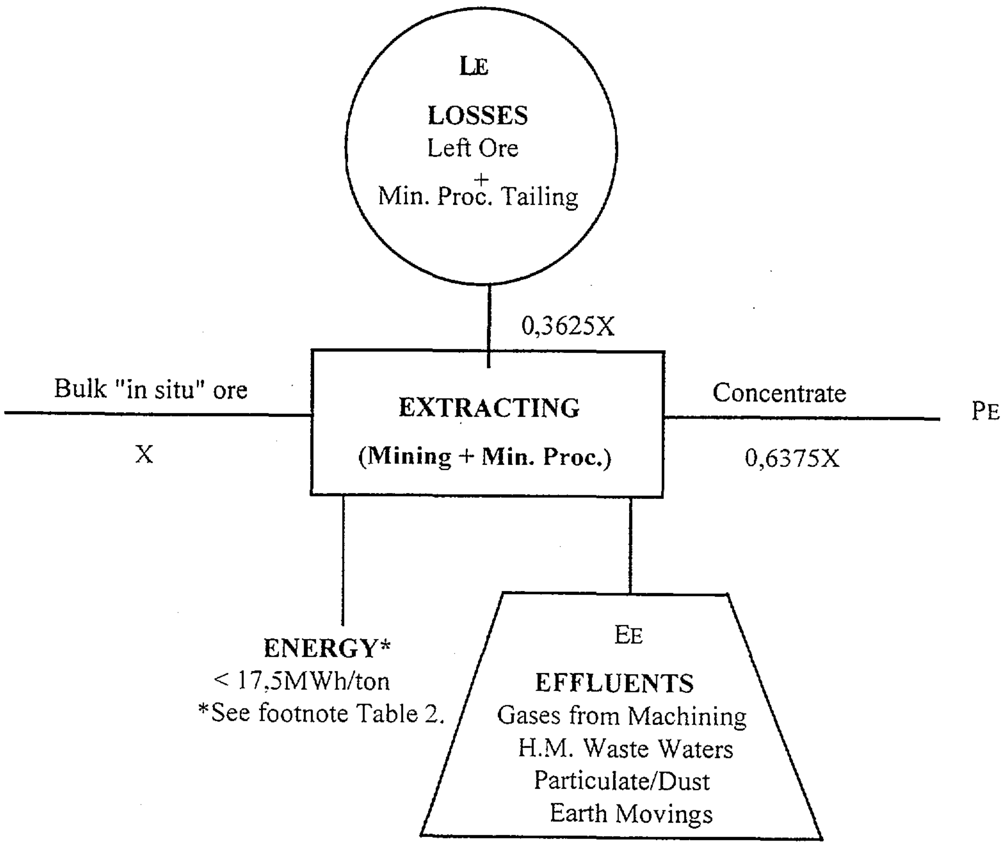

Figure 2. Income/outcome of the **extracting** step.

2.3 Identifyable environmental impact and prospects in the extracting step

From Figure 2:

A. **Energy:**

Taking up of energy. There are technical rooms for improvements. Figures in kWh (thermal), per tonne of primary metal, as reported in ref. 16; Al (10,175); Cu (17,420); Zn (1,240).

B. **Losses:**

B.1 Left ore, function of cut-off and mining method, there are technical rooms for improvement.

B.2 Mineral Processing tailings, rooms for gains pending on improvements in the next step (processing), since commercial grade concentrates are inputs to a given processing technology.

C. **Effluents:**

C.1 Mining, earth moving impacts associated to land reclamation; rooms for improvement based upon compromises between legislation (function of social pressures) and costs of reclayming. Physical disturbances are permanent; dust

C.2 Mining: gases from machinery and equipment (as well as noises and vibrations), there are technical rooms for improvement.

C.3 Mining: disruption of water regimes. Little room for improvements in present day mining methods.

C.4 Mineral processing: process waters and dust, still technical rooms for improvement.

C.5 Mineral processing: tailing disposals, solids, and control of acid generation.

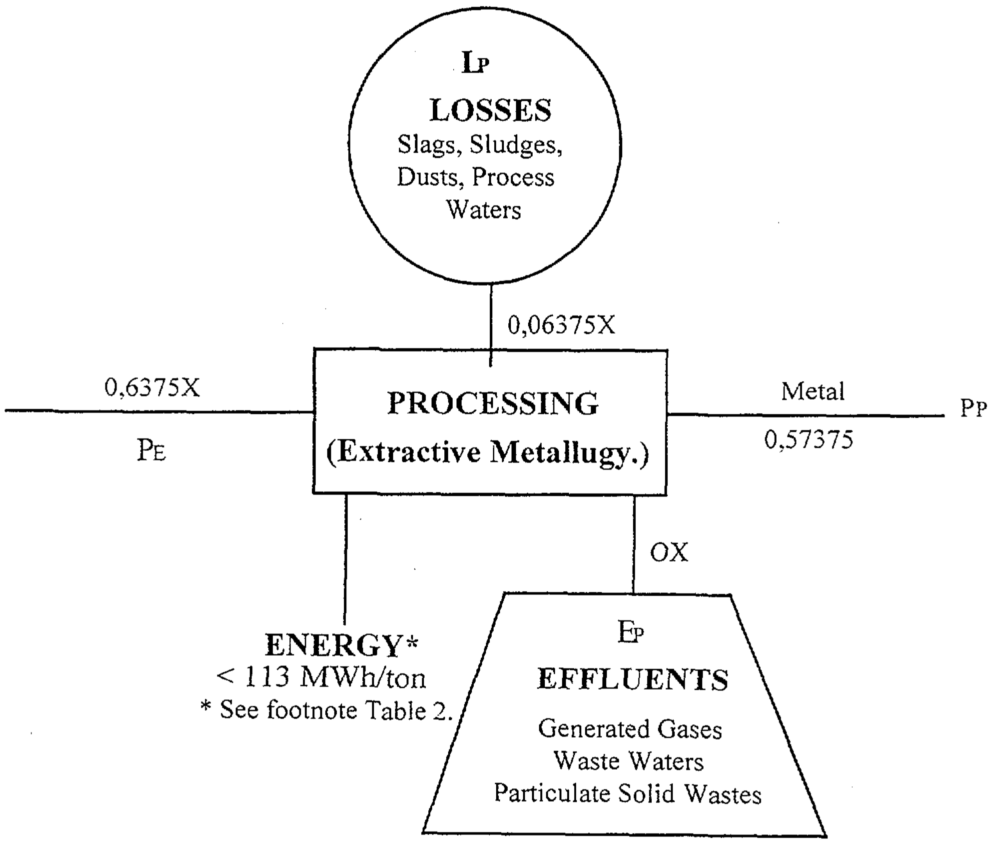

Figure 3. Income/outcome of the **processing** step.

2.4 Identifiable environmental impacts and prospects in the processing step

From Figure 3:

A. Energy:

Taking up of energy. There are rooms for improvements. Figures in kWh per tonne (thermal) as reportes in ref. 16; Al (35.384); Cu (26,520); Zn (17.560); Mg (103,000). Other figures are reported for Al and Mg if hydro-based power is available (much lower figures).

B. Losses:

Left metal as function of the process technology utilized, skills and legislation. There are rooms for improvements, specially those devoted to recover metal from slags, sludges and dusts of existing technologies or new technologies based on decreasing the number of operations/equipment stages (i.e., continuous converting for Cu and the still pending solution to the red mud problem in Al.).

C. Effluents:

Generated process gases (CO_x, NO_x, SO_x); waste waters after eventual removal of metal(s) from process waters; particulates throughout the processing stages and solid wastes other than slags, sludges, etc... (for the Al industry, for instance, spent potlinings, drosses, electrodes, etc...),still rooms for technical improvements.

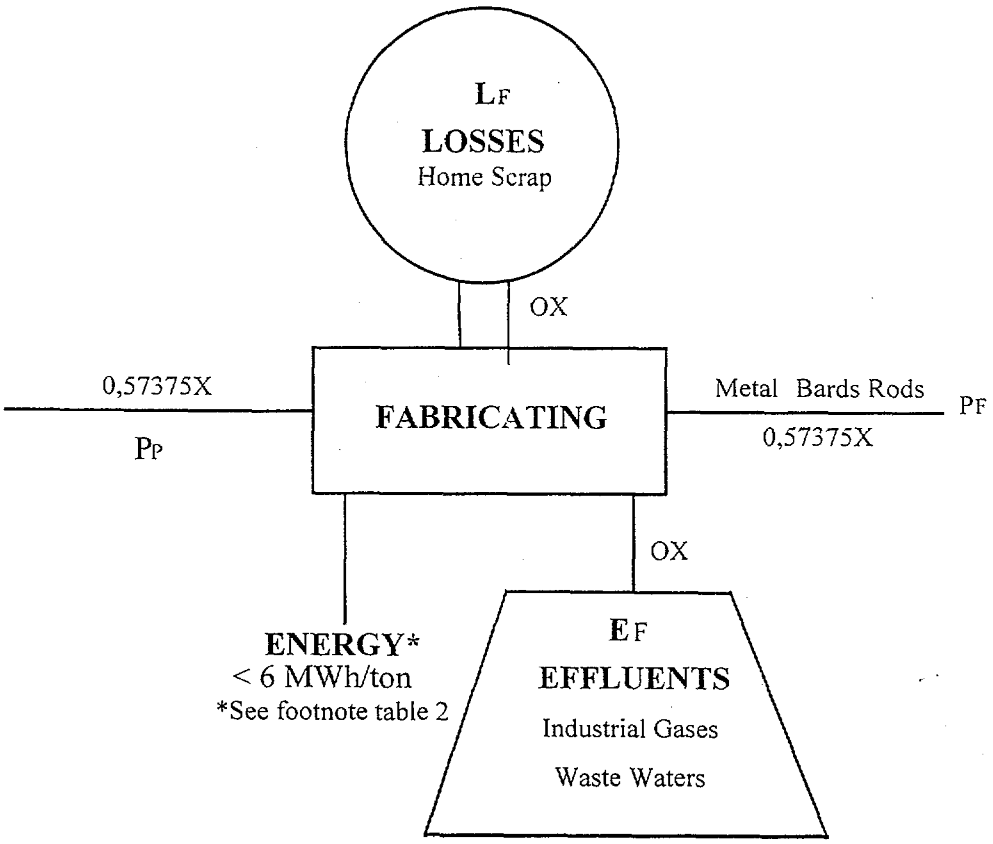

Figure 4. Income/outcome of the fabrication step.

2.5 Identifiable environmental impacts and prospects in the fabricating step

From Figure 4:

A. Energy:

Taking up of energy. There are rooms for some improvements. Figures in kWh/tonne (thermal), as reported in ref. 16; Al (4,937); Cu (5,970); Zn (1,492).

B. Losses:

Generation of home scrap, no net losses. However, rooms to reduce such generations as fabrication operations/equipments become more efficient.

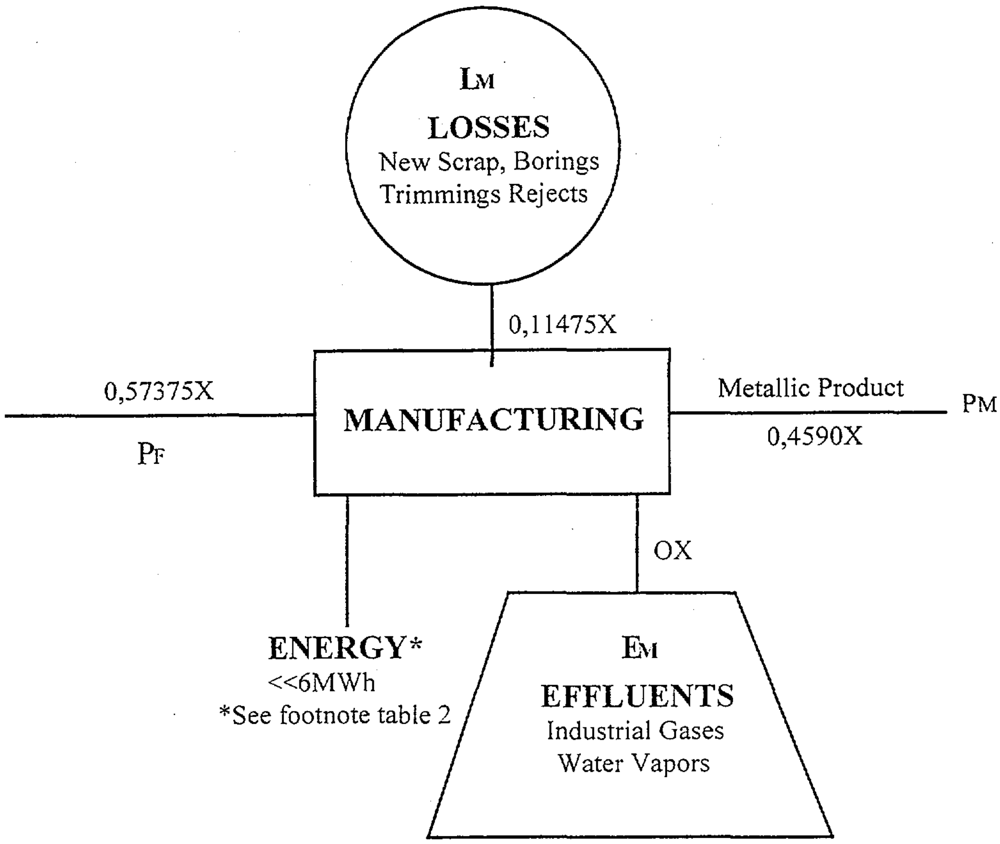

Figure 5. Income/outcome of the manufacturing step.

2.6 Identifiable environmental impacts and prospects in the manufacturing step

From Figure 5:

A. Energy:

Quite variable depending on the particular metallic product through forging, stamping and machining. Much less than any other of the previous production stages.

B. Losses:

They are the so called new scrap that usually goes to secondary production.

C. Effluents:

Industrial gases and water vapors.

3 Role of the hydrometallurgist

For an account of the role of hydrometallurgy in achieving sustainable development the interested reader refers to CONARD[17], where acidic mine drainage, metals removal from waste streams, arsenic management, reduction of gaseous pollutants and energy conservation, cyanide destruction, waste processing and product recycling are matters discussed through selected examples of hydrometallurgical technologies as applied to a better environment.

For those interested in research and novel techniques in hydrometallurgy and the aqueous processing of materials and industrial minerals, the recent review of DOYLE and DUYVESTEYN[18] is indicated, as well as that of NICOL[19] on electrometallugy.

If the interest is in energy requirements for manufacture of some non-ferrous metals and to process ingots, semifinished, and finished products, besides the already mentioned references, the reader may address to HANCOCK[20] and WHITTER & HOSKINS[21], as well.

The points to be raised, in this section however, are those of a general nature that may guide the hydrometallurgist towards a better understanding of the overall effect a given process has upon the environment, thus hopefully enhancing his/her chances of designing environmentally sound processes which in turn produce products.

Let's raise some major points in each of the **income/outcome** of the production steps, namely **energy**, **losses** and **effluents**.

3.1 Energy

Table 2 lists the energy taken up in each production step.

Table 2. Energy utilized in each production step

PRODUCTION STEPS	ENERGY (MWh [thermal]/ton*
Extracting	< 17.5
Processing	< 113.0
Fabrication	< 6.0
Manufacturing	<< 6.0

* Figures as mentioned, not averages but maximum, for a selected class of metals (Al, Cu, Zn, Mg, Ti)

The role of the hydrometallurgist is to seek for processes that minimizes energy consumption; his/her tasks are, thus, primarely devoted to the **processing step**, following the **extracting step** and, then, **fabrication** and **manufacturing**.

Indeed, the efficiences of processing operations have been compared by CHAPMAN & ROBERTS[13], appearing in other papers dealing with the subject of environment, metals production and energy such as YOSHIKI-GRAVELSINS, et al.[16], and FORREST & SZEKELY[22].

For the purposes of this article, the overall energy efficiences in the processing step, i.e. the energy take up by the whole step and not just the direct one, as compared to the thermodinamical Gibbs Free Energy, ΔG, for that same processing step, are of interest, since they give a strong indication to where to search for process improvements, energywise. Table 3 lists some selected metals and their overall efficiencies[13][16].

Table 3. The **processing step** overall energy efficiences for selected metals.

PRIMARY METALS	OVERALL ENERGY EFFICIENCIES* (%)
Al	13
Cu	1.4
Zn	5.5
Mg	6.1
Ti	4.1

* Energy take up by the whole step, as related to the Gibbs Free Energy.

Of great concern to the hydrometallurgist is the **power source** of energy, i.e., hydro or coal based, due to the greenhouse effect. Such a concern was extensively dwelled by FORREST & SZEKELY[22].

3.2 Losses

Table 4 list the average metal losses to the environment, per production step.

Table 4. Metal losses to the environment per production step.

PRODUCTION STEP	AVERAGE METAL LOSSES*
Extracting	0,3625 X
Processing	0,06375 X
Fabrication	0
Manufacturing	0,11475 X

* Average metal loses as referred in the text.

Here, the hydrometallurgist has to focus his/her attention to the **extracting step**, first, and to a lesser degree to the **manufacturing step**.

It is worthy point out, however, that those average figures may be misleading. For each particular metal/substance that the hydrometallurgist is studing he/she has to refer to the actual values that are particular to the mining method. metal. process. skill. country, etc..., as previously discussed.

Nevertheless, mining and minerals processing techniques are, in general, responsible for the greatest losses. In-situ mining techniques, that usually refer to the injection of a leach solution through boreholes into the ore are to be taken into account whereas possible[17].

The losses of the **manufacturing step** usually goes to secondary recovery and besides the strategic/economic aspect to the enterprise itself, as discussed by CHAPMANN and ROBERTS[13] through the GER (gross energy requirement) concept, no major role of the hydrometallurgist is to be foreseen, since such efficiencies are rather linked to the mechanical/electronics/physical metallurgical aspects of the issue.

In the **processing step**, several improvements have been and are still made through process optimization and process improvements[16][17][18].

3.3 Effluents

Regarding the effluents, the discards to the environment are several assuming the liquid, the gaseous and the solid states, giving to the hydrometallugist an extraordinary opportunity and offering several challenges.

Table 5 gives a list of problems that seek solutions at each of the production steps, compairing in relative terms the land, water and air impacts; the relationship is made referring to acceptable environmental standards in OECD's countries and they may vary considerable from country to country and from metal to metal.

Table 5. Comparison between the impacts of the effluents in each production step.

PRODUCTION STEP	LAND	IMPACT WATER	AIR
Extracting	S	S	M
Processing	M→S	M→S	S
Fabrication	L	L	S
Manufacturing	L	L	L

L ≡ low impact
M ≡ moderate impact
S ≡ severe impact

For the identification of the specific problems that face the particular metal industry, the reader is referred, for instance, to references[23] and [24].

Thus the role of the hydrometallurgist in developing environmentally sound processes has to be focused on the **extracting step** (i.e., land disturbance, soil erosion, mine run-off water, water regimes, dust tailing disposal, revegetation, etc...) and the **processing step** (i.e., acid generation, heavy metals effluents, disposal of solids, gas generation), primarely. For the specific techniques (biosorption, liquid-liquid exchange, electrowinning of dilute solutions, membranes, etc... see references[17][18] and [19]). Table 6, lists some environmental impacts associated to selected mineral industries.

Table 6. Major environmental impacts for selected mineral industries.

METAL	IMPACT
Al	Red mud slurry; HF; CO_2; tar pitch volatiles; spent pot linings; cyanide
Cu	SO_2; metal fumes; heavy metal effluents
Zn	Iron oxide; SO_2; Cd; heavy metal effluents
Mg	CHCs; dioxin
Ti	$FeCl_3$; volatile chlorides; CO_2
Ni	Metal carbonyl; heavy metal leachate;severe dusts and particulate emissions
P_2O_5	Gipsum, water consumption and disposal; radiation (whenever present)

4 Minerals as Environmental Helpers

Up to here, the discussions were focused on the effects on the environment due to the utilization of minerals.
It is worthy remember, at least, that minerals may be viewed not just as vilains, but as well as helpers to the environment. Tightening environmental legislation are forcing that the rules governing waste water treatment and disposals be stricter; bentonite, lime, soda ash, magnesium hydroxide and zeolites are reported as environmental helpers in the literature[25] and open, as well, a vast field of investigation to the hydrometallugist, or mineral technologist as a whole.

5 Conclusion

It is hoped that the presentation of the **production steps** always present in the production of materials, namely, **extracting**, **processing**, **fabrication**, and **manufacturing** that incorporates the incomes/outcomes for each of these steps, namely, the **input/output** of **materials**, **energy**, **losses** and **effluents**, and their discussions, have helped the hydrometallurgist to choose the relevant areas of his/her research interests from the sake of designing environmentally sound processes to promote sustainability.

No universal claims, regarding the average or maximum figures presented throughout the text, are made; rather the figures are for illustrative purposes in an attempt to point out some guidelines that the hydrometallurgist may take in his/her suggestions of scientific and societal conditions to achieve sustainability.

6 Acknowledgements

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A NOTE ON

APPROACH TO AN INTEGRATED MINERAL – MATERIAL – PRODUCT DEVELOPMENT

by

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APPLICATION CENTRE (IMAAC)

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Introduction

In general, a material is not an end in itself. Neither does it arise all by itself. In the case of metals, which will be the type of material selected in this presentation, they are extracted from an orebody with which they are associated. The metal concerned is invariably alloyed, processed into semi-finished products from which components are made and used in service application. We will make here a broad-based case for an integrated approach that will encompass the range of activities required to reach the end product beginning with the ore material concerned. A gap analysis constitutes a key feature of this approach. This approach, it will be seen, effectively assists in making the right decisions in shaping a wholesome indigenous development programme.

Activity Charts

In an integrated approach to mineral-material-product development, a comprehensive analysis needs to be carried out for each metal with regard to the various segments in the activity chain, from exploration of the ore to the production of metal and its application. The analysis will indicate the bottlenecks that have to be addressed and eliminated so that the indigenous picture for the product development appears smooth sailing from whatever angle the same is viewed.

Choosing the Indian context, three metals, titanium, tungsten and light rare earths will be considered to highlight the specific features requiring attention in each case. It is interesting to observe that these three metals have received varying degrees of attention, and this will be clear from the following discussion.

To facilitate the analysis suggested above, a flow chart has been prepared for each metal depicting the various activities and their mutual interaction. Each box represents one activity, and related activities are joined by "arrowed" lines. There are accompanying indications to show if an activity has already been developed to a satisfactory level in the country, (green boxes) is yet to be fully developed (yellow boxes) or is one demanding urgent attention (red boxes). Figures 1, 2 and 3 represent such flow charts respectively for these three metals, titanium, tungsten and light rare earths. These charts are self-explanatory.

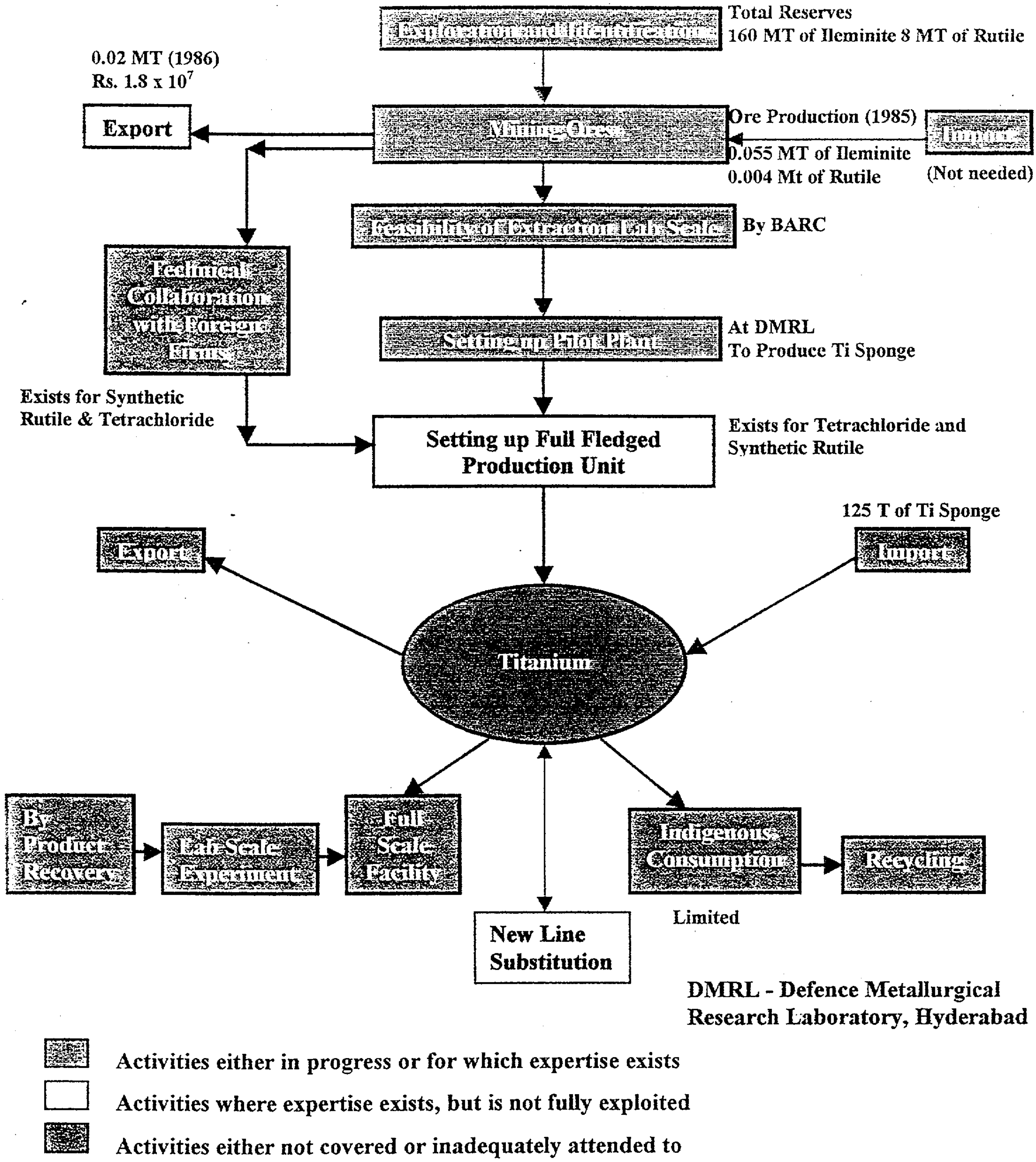
Titanium

We shall discuss the case of titanium metal at some length. Despite the fact that India is richly endowed with vast resources (especially ilmenite in the coastal belts) of this light engineering metal with exceptional physical and chemical characteristics, India has not made anywhere near spectacular progress. This situation is being corrected. Titanium is a special metal which India is fortunate to possess in abundance. The potential for titanium is immense both for applications appropriate to its own characteristics as well as in areas where titanium can be a substitute for metals not available in our country such as nickel. Titanium presents itself for a case study in an integrated ore-to-product analysis.

The current titanium scene in India is depicted in Fig.4. The following salient features emerge from this figure.

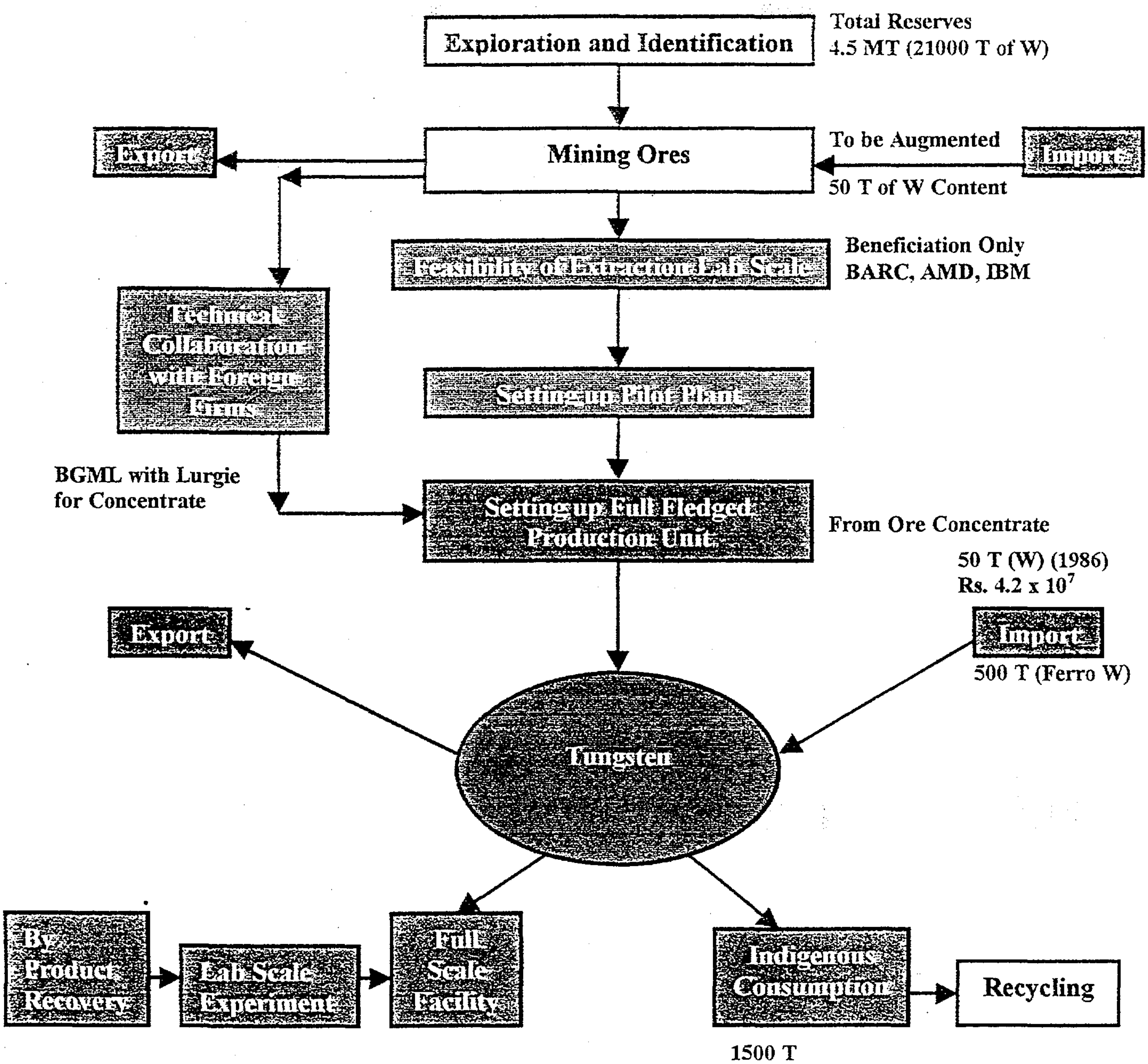
- A well established beach sand industry for mineral separation exists in the country.
- Large scale production facilities for synthetic rutile, titanium tetrachloride and pigment grade titanium dioxide are already in operation.
- No commercial plant exists for the production of titanium sponge metal and the country's requirement is, practically speaking, met entirely by imports.
- Capacity for mill products production exists at MIDHANI (A Special Metals Plant in Hyderabad, India).
- Technology for equipment fabrication is available but needs augmentation in respect of end-products such as power plant condensers.

As mentioned earlier, the first and foremost task is to establish a full-fledged production facility for titanium sponge metal with a capacity of say 1000 TPY initially, for meeting the indigenous requirement. While there is scope for increased production of the minerals for export, a serious effort is needed for converting the mineral wealth into value added products such as pigment grade titanium dioxide, titanium metal and alloys, and their product forms, for domestic use and export.



Exploration and Identification
Total Reserves
160 MT of Ileminite 8 MT of Rutile
0.02 MT (1986)
Rs. 1.8 x 10^7
Export
Mining Ores
Ore Production (1985)
0.055 MT of Ileminite
0.004 Mt of Rutile
Import
(Not needed)
Feasibility of Extraction Lab Scale
By BARC
Technical Collaboration with Foreign Firms
Exists for Synthetic Rutile & Tetrachloride
Setting up Pilot Plant
At DMRL
To Produce Ti Sponge
Setting up Full Fledged Production Unit
Exists for Tetrachloride and Synthetic Rutile
125 T of Ti Sponge
Export
Import
Titanium
By Product Recovery
Lab Scale Experiment
Full Scale Facility
New Line Substitution
Indigenous Consumption
Recycling
Limited
DMRL - Defence Metallurgical Research Laboratory, Hyderabad
Activities either in progress or for which expertise exists
Activities where expertise exists, but is not fully exploited
Activities either not covered or inadequately attended to

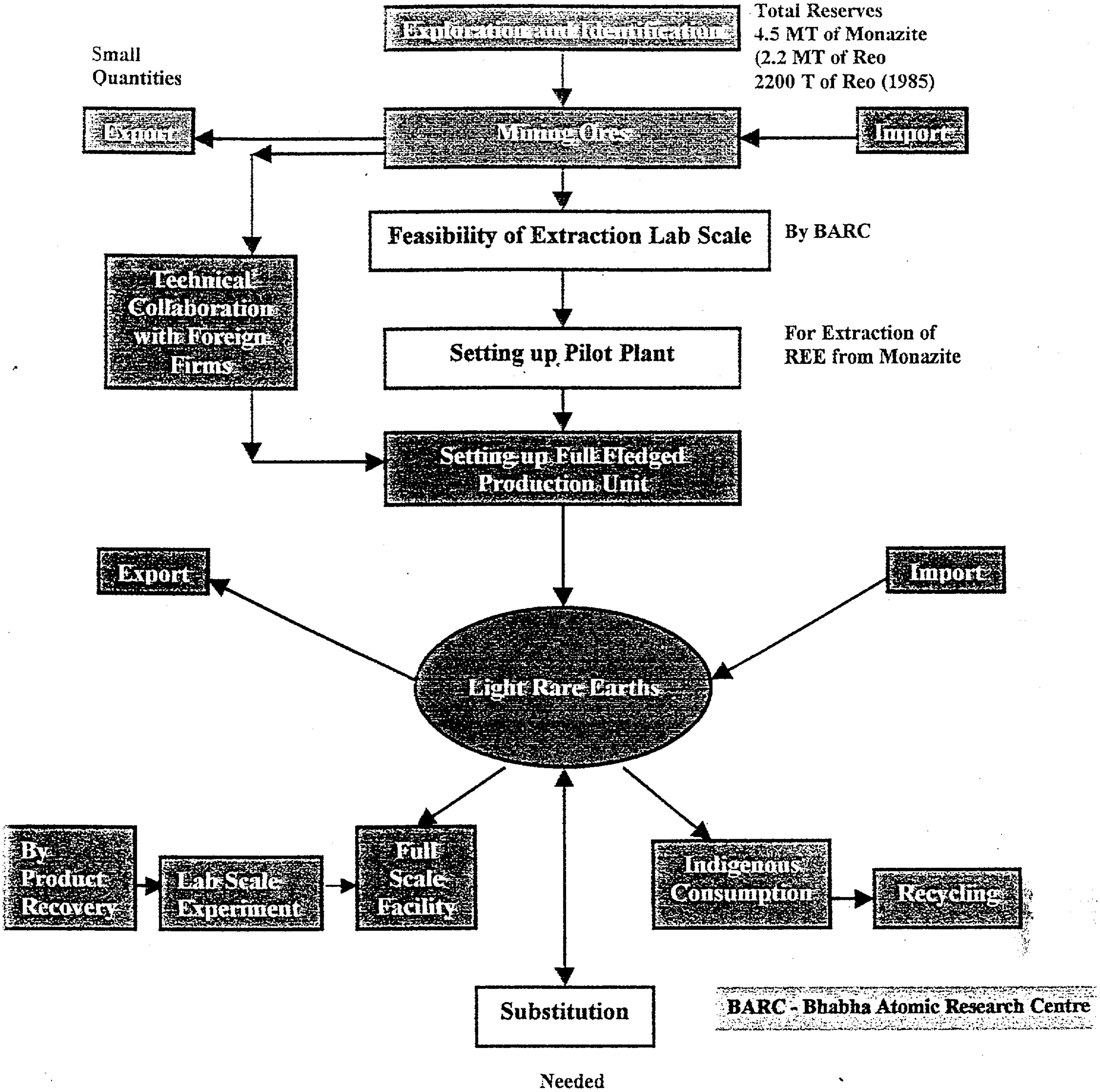
Fig. 1



BARC - Bhabha Atomic Research Centre
AMD - Atomic Minerals Division
BGML - Bharat Gold Mines Ltd.
IBM - Indian Bureau of Mines

- Activities either in progress or for which expertise exists
- Activities where expertise exists, but is not fully exploited
- Activities either not covered or inadequately attended to

Fig. 2

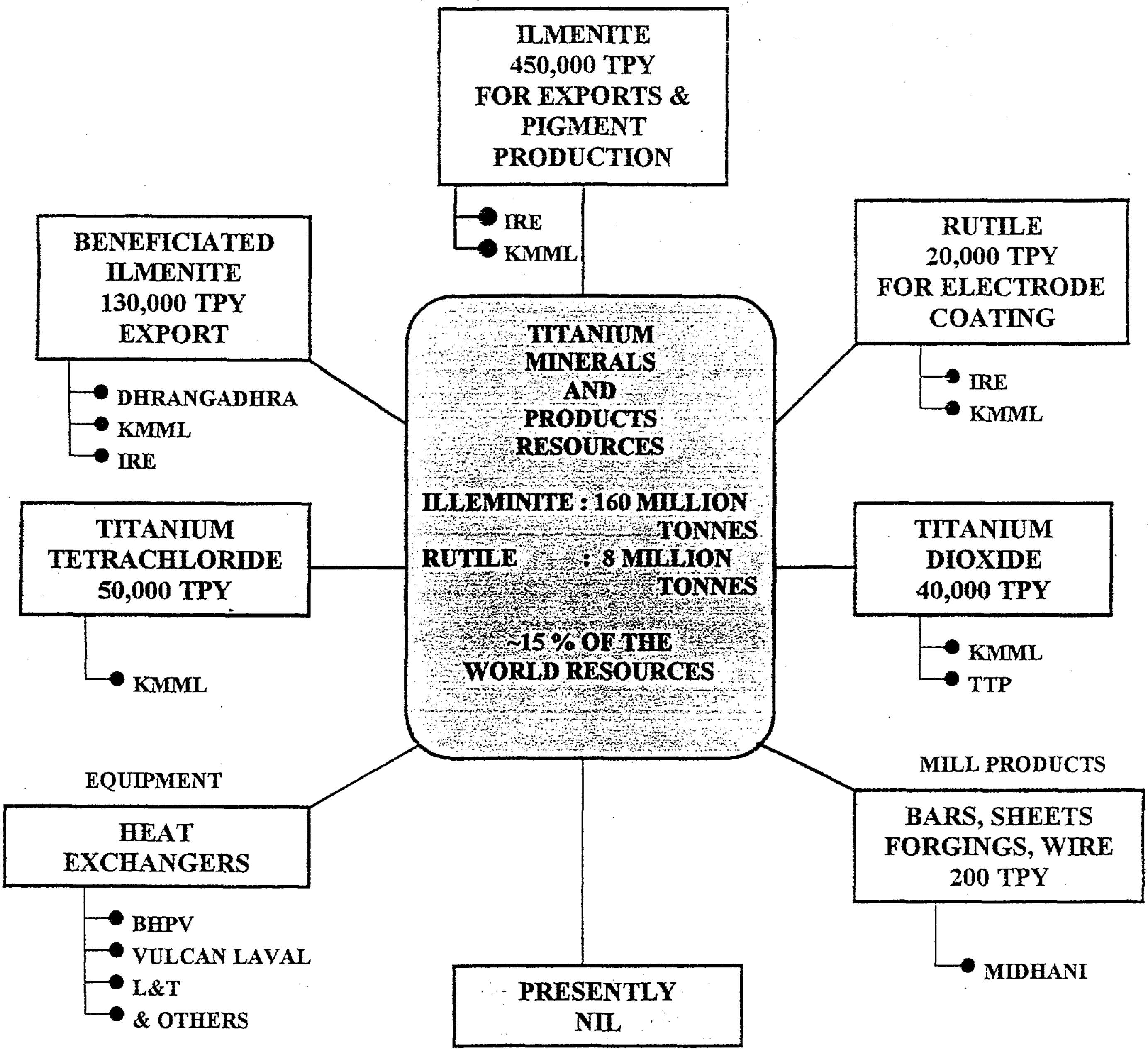


Activities either in progress or for which expertise exists

Activities where expertise exists, but is not fully exploited

Activities either not covered or inadequately attended to

Fig. 3



* DMRL IS BRIDGING THIS TECHNOLOGY GAP
VIA A PLANT OF 100 TPY CAPACITY

KMML - Kerala Minerals and Metals Ltd.
IRE - Indian Rare Earths Ltd.
BHPV - Bharat Heavy Plates and Vessels
L&T - Larsen & Toubro Ltd.
DMRL - Defence Metallurgical Research Laboratory

Fig. 4

Till now, technology for metal production on an appropriate scale was not available for ready exploitation. However, this gap has now been bridged with the establishment of the technology for titanium extraction on a 4 ton batch size at the Defence Metallurgical Research Laboratory, Hyderabad. Thus the country is now ready for establishing a full scale production plant based entirely on indigenous technology.

At present the extent to which titanium is used in our country is insignificant when compared to the levels of consumption reported by the developed countries. In Table-1 the world titanium sponge capacity is presented. In Table 2 the projections of titanium requirements by the year 2000 are brought out. As far as titanium is concerned, it is necessary to adopt a deliberate policy of nurturing its growth and promoting its widespread use by taking the following steps :

Table 1

World Titanium Sponge Production Capacity

Country	**Annual Capacity (in Metric Tonnes)**
CIS (earlier USSR)	45,000
Japan	35,000
USA	32,000
UK	5,000
China	3,000
Total	**1,20,000**

Table 2

Demand Forecast of Titanium (all Figures in Metric Tonnes) (Year 2000)	
USA	41,000
Rest of World	1,45,000
Total	**1,86,000**

- Increase user awareness of the exceptional properties of titanium:high specific strength, high specific toughness and excellent corrosion resistance.
- Encourage its use, in place of stainless steels, in chemical plant equipment and piping systems (this will substantially bring down import of nickel for stainless steel manufacture).
- Adopt a policy of using titanium tubing for all power plant condenser systems.

The Indian demand for titanium mill products is estimated at 715 tonnes, as per details in Table 3, which requires around 1400 tonnes of primary metal. This projection assumes a limited use of only around 200 tonnes of titanium tubing by the power generation industry. It is well know that one of the main industrial uses of titanium is in the form of welded titanium tubing for steam condenser applications in power plants for reasons recorded in Table 4. From Table 5 it can be seen that more than 100,000 MW(e) of power has been generated using titanium tubed condensers. It is to be emphasised that in India condenser tube failure accounts for as much as 38 per cent of all power plant outages. The experience abroad, particularly in the UK, Japan, France and the USA, has clearly indicated that steam condensers fabricated with titanium tubes, even in coast-based power plants, can operate without shut-down during the entire design life of a power station, i.e., about 40 years.

Table 3

Expected Annual Demand for Titanium	
Sector	**Expected Annual Demand (Tonnes of Finished Products)**
Aeronautics	80
Space	15
Power Generation	200
Petroleum and Petro-chemical	50
Electroplating	100
Heat Exchangers	50
Miscellaneous	20
Total	**715**

Titanium sponge requirement for above 1,430 TPY

Table 4

Titanium Tubed Condensers for Power Generation Industry

1. Excellent corrosion resistance to saline waters.
2. Outstanding erosion resistance permitting higher water velocities.
3. Acceptable thermal performance over prolonged periods.
4. No retubing necessary during life-time of power plants (~40 years) (No shutdown on this account)
5. Zero leak rate – essential for nuclear power plants.
6. Substantial cost savings over the power station life-time.

In Table 6 a cost comparison of alternate condenser tube materials for 500 MW(e) sea water cooled power plants is presented. It is clearly seen from this table that titanium is the obvious choice particularly when the "cost of power not produced" due to outages for plugging/retubing is taken into account. With titanium tubes for power plant condensers, the following advantages arise :

Table 5

Titanium Condensers in Power Industry

Country	**Power-MW(e)**
United Kingdom	26,000
Japan	21,000
France	15,500
Other Non-Communist Countries	37,000
India	500 *
Total	**100,000**

Titanium tubing installed 16,000 Tonnes
*Tata thermal power station, Bombay

Table 6

Cost Comparison of Condenser Tube Materials in Sea Water Cooled 500 MW(e) Power Plant (Cost prices 1988)			
	Material [1]		
	Titanium	**Cupro-Nickel**	**Al-Brass**
Density gm/CC	4.5	8.9	8.4
Length of tubing (Km)	38.0	38.0	38.0
Size of tube (OD x WT in mm)	25.4x0.7	25.4x1.6	25.4x1.6
Cost of tubing/Metre(Rs.)	63	85	58
Initial cost of tubing for one plant (Rs.10^7)	2.4	3.2	2.2
Number of replacements During life-span of 40 yrs	Nil	Two (Min)	Three (Min)
Cost of replacement-Rs.10^7	Nil	6.4	6.6
Total Cost (Rs.10^7)	2.4	9.6[3]	8.8[3]

1 Stainless steel unsuitable for sea water application
2 Does not include cost of other condenser components and fabrication
3 Does not include cost of power not produced due to outages for Plugging/retubing which is very substantial.

- Recurring imports of condenser tubes and condenser tube materials is totally avoided.
- There will be a substantial improvement in power station availability due to absence of outages for plugging/retubing.
- Substantial savings in long term power generation costs assured.
- Self-reliance in the manufacture and application of titanium based products.

Let us now look at a titanium based product development, namely a power plant steam condenser. In Fig.5 the various elements involved in the large scale manufacture of titanium tubed steam condensers are projected. It can be seen that engineering designs of such condensers and the augmentation of fabrication technology through indigenous development effort is essential.

While we have discussed the use of titanium tubes for power plant condensers, the potential for its widespread application is large and ever-expanding. Traditionally titanium has been chosen for aerospace applications. In this context it is interesting to point out that, in the USA, titanium sponge is therefore included in the list of critical materials for stockpiling. The metal is requisitioned by the US Government through defence production act contacts. It is reported that the US stockpiling of titanium in 1984 was as much as 33,150 tonnes while the target set by the Federal Emergency Management Agency (FEMA), based on a 3 year war criterion, for establishing stock pile objectives is a phenomenal 1,95,000 tonnes. This is a reflection of the importance of the metal to the future years.

Indigenous capability to produce aerospace components correspondingly assumes considerable significance due to their strategic nature. The chloralkali industry, the petro-chemical industry, the fertilizer industry and the paper and pulp industry use a variety of equipment fabricated in titanium. For a country which has to import every gram of its nickel requirement, the indigenous availability of titanium should be reckoned as balancing.

Titanium's usage is not restricted to just the few industries mentioned above. The Russians have successfully exploited its combination of properties for building deep diving ocean going vessels such as submarines, utilising several thousand tonnes of titanium in the process.

The Japanese, in particular, have not only used this metal for sheathing in protection of bridges but were the earliest to come out with consumer products such as ball pens, table ware and bicycles in titanium that will last a life time and more.

Bio-compatability of titanium has led to its widespread usage for prosthetic applications including such vital parts as heart valves.

For a country like India, that depends on imported paper for printing currency, titanium coinage is an alluring alternative. With its light weight, high strength, excellent corrosion and wear resistance, titanium is an ideal coinage metal and requires serious consideration not only for its own merits but also as a substitute for scarce nickel whose import prices are constantly on the rise.

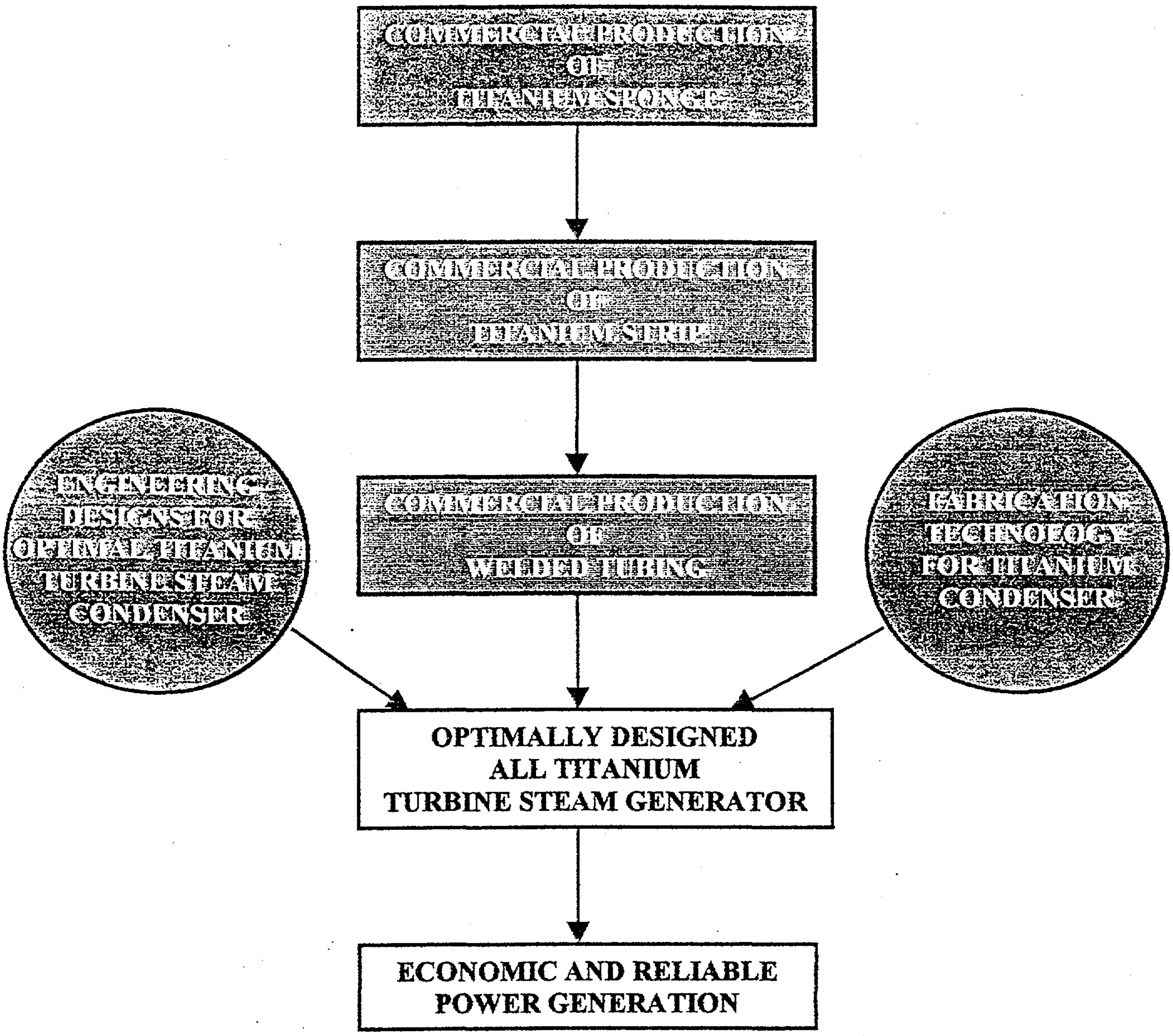

COMMERCIAL PRODUCTION OF TITANIUM SPONGE
COMMERCIAL PRODUCTION OF TITANIUM STRIP
ENGINEERING DESIGNS FOR OPTIMAL TITANIUM TURBINE STEAM CONDENSER
COMMERCIAL PRODUCTION OF WELDED TUBING
FABRICATION TECHNOLOGY FOR TITANIUM CONDENSER
OPTIMALLY DESIGNED ALL TITANIUM TURBINE STEAM GENERATOR
ECONOMIC AND RELIABLE POWER GENERATION

Fig. 5

In conclusion, the following steps are recommended :

- Production plants to be set up for titanium sponge for meeting domestic demands and exports.

- Once titanium tube products become available, a policy decision must be taken to use titanium tubed condensers in all future power plants, both sea-water cooled and river-water cooled.

- The latest technology for the design and fabrication of titanium steam condensers to be developed.

- An imaginative stockpiling policy for titanium sponge, similar to the one in operation in the USA, to be evolved for nurturing the growth and protecting the titanium sponge industry at least during the formative years.

Interestingly, the total investment required to place titanium on a firm footing is less than one billion rupees for bridging the gaps pointed out in the ore to product picture. This amount can cater for

- 1000 TPY titanium sponge plant.
- Augmentation of facilities for power steam condenser design and manufacture.

With such a not-too-large investment, the titanium metal scene will be rendered substantially more complete.

Tungsten

We have a situation in regard to tungsten which may be considered as diametrically opposite to that pertaining to titanium.

In the case of titanium, the resources have been identified and are plentiful. The production of the mineral on a large scale is in progress. However, the country is yet to take advantage of this abundant resource position for product development and utilisation in critical areas, such as the power generation sector. In contrast, we have gone much ahead in regard to the development of products and components made of tungsten. There are industries successfully functioning which use tungsten-based materials such as the alloy steel and cutting tool industries. The country has set up a major manufacturing plant, based on indigenous design, research and development, for producing tungsten-based anti-tank ammunition. However, the tungsten mining activity in the country is in a stage of infancy (Fig.2). Deposits of tungsten are indicated in various parts of the country. However, the only mine operating currently is the one at Degana in Rajasthan producing about 50 tonnes of wolframite per annum. It is only recently that a pilot benefication plant has been installed here and much more needs to be done to augment the output of the mine as well as evaluate the viability of exploiting the substantial resources indicated in the granite rock of the region. Bharat Gold Mines Limited have also set up a pilot plant for beneficiation of their scheelite. Beneficiation studies on the other ore deposits are still to be carried out.

The issues requiring urgent attention in regard to tungsten are therefore **at the ore end**, not at the product end as was the case with titanium. The exploration strategy for minerals of tungsten is presented in Fig.6. Beneficiation studies on various deposits is of importance and to be taken up concurrently with exploration.

Tungsten products are almost always processed through the powder metallurgy route. The present technology for the production of tungsten powder requires about 65 per cent WO_3 concentrate which is treated to yield ammonium para tungstate (APT) which, in turn, is converted to tungsten metal powder. There are technologies in the West and South Korea for the manufacture of APT using 30 per cent WO_3 concentrate. In view of the fact that the indigenous tungsten deposits contain only 0.1 to 0.3 percent WO_3, such technologies for the production of APT need to be looked at and adopted.

Tungsten is a metal which is amenable to recovery from scrap. In the United States as much as 30 percent of the tungsten requirement is met through scrap recoveries. India can ill-afford not pursuing such means of generating tungsten metal.

In view of tungsten being a strategic product and the fact that its indigenous resource position is as yet not firmed up, there is a strong case

MINERALS DEVELOPMENT

WOLFRAN MINERALS

STRATEGY FOR EXPLORATION

MAJOR MINERALS **WOLFRAMITE - SCHEELITE**

STATUS

DEPOSITS [YES] OCCURRENCES [YES] POTENTIAL AREAS [YES]

1. DEGANA, RAJASTHAN
2. AGARGAON – KUHI, M.P.
3. KOLAR – HATTI GOLD FIELDS, KARNATAKA
4. BANKURA AND KALIMATI, W. BENGAL
5. ALMORA – CHAMOTI, U.P.
6. ATTAPADI HILLS, KERALA

WHERE TO LOOK FOR

GEOLOGICAL CRITERIA	MAJOR	BYPRODUCT RECOVERIES	PRIORITY AREAS
1. HYDROTHERMAL DEPOSITS IN METAMORPHIC BELTS IN AND AROUND GRANITE PLUTONS	✓	✓ (ASSOCIATED WITH Mo OR Sn)	METAMORPHIC AUREOLES AROUND GRANITE PLUTONS IN FORMATIONS OF THE 1. IRON ORE SERIES IN BIHAR 2. SAKOLI SERIES IN M.P. 3. JALOAR – SIWANA GRANITES OF RAJASTHAN 4. KOLAR – HATTI – BISANATTAM GOLD FIELD BURUGUBANDA BELT IN EAST GODAVARI OF A.P. 5. THE LOW GRADE METAMORPHIC ROCKS ALONG THE LESSER HIMALAYAN BELT.
2. SKARN AND GREISEN TYPE DEPOSITS	✓	✓ (ASSOCIATED) WITH Mo OR Sn)	

Fig.6

here for stockpiling the raw materials needed through imports. It is worthy to be kept in view that stockpiling presents itself as a policy option in an integrated approach.

In conclusion the gap is really in the exploration of tungsten bearing resources. The mineral exploration activity will be greatly facilitated through the adoption of modern theoretical approaches, involving modelling methodologies, better data generation and dissemination and regular and widespread application of current exploration technologies. Thus we need to develop a strategy for exploration itself which should have the following features :

- Choice of favourable target areas on the basis of relevant geological modelling.
- Speedy publication of geological maps.
- Generation of regional geophysical and geochemical data, especially gravity maps and magnetic maps, so that geological models become more meaningful and relevant.
- Development of polymetallic deposits for extraction of the major metals and the low content metals aggregating to economically workable levels.

The use of modern technologies in exploration is illustrated in Fig.7.

Rare Earths

The example of rare earths in the present discussion constitutes an extreme instance of a national resource which has remained largely untapped for metal production or for product manufacture (see Fig.4), considering its potential.

The country is endowed with sizeable natural resources of rare earths in the beach sand deposits of the south west and eastern coasts. The Indian Rare Earths, one of the major producers of monazite in the world, has attained an annual production of about 6,000 tons.

The problem with the rare earth metals is their close similarity in chemical properties and the resultant difficulty in separating individual elements with a high degree of purity. The onset of the nuclear age has given much fillip, elsewhere in the world, to the development of rapid and

MINERALS DEVELOPMENT

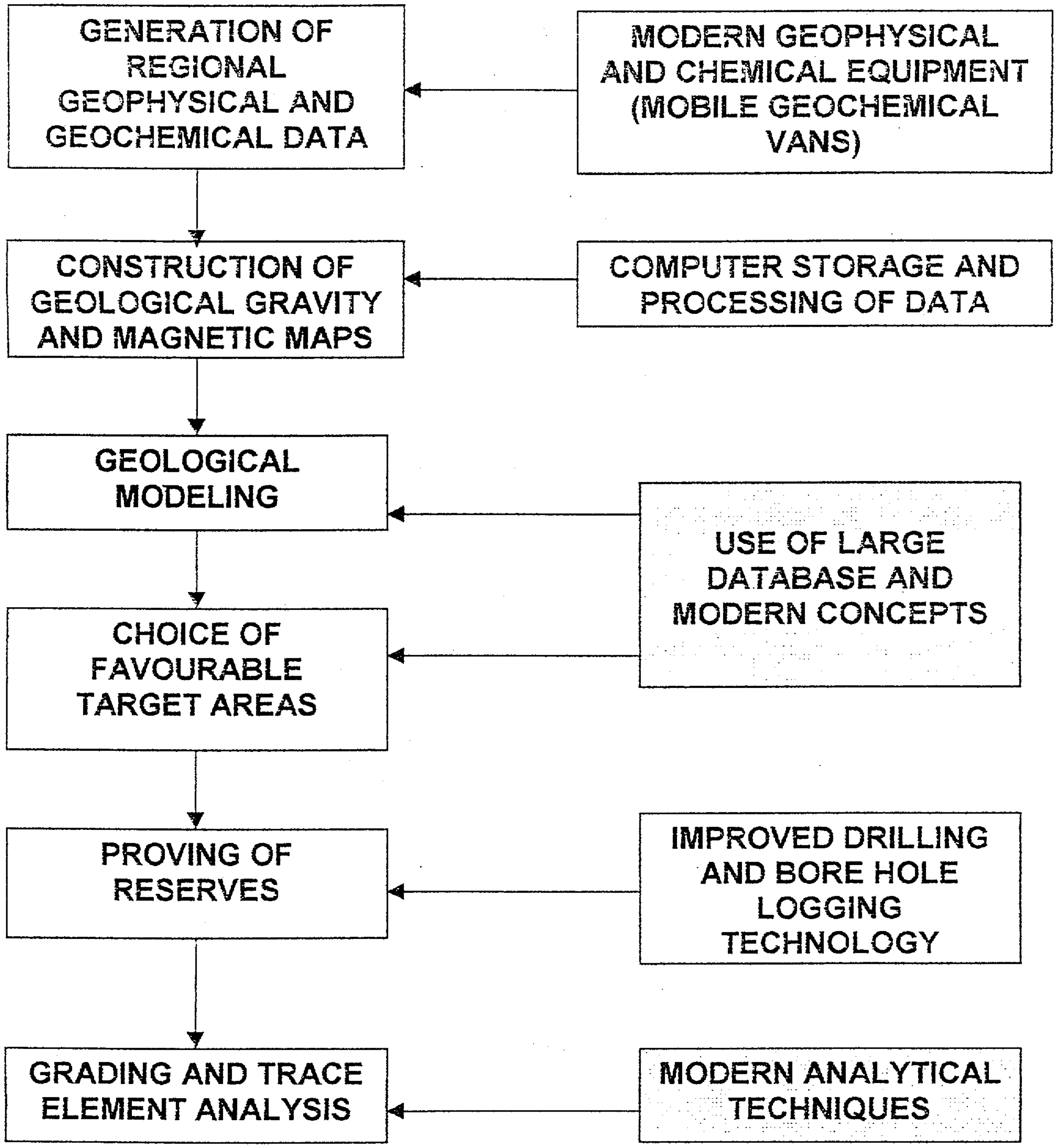


Fig. 7

effective methods of separation. Techniques like ion-exchange chromatography and solvent extraction, originally intended for separating trace level rare earth fission products from the fission of uranium, are today precisely the methods adopted for large scale production of individual rare earths.

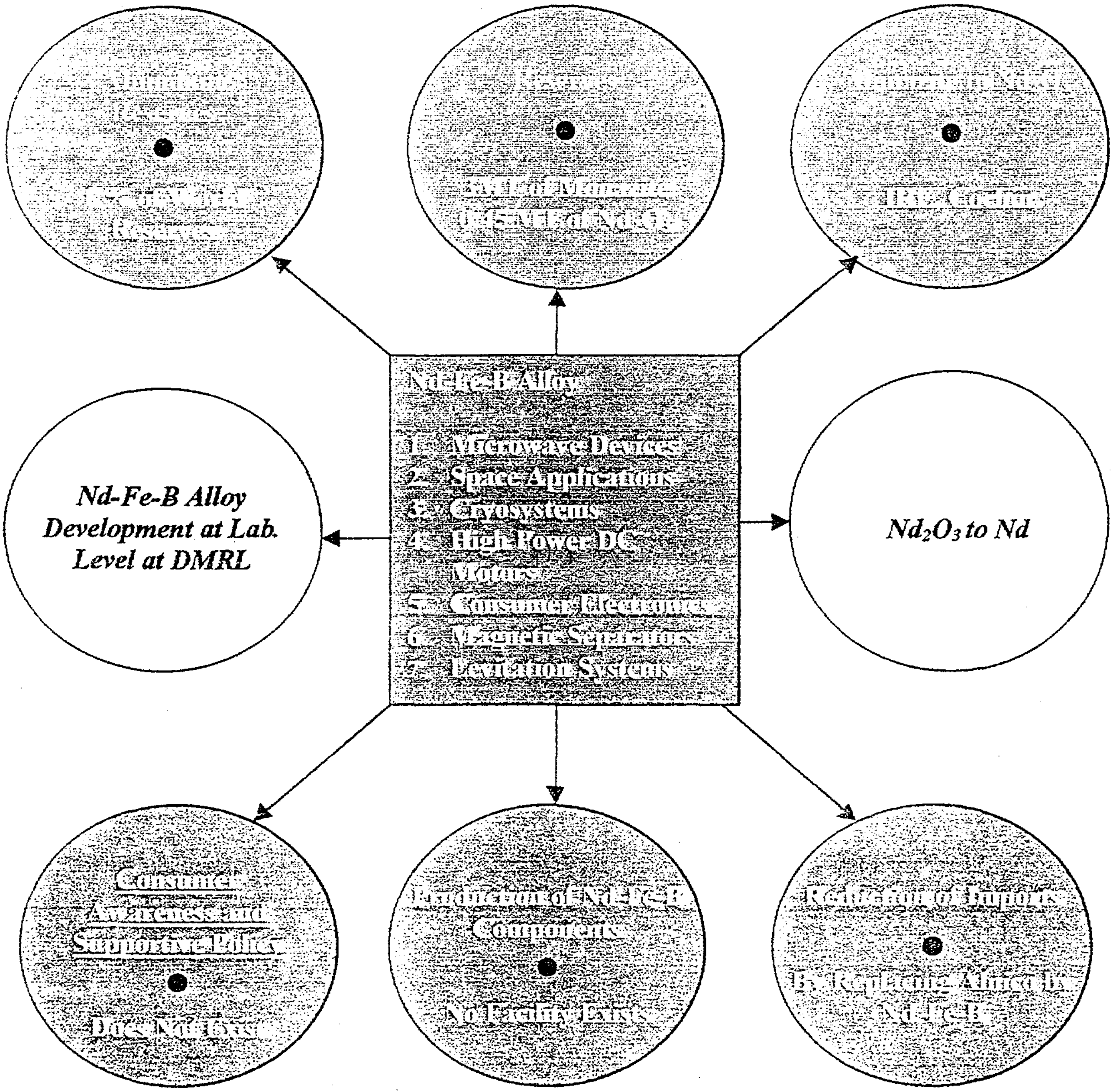
India has established the capability in separation techniques. However, substantial scales of production have not yet been achieved.

The metallurgy of rare earths for extraction and refining of individual and mixed rare earths needs to be vigorously built up, if the present level of indigenous consumption of rare earth minerals, which is about 10 percent of the production, is to be meaningfully raised.

As in the case of titanium, the potential for industrial applications of rare earths, e.g. in electronics and optical industry, as catalysts in the petro-chemical industry and for pollution control have not been widely exploited in India. There are further application areas. Rare earth additions to a variety of non-ferrous alloys are becoming increasingly popular for enhancing oxidation resistance and for grain refinement. In the new emerging class of rapidly solidified aluminium alloys (like Al-Fe-Ce alloys), rare earth additions are effective in accentuating undercooling effects and globularising precipitate morphologies. In the important area of permanent magnetic materials, neodymium-iron-boron magnets, based on the ternary intermetallic compound Nd2Fe14B, have registered considerable success. India has a stake in development of this and other rare-earth based products in an internationally competitive fashion. Again the integrated approach should encompass the gamut of issues pertaining to the ore at the one end and the usable product at the other.

In view of the emergence of Nd-Fc-B magnets as a commercial success, we will discuss this magnetic material further in the present context. The ore-to-product development scenario pertaining to Nd-Fe-B in India is depicted in Fig.8

Generally rare earths are recovered as individual metals by two important processes, the molten salt electrolysis process and metallothermic reduction process. Other than promethium which is obtained by a radioactive process, all other rare earths can be recovered by one of the processes listed below. (Misch metal is recovered almost exclusively by



- **Activities/processes available to an adequate degree**

Activities/processes inadequately attended are *italised*

- **Activities/processes not available are underlined**

Fig. 8

molten salt electrolysis. Lanthanum and its alloys are also recovered by fused salt electrolysis).

The metal neodymium used for the NdFeB alloys is extracted (Fig.9) both by the fused salt and calciothermic reduction process (calcium is obtained by an electrolytic process). Commercially, the well established process for neodymium extraction is by molten salt electrolycis.

For the production of neodymium-iron-boron magnets, the individual elements such as neodymium, iron and boron or ferroboron are melted, crushed and milled to micron size, compacted under magnetic field and then sintered. This known process requires a number of steps like crushing, milling which is not only energy intensive but also increases the cost of production. Moreover, the rare earth metal, neodymium, which is the raw material of the process, is expensive because of the difficulties in the separation of neodymium from the mixture of rare earths such as lanthanum, cerium, paseodymium, samarium and of the energy intensive nature.

In another known process wherein metallothermic reduction-diffusion is involved, neodymium chloride/fluoride or oxide, iron and boron or ferro-boron are reacted with calcium in the presence of hydrogen to get the neodymium-iron-boron alloy along with calcium oxide and unreacted calcium. This is further reacted with water/moist nitrogen to remove calcium and then leached with acetic acid to remove calcium oxide. This process also requires considerable amount of energy input in the preparation of the alloy powder during reduction with calcium at high temperature in the range of 1000 to 1200 degree centigrade.

A recent project in India (National Metallurgical Laboratory, Jamshedpur) has succeeded in developing a process for the production of nano-sized neodymium-iron-boron permanent magnet alloy powder by overcoming the above mentioned difficulties. The process developed employs a chemical route involving neodymium oxide/salt, iron salt and a reductant for making neodymium-iron-boron alloy powder with particle sizes in the range of 20-100 nm (nm = nanometer). The formation of the compound Nd2Fe14B is accomplished through suitable heat treatment. The process is being transferred to M/s. Indian Rare Earths Limited, Mumbai for large scale trials.

PROCESS FLOW CHART FOR Fe-Nd ALLOY

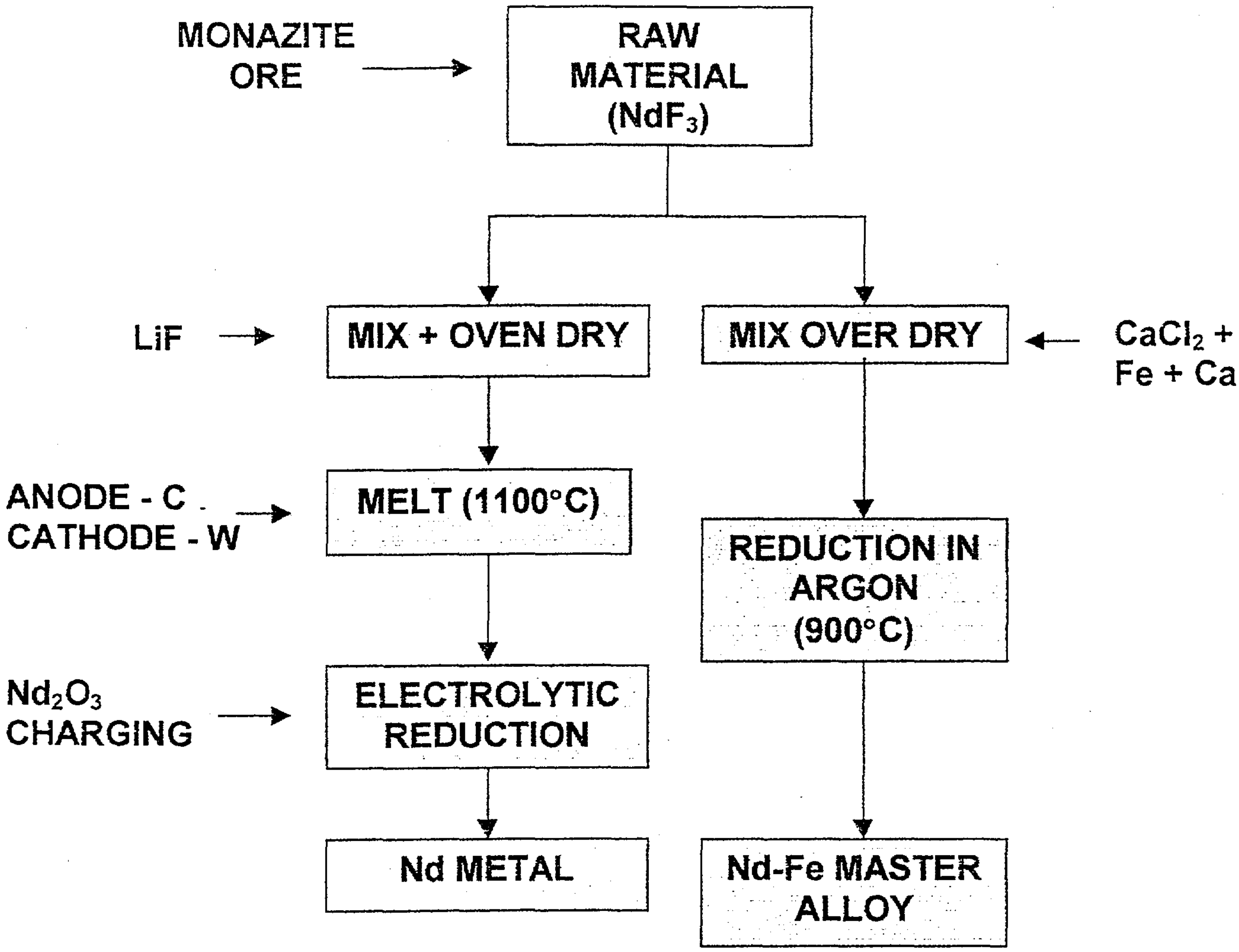
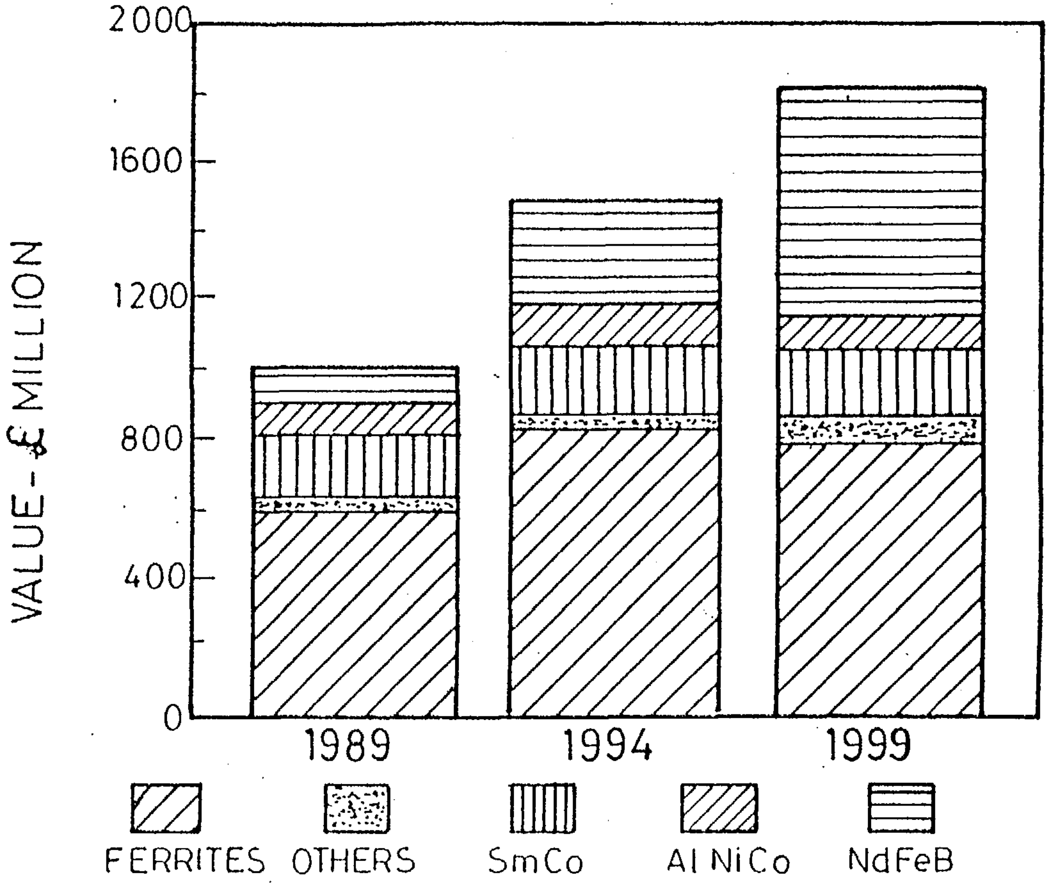


Fig. 9

Viewed in the context of the global permanent magnet industry (Figs.10&11), India's performance is not impressive, despite the availability of resources in abundance. More than about 45 companies commercially produce rare earth metals globally and a majority are located in USA followed by China and Japan. Of them 35% produce magnetic alloys, 35% produce high purity rare earth metals and about 30% produce misch metal, while in India there are only two misch metal producers and there is no large-scale commercial activity in rare earth metal extraction. The quality of the misch metal is suitable for applications such as lighter flints and as alloying additive to steel and cast iron, but not adequate for advanced applications such as for magnetic materials processing unless subjected to vacuum distillation.

As mentioned earlier some of the metals are extracted by calciothermic reduction and the calcium metal production by fused salt electrolysis is at an exploratory level at the Central Electrochemical Research Institute (CECRI). The necessary step to improve the purity by vacuum distillation is being persued by the Bhabha Atomic Research Centre (BARC), Mumbai. The integrated technology development to produce purer calcium metal based on the above initiatives is planned to be quickened since calcium of such purities are not only important to produce other metal alloys but also is relevant for steel industry to be used as deoxidiser and desulpheriser in addition to rare earth metals of high purity required for magnets manufacture.

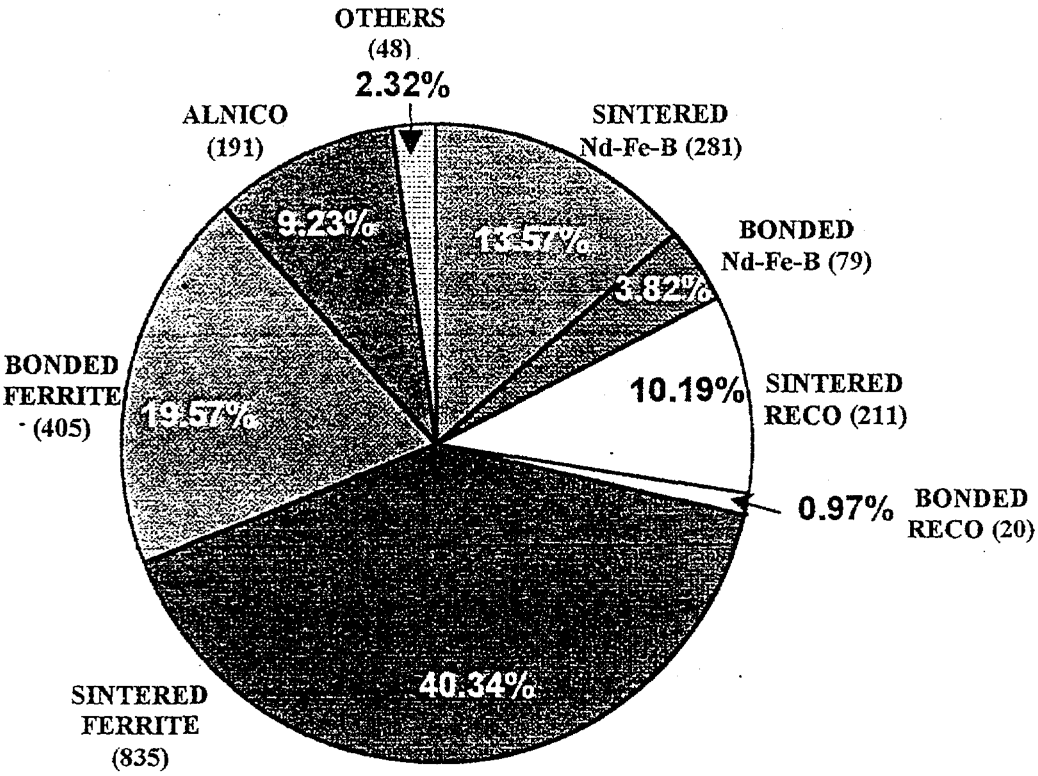
In India there are several devices which are being imported with permanent magnet components. The non-availability of appropriate magnets in the local market restrained the growth of *device* industry. In a world driven by information super highways, many devices are permanent magnet based. The industry is thus poised for significant growth. To meet such emerging needs, developments have to be accelerated. Appropriate technologies for the rare earth metal extraction have to be deployed urgently with a wholistic approach **viz. sand to mineral, mineral to salt, salt to metal, metal to magnet and finally magnet to device.** And the design aspects of a device using a new material, exemplified by high energy Nd-Fe-B permanent magnets, should not be underestimated. Notice the miniaturisation that has been achieved in the size of the travelling wave tubes when they are made of Nd-Fe-B (magnetic energy product ~ 40 Mega Gauss Oersted) magnets instead of the Alnicos (magnetic energy product ~ 4 Mega Gauss Oersted) as in the past.



ESTIMATED WORLD MARKET FOR PERMANENT MAGNETS

Fig.10

PERMANENT MAGNET MARKET 1990
MILLION $



TOTAL 2070 $ MILLION

(WHEELER STUDY)

FORECAST

TOTAL : 6500 $ MILLION
Nd-Fe-B : 2700 $ MILLION

Fig. 11

Permanent magnet technology is a well structured and recognised technology the world over and undue secrecy is being built on the technology. According to an expert on permanent magnet technology, the advancement of a country can be measured by the extent of utility of these rare earth magnets.

Concluding Remarks

The integrated approach covers a range of activities from exploration of the ore reserves, mining, beneficiation, establishment of extraction, refining and finally processing to relevant products (Fig.12). A comprehensive analysis should be carried out for each material with regard to each of the activities in the ore-to-product chain and the integrated policy should then aim at removing the bottlenecks. Such a policy, covering the range of activities from ore to product, requires linkages to be established among several organisations. In this endeavour, the manner in which the Department of Atomic Energy (DAE) is structured, although specific to strategic atomic minerals and nuclear materials, is illustrative (Fig.13).

In the framework of the present discussion, case studies (Fig.12) on abundant minerals like iron ore (steel), ilmenite (titanium) and monozite (rare earths) point to contrasting pictures. Iron and steel bring home, against the backdrop of abundance of indigenous resources, the necessity for improving the quality of production and matching the production profile (with regard to shape and type of steel) with the consumer demand, so that imports are minimized. Rare earths illustrate the requirement of compound separation and metal extraction technologies on a production scale as weak as commercialisation of product development while, in the case of titanium, a policy directed towards use of titanium in the power generation and other (e.g. chemical) industries along with the setting up of a large scale metal production facility is indicated.

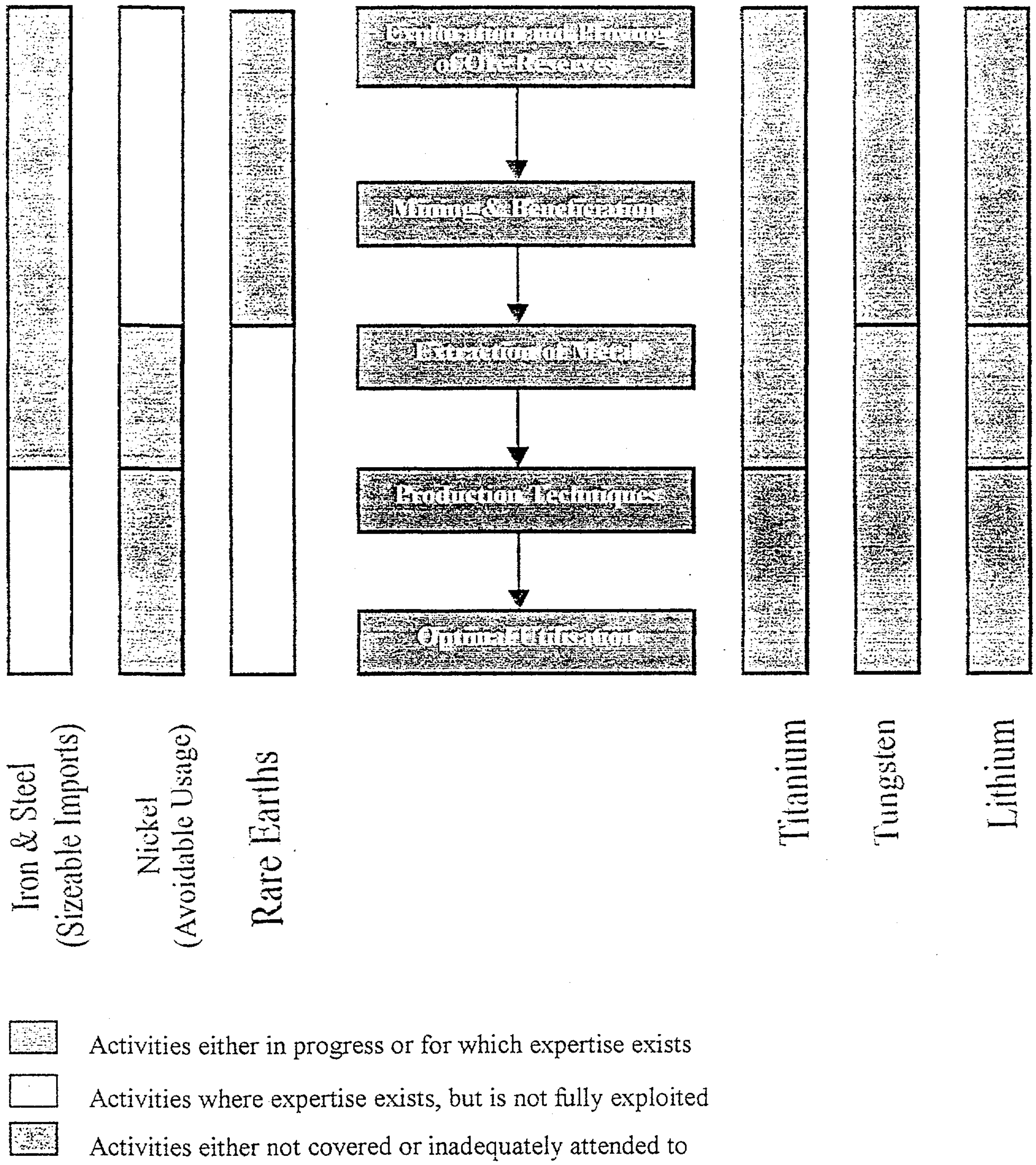

Exploration and Proving of Ore Reserves
Mining & Beneficiation
Extraction of Metal
Production Techniques
Optimal Utilization
Iron & Steel (Sizeable Imports)
Nickel (Avoidable Usage)
Rare Earths
Titanium
Tungsten
Lithium
Activities either in progress or for which expertise exists
Activities where expertise exists, but is not fully exploited
Activities either not covered or inadequately attended to

Fig. 12

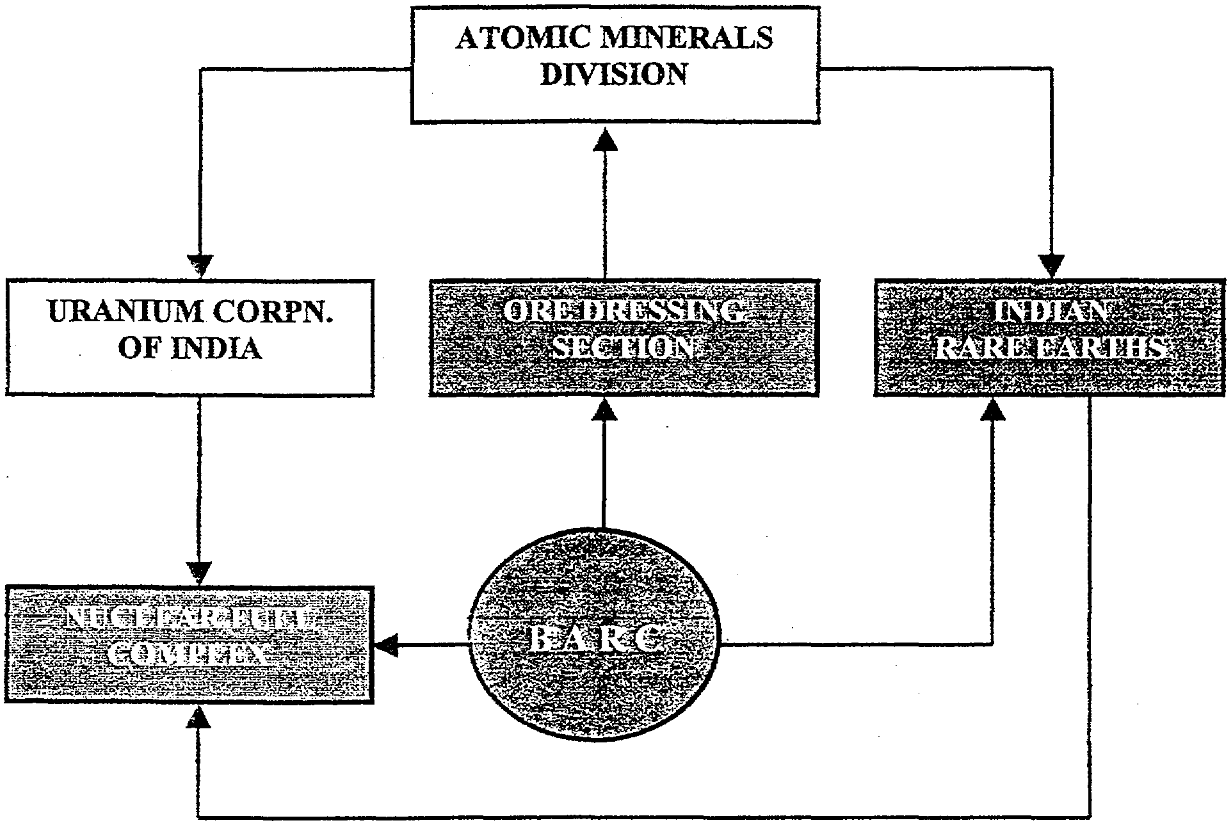

ATOMIC MINERALS DIVISION
URANIUM CORPN. OF INDIA
ORE DRESSING SECTION
INDIAN RARE EARTHS
NUCLEAR FUEL COMPLEX
BARC

Fig. 13

As per the definition* for strategic materials, tungsten, lithium and nickel qualify as strategic materials. With regard to these metals our analysis (Fig.12) shows that there is a need for intense exploration and mining efforts is indicated in the case of tungsten and lithium. In particular, the growing scientific inputs into our mineral exploration activities need to be considerably encouraged. In contrast, in the case of nickel, the critical bottleneck is the development of an efficient and economic method to extract nickel from the identified laterite ores. Till such an option becomes viable, substitution and recycling need to be accorded priority.

The above analysis, though illustrated through examples pertaining to metallic minerals, apply equally to non-metallic minerals. A case in point is rock-phosphate, in which case indigenous efforts for exploration (for high grade variety), beneficiation and even development of methods to use low grade material are called for to reduce the growing volume of import.

In the ultimate analysis not only an integrated approach but a vastly more extended vision, in space and time, is needed. (Fig.14). As stated in Limits to Growth : "Although the perspectives of the world's people vary in space and in time, every human concern falls somewhere on the space-time graph. The majority of the world's people are concerned with matters that affect only family or friends over a short period of time. Others look further ahead in time or over a larger area – a city or a nation. Only a very few people have a global perspective that extends far into the future".

It is earnestly hoped that IMAAC will contribute to defining the needed global materials perspective in the years to come.

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* **(U.S. Government Printing Office, Washington D.C.)** defines *strategic materials as those for which the quantity required for essential civilian and military uses exceeds the reasonably secure domestic and foreign supplies, and for which acceptable substitutes are not available within a reasonable period of time.*

IMAACTEXT

HUMAN PERSPECTIVES

(from Limits to Growth : Club of Rome)

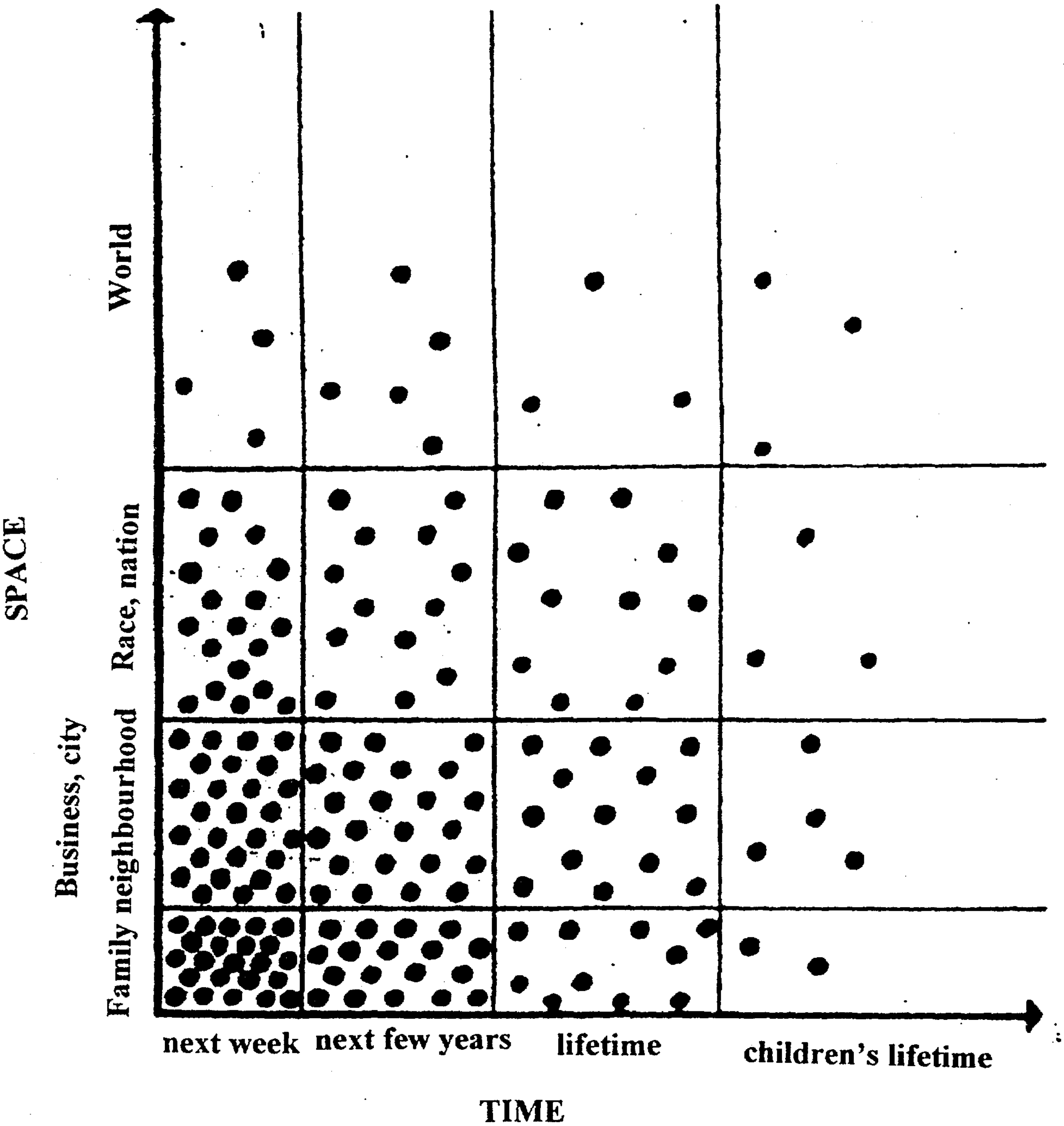


Fig. 14

MINUTES OF THE SECOND ADVISORY COMMITTEE MEETING HELD IN BEIJING DURING THE FIFTH IUMRS

Roberto C. Villas Bôas
Chairman ACP

NOTES

1. At the end of May 98, IMAAC Advisory Committee was set up and met in Rio de Janeiro, Brasil, for the first time ;
2. At the occasion , the objectives, mission and functions of the Centre were established and diffused throughout interested parties ;
3. A pilot phase , of two years of duration, was set up , involving the following activities :
   a) proposal of the operation nodes and the main hub : completed ;
   b) adhesion of participating organizations : 65 organizations, till end of may 99 had manifested intentions to join IMAAC ;
   c) the design of the hardware and software for the hub : from a sketch made by Prof. Valladares at the Rio meeting, a complete set of requirements were made and then modified , recently, by UNIDO experts ;
   d) acquisition and installation of the designed hard + soft for the hub : operation delayed due to organizational restructuring of UNIDO and expected to be completed by the end of OCTOBER 99 ;
   e) proposal of the profile of the operating personnel for IMAAC hub : completed and submitted for final approval by the Ministry of Science and Technology of Brazil: expected approval by the end of SEPTEMBER 99 ;
4. Realization of the IMAAC FORUM '99 in Beijing : an awareness FORUM; operation completed with full adhesion of the following institutions :
   a) Chinese Academy of Cement and Building Materials ;

b) Institute of Corrosion and Protection of Metals of the Chinese Academy of Sciences ;
c) Northwest Institute for Non-ferrous Metals Research ;
d) Central South University of Technology ;
e) Chinese Academy of Iron and Steel ;

5. Revision of the two remaining FORUNS to be held by IMAAC during the pilot – phase :
   a) the "go ahead" with the IMAAC COPPER FORUM, now scheduled to be held in conjunction with the CYTED event "Mining and Sustainable Development ", possibly in Portugal and Spain, at the end of October 99 ;
   b) the 'go ahead " with the IMAAC CEMENT FORUM , now scheduled to be held jointly with the Chinese Academy of Cement and Building Materials , possibly at the end of April 2000 ;
6. Review of possible pilot projects, under the auspices of UNIDO ongoing projects :
   a) MOZAMBIQUE : the conceptual design of R&D facilities for strategic areas in Mozambique : scheduled to start by SEPTEMBER 99;
   b) MALASIA : training in technology assessment and forecasting : scheduled to start by late SEPTEMBER 99 :
   c) MONTREAL PROTOCOL : assessment on materials technological issues ; still under negotiations internally to UNIDO ;
7. Establishment of the IMAAC BULLETIN :
   a) the printing of the two first BULLETINS containing pertinent material presented at the Rio and Beijing meetings ; late OCTOBER 99 ;
   b) next, the printing of the COPPER and CEMENT FORUM as IMAAC BULLETINS ;
   c) to appoint Prof. P. Rama Rao as the Editor-in-Chief of the IMAAC BULLETIN ;
8. Approval of setting up a diffusion plan , as follows :

a) to build an IMAAC HOMEPAGE at the UNIDO site : conclude in OCTOBER 99 ;

b) to print leaflets and distributing to interested parties and events : conclusion by NOVEMBER 99 ;

9. Approval of establishing close relations between IMAAC and ICMET , both UNIDO Centers, as well as others, for projects participation and cooperation ; the responsible directors of ICMET/UNIDO were invited to attend the IMAAC FORUM '99 presenting their views and missions ;

10. Approval of the release to the IMAAC hub at CETEM of USD 20 thousand to cover operational cost and general expenditures related to the decisions made ;

HARWARE DESIGNED BY UNIDO FOR THE HUB

The following are expected to reach CETEM by SEPTEMBER 99 and have installed before the end of OCTOBER 99 :

- 2 INTEL Pentium III 450 MHz 512 k cache, 512 MB RAM (ECC) , 6*9 GB Disk, RAID – 5 Controller (54 GB Gross), Secondary Gross Controller ;
- DDS-3 autoloader streamer, 192 GB net, 24 speed CDROM; Dual Power Supply ;
- 100 Mbps ethernet adapter ;
- NT 4.0 Server , 5 users ;
- APC smart 1400 UPS with 15"svga monitor 3 years next workday on-site service;
- 2 x spare 9 GB hard disks ;
- 2 Intel Pentiun III 450 512 ... ;
- RAID – 5 Controller Secondary Raid Counter ;
- 24 speed CDROM ;

the optical fiber connection:

OVERALL VALUE FOR THE ITEMS : USD 30,000.00

AFTER THE PILOT PHASE

A preliminary assessment of what to do after the pilot – phase was conducted and it was approved to held Advisory Committee meetings both at the COPPER and CEMENT FORUNS in order to close assess progresses made and demands of IMAAC, as well as its performance within the aforementioned pilot projects (MOZAMBIQUE , MALASIA and MONTREAL) ;

DUE RESPONSABILITIES

To the following activities as approved and planned were designated the following persons :

a) Acquisition of the hardware as stated above : Vladimir Khozharnovich ;up to the end of AUGUST 99 ;
b) Transferring of the hardware to CETEM : Vladimir and Lelio Fellows Filho; up to the end of September 99 ;
c) Installing of the hardware at CETEM hub : Lelio and Roberto Villas Bôas , up to the end of October 99 ;
d) Assigning Operational personnel to IMAAC hub : Lélio and Villas Bôas ; as soon as possible : end of August 99 ;
e) World's Resource Assessment to be prepared by the hired personnel ;Villas Bôas ; up to December 99 ;
f) Terms of References for the COPPER and CEMENT FORUMS : Villas Bôas ; for the COPPER up to the end of August 99 ; for the CEMENT up to the end of January 2000 ;
g) Liberation of the USD 20,000.00 for operational costs for IMAAC : Vladimir Up to the end of August 99 ;
h) Homepage : Lélio ; up to October 99 ;
i) Report on the IMAAC FORUM '99 : Hengde Li ; up to September 99;
j) IMAAC BULLETINS : P. Rama Rao ; the first two up to November

NOTES ON THE IMAAC FORUM '99 HELD IN BEIJING DURING THE FIFTH IUMRS INTERNATIONAL CONFERENCE ON ADVANCED MATERIALS

Roberto C. Villas Bôas
Chairman ACP

IMAAC FORUM '99

With the presence of especially invited people from the Ministry of Science and Technology of China , the General Research Institute for Nonferrous Metals, the Institute of Corrosion and Protection of Metals of the Chinese Academy of Sciences, the Central Iron and Steel research Institute, the China Building Materials Academy, the Guangzhou Research Institute of Nonferrous Metals, the South China University of Technology , the Tsinghua University , the Northwest Institute for Nonferrous Metal Research, the Advanced Technology & Materials Co. Ltd. , and some three other organizations outside China , the University of Aveiro, in Portugal, the Queen Mary College of the University of London, and the Materials Science Engineering Dept. of the University of Queensland, in Australia, the IMAAC FORUM '99 was held from june 17^{th} to june 18^{th} at the Beijing International Convention Center (BICC) .

The objectives of the FORUM, as stated during the First IMAAC ACP meeting held in Rio, were :

- the diffuse IMAAC objectives, missions and functions in the host country and other interested parties
- to attract interested organizations to be part of IMAAC nodes
- to listen to selected invited scientists and engineers from the host country in relevant topics to IMAAC's missions and objectives
- to devise alternative routes to reach associates for IMAAC

In order to accomplish with such goals the sections were so designed that the overall UNIDO new polices on investment and technology promotion were presented to the audience , followed by how does IMAAC fit within them and the accomplishments, as well as drawbacks, that IMAAC has had throughout this first year of its pilot-phase . Two presentations were held at this part :

1.-) UNIDO Investment and Technology Promotion Programme, by V. Kozharnovich .

2.-) IMAAC Objectives and Missions : Present and Future , by L. Fellows Filho .

In the sequence of the FORUM, several papers were distributed and presented, as follows :

1.-) Materials Production and the Environment , by R.C. Villas Bôas .

2.-) China's Cement Industry – Present State and Strategy of Development, by Ouyang Shixi .

3.-) The Current Development and Outlook for Advanced Surface Technology and Engineering in China, by Zhou Kesong and others .

4.-) On the Issues Concerning the Development of Steel Industry in Developing Countries, by Yin Ruiyu .

5.-) Prospect of Plastics Processing in Developing Countries, by Qu Jingping and others .

6.-) Corrosion Science, Corrosion Engineering and Sustainable Development , by En-Hou Han and others.

7.-) Application of Rare Earth in High- Tech Industry , by Tu Hailing and others .

8.-) Application for Setting up of an "International Rare Metal Material Assessment and Application Center ", by Zhou Lian .

This last one being an official application to IMAAC and UNIDO to accredit the Northwest Institute for Nonferrous Metals Research (NIN) as the node for Rare Metal Material Assessment and Application within IMAAC objectives and missions .

Also, the paper by P. Rama Rao, entitled "Approach to an Integrated Mineral-Material-Product Development " was distributed to the participants , although not presented, since Prof. Rama Rao rather allowed the time he will utilize for the exposition to other Chinese participants not listed above (for instance , the Vice Minister of S&T of China and an enterpreneur from ATM Co. Ltd.) .

The relevant points raised throughout the FORUM were :

1.-) lack of clearness from the part of the attendees of what in fact is IMAAC, how it works, and how can you join it ;

2.-) the eagerness on the part of the interested entities, previously contacted by Prof. Hengde Li, in joining IMAAC, as soon as the questions regarding IMAAC – see above - were answered ;

3.-) the views raised by all of the expositors on cost internalization of the environment as a crucial question to the materials engineer and scientist ;

4.-) the very interesting particularities of the Steel and Cement industries in the developing world that were posed by Drs. Yin Ruiyu and Ouyang Shixi , when analyzing the Chinese case-study ;

5.-) the decision , by the ACP, of confirming the CEMENT FORUM and to held it

jointly with the Chinese Academy of Cement and Building Materials ;
6.-) to consider the papers presented , and/or distributed, in the FORUM as worth of publishing in a IMAAC BULLETIN ;
7.-) the absolute place of these FORUMS within the activities of a bigger Conference , as the IUMRS one, in order to attract interested parties to IMAAC , in accordance to Hengde LI and Ariel Valladares when they proposed it in Rio, back in 1998 .

IN CONCLUSION

The ACP decided :
1.-) to publish the IMAAC FORUM '99 in a IMAAC BULLETIN which Editor-in-Chief was designated to be Prof. Dr. P. Rama-Rao ;
2.-) for that matter, Prof. Dr. Hengde Li , will convey to him all relevant writings that were eventually missing during the oral presentations ;
3.-) that the IMAAC CEMENT FORUM will be held in 2000 , probably by April , in a joint effort between IMAAC and the China Academy of Cement and Building Materials ;
4.-) for that purpose, the International Coordinator, Dr. Vladimir Khozarnovich was entitled to negotiate directly with that Academy, with the help of Prof. Dr. Hengde Li ;
5.-) to adopt for the next IMAAC FORUNS say the COPPER and the CEMENT , specific "TERMS OF REFERENCES "in order to enhance and enlarge the participation of interested entities ;
6.-) for that matter Villas Bôas was assigned responsible ;

The Issues On The Development Of Steel Industry In Developing Countries

YIN Ruiyu

(Central Iron and Steel Research Institute)

May 1999

1. Steel will still be an important material

Steel industry has been flourishing in the 20th century. Global steel output will increase from some 30 million tons in 1900 to round about 800 million tons in 2000, Fig.1. Steel has played an important role in the development of world economy and civilization. Before the oil crisis, the production and investment of steel industry enhanced the manufacturing, construction, transportation etc.. After the oil crisis, steel industry is still the substance foundation for global economic development. In the foreseeable period, steel will still be a very important material.

2. The development of the world steel industry

In the 20th century, steel industry has undergone a process of productivity increasing, quality improving, products developing, energy saving, environment-friendly etc..

In the view of worldwide, the competition among materials such as steel, cement, plastic, glass, aluminum, titanium, paper etc. is very intense in different application fields. One of the very important reasons why steel products can be developed in the intense competition is that the price of steel is stable for 25 years since 1974, Fig.2. The steel price decides the direction of producing technology, product structure, plant rational size and corresponding investment strategy.

From 1947 to 1973, the steel consumption increased greatly in the world. During the same period, the output of global crude steel has increased by 6.3% each year. Before 1973, with overestimation of future steel market, a lot of steel plants enlarged their annual capacity to 10 million tons, even to 16 million tons with the thinking of that the larger size steel plant would bring in more profit. In fact, these super large steel plants could not obtain the expected benefit.

The main reason is that the investment is too huge. When market requirement fluctuated, these plants were affected and could not work efficiently, and due to long distance from plants to customers, the transportation fee is high. So, the international steel producers have gradually realized that the sale radius should not be too long except some high value-added products such as stainless steel and silicon steel sheets etc.. Long transportation distance would weaken the competitiveness of some steel plants. Some plants that had planed to enlarge their capacity in 1960s and 1970s had to adjust plant structure and reduce capacity. Generally speaking, the annual capacity of these super large steel plants was reduced to about 5-8 million tons and even less. These super large steel plants are characterized with large BF-BOF process and mainly produce flat products. The developing process has shown that the profits of super large integrated mills are offsetted by high capital cost, lower operating efficiency, long transporting distance and corresponding high transportation fee etc..

At the same time, "Mini-mills" have gradually appeared in the United States. The philosophy for "Mini-mills" is operating and taking market with the lowest possible costs and the minimum of capital investment. The service radius of this type of mills is less than 100km, and the annual yield is from 300,000 tons to 1,000,000 tons. These mills mainly produce long products by using local scrap to satisfy the local needs for steel products. Due to very good benefit of "Mini-mills", a lot of medium and small "Mini-mills" have been developed in the world. With that the international concept for medium and small steel plants has been formed.

3. The development of China's steel industry and the advancement for technology

Through the development of nearly 50 years, especially the development since 1980s, China's steel industry has been growing rapidly. The annual crude steel production was over 100 million tons since 1996, reaching 115 million tons in 1998.

The geographical distribution of steel industry has changed significantly in China. The crude steel production in the northeastern part of China decreased from 82.83% in 1950 to 14.3% in 1998. The crude steel production in the eastern part and northern part of China increased remarkably to 31.6 and 26.1 per cent respectively in 1998. As a whole, the major parts for the growth are the southeastern coastal land, as well as the middle and down stream of the Yangtze River Fig. 3.

The iron ore resources in China are mainly low-grade ore, high proportion of paragenetic iron ore, and complicated compositions. The average iron content of crude iron ore in China is about 33 per cent, thus a large amount of study has been carried out in ore dressing, the grade of magnetite concentrate now maintains above 64 per cent iron, and hematite concentrate above 62 per cent iron.

In China, the steel industry can be classified into three types: integrated enterprises(e.g. Top Big Ten), local steel plants and special steel works. Baoshan Steel Corporation was built up since 1980. The annual production is now over 10 million tons, mainly flat and seamless tube. In 1980s, a large number of local steel plants are also developed rapidly. These of local steel plants consist of small blast furnaces and small oxygen converters, and produce mainly long products.

The blast furnace (BF) technology in China has been developed rapidly. Blast furnaces of 1260m^3, 2560m^3, 3200m^3 and 4300m^3 have been designed and built on her own in China. The process of pulverized coal injection has been also developed rapidly. The process of 200kg/ton hot metal of pulverized coal injection has been developed in Baoshan Steel Corporation and Anshan Steel Company. The productivity of 300~350m^3 BF can be efficient. In 1998, the average productivity of 200~350m^3 BF has been up to 2.33metric ton/m^3.day (2.69metric ton/m^3.day for working volume) in China, Fig.4. It means that a 350m^3 BF (diameter is 5.1m) can produce 285,000 tons or even 300,000 tons hot metal annually.

From 1960s to 1970s, 20t、30t and 50t basic oxygen furnaces (BOF) were developed and established in China. The 250~300t BOF are introduced into Baoshan Steel Corp. and Wuhan Steel Co. from abroad. Today, China is able to design and construct a steel plant of 250t BOF on its own technology. In China, the output of BOF is now above 70 percent of total crude steel production.

Beginning from 1988, continuous casting technology was developed rapidly in China. In 1988, the output of continuous casting steel was 8.72 million tons, or 14.7% of the total production, in 1998, it was over 78.83 million tons, a ratio of 68.8%. The annual increment has been over 10 million tons for last three years. During the same period, the continuous casting technology was developed more rapidly in local steel plants, and the percentage of continuously cast reached 82.59% in 1998. The continuous casting process improved the productivity of BOF plants greatly, as shown in Table 1, a 30t BOF can produce 0.5 million tons steel a year. Now there are 75 fully continuous casting workshops in China. The casting speed of a 120mm×120mm billet caster has reached 3.5~4.5m/min, with the productivity greatly increased with an annual output per stand up to 120,000~150,000 tons.

Based on the above technological progress, China witnessed the appearance of a number of medium and small BF-BOF steel mills with annual output up to 1 million tons, even to 2 million tons or more.

As a developing country, China's steel produces mainly long products, contributing a share of around 60% of the steel products for long time. Since 1980s, the flat products has shown an increasing tendency from 22 per cent in 1980 to 31 per cent in 1996 in the make-up of steel products. The increase comes mainly from the new hot rolling mills in Baoshan, Panzhihua, Taiyuan and Meishan Steel Company. Since 1990s, China has developed on its own bar mills with annual output of 0.3~0.5 million tons and wire rod mills with annual output of 0.35 million tons, reducing the investment of the equipment by 50 per cent than that of imported one.

After undergoing the period of rapid increase in output, China's steel industry will step into a new stage characterized by restructuring, improving its market competitiveness and paying more attention to the sustainable development. During the course of optimizing and restructuring of enterprises, some old process and equipment will be eliminated quickly. The open hearth furnaces will be eliminated basically by the year 2000 in China.

China's crude steel output is expected to reach 115 to 120 million tons in the year 2000, and the domestic demand for steel would be about 120 million tons. Some experts forecast that the consumption of steel products in 2010 would be 140 to 150 million tons. In a word, China's steel industry will continue to develop during the reforming and opening up to the outside world.

4. The concept of medium and small steel mills in China

Some factors such as resource, energy, technology, market and capital influence the product structure and rational size of steel plants. China is a continental country with unevenly distributed domestic market. Many capital constructions have to be built and people's living standard has to be improved. In the next 5-10 years, the consumption of long product will still be more than 50% of the domestic market. At the same time, China is short of scrap and capital. And these factors determine the necessity of existence of medium and small size steel mills.

In China, the medium and small steel mills not only include "Mini-Mill" which have been developed in the southeastern coastal area, but also include the local steel plants with medium and small BF-small BOF-continuous caster-hot rolling mills which produce long products and narrow-medium gauge plates. In China, the rational annual capacity of a "Mini-Mill" is 0.4~2 million tons, and that of a local steel plant is 0.6-2.5 million tons. Among these, some plants are building up thin slab caster for producing thin hot strip.

5. Prospect of medium and small steel mills in the world

Since 1980s, the technological process of medium and small steel mills has been improved considerably in the world and the productivity has been increased. These plants have shared the market accordingly. Their destination is to produce long products and some flat products with minimum capital investment and production cost and to occupy local market. These advantages will still be kept in the future.

Due to the different situations between developing countries and developed countries, the structure and rational size of the medium and small steel mills are different. Generally speaking, the medium and small steel plants mainly produce long products. Some plants will go into flat product market when enough capital is available. This trend must be paid attention to.

As to the producing process of medium and small steel mills, industrial countries mainly develop "Mini-mill" with EAF, but in developing countries, some should develop both BF-BOF process and "Mini-mill" process, some should only be with small BF-BOF process, and some can develop the "Mini-mill" .

Looking forward to the future, medium and small steel mills will still be developed in the world as a specialized producer. However, They will still compete with integrated companies in some steel products market. The result will get rational role respectively, specialized production and sharing the markets with different products and in different regions.

6. Suggestions

With coming into the 21 century, steel will be an important material for the improvement of the living standard in the developing countries. The requirement of steel will continue to increase in the first and second decade of the next century in the world. The increasing requirement will be needed in developing countries such as China, India, Pakistan, Southeast Asia, the Middle East, Latin America and some areas of Africa. During the initial stage of the development of steel industry, the long products will be mainly consumed so that it is suitable to develop various medium and small steel plants in these countries and areas. And it is also easy to raise capital. It is very important to study the steel work mode for developing countries because the existence mode are fit to developed countries.

Based on above-mentioned, we suggest:

1. The issues on the study of the steel work mode for developing countries should be approved by IMAAC.
2. "Research Center of Steel Work Mode for Developing Countries" should be established mainly by Central Iron and Steel Research Institute of China (CISRI) to promote the rational development of steel industry in developing countries.

References:

1. Yin Ruiyu, Engineering Review on Structure Optimization of Iron and Steel Industry as well as Steel works, Iron and Steel, CSM,Vol.29, No.3, 1994, P7

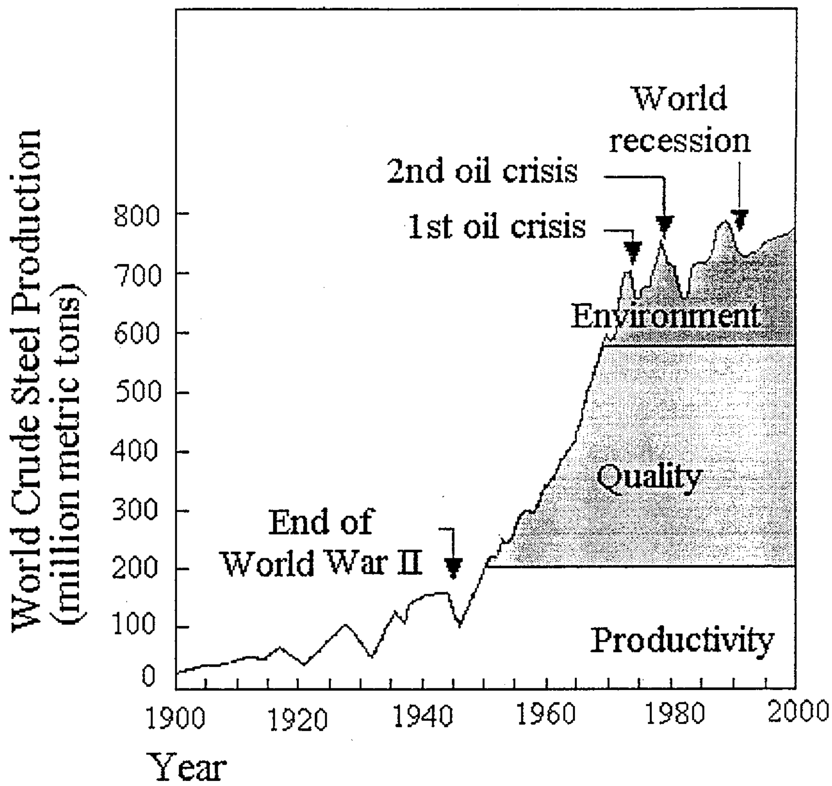


Fig.1 World steel productions has experienced dramatic in the 20th century

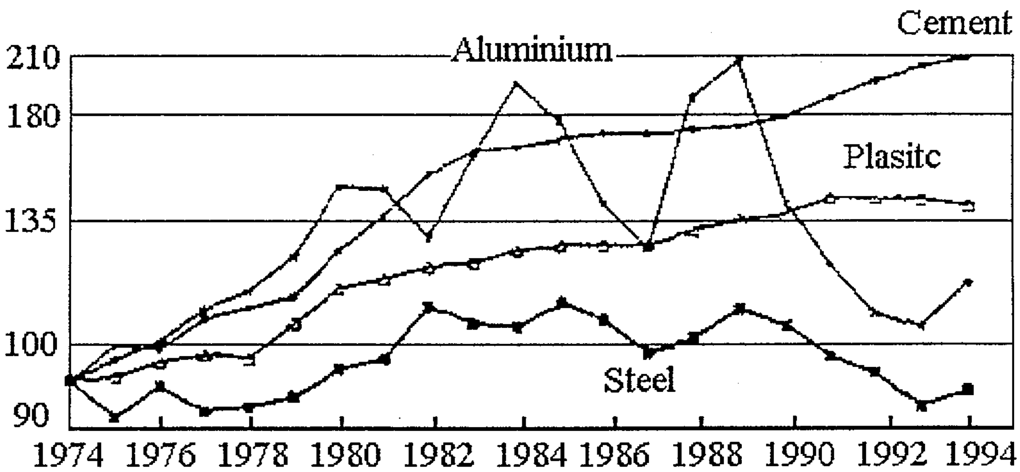
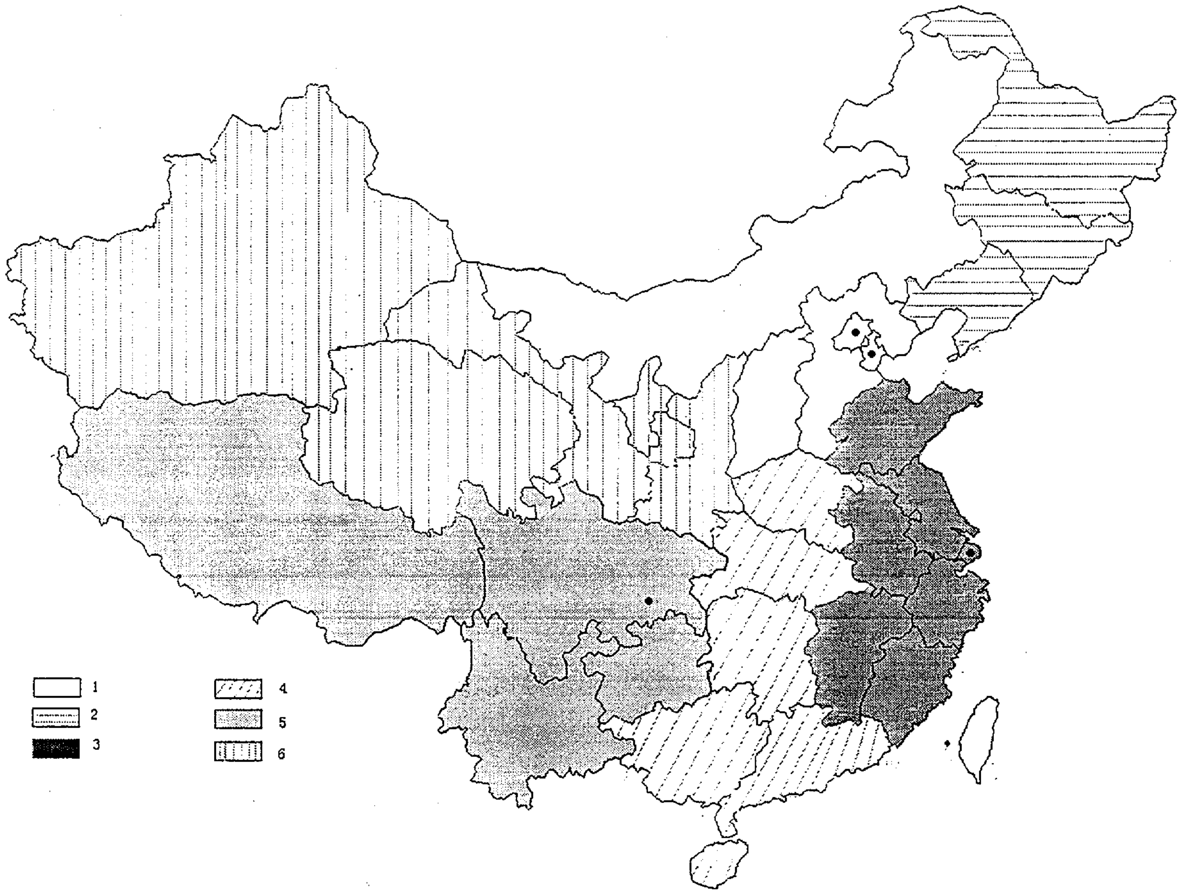
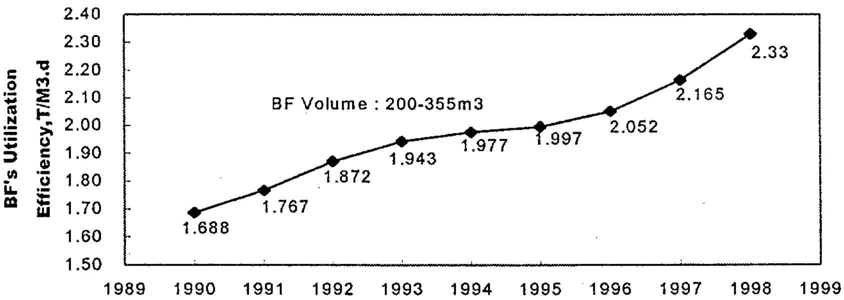


Fig.2 The change of price for various material (Price Index (logarithm) 1974 =100)



Regions	1950	1970	1980	1990	1998
North (1)	12.72	19.96	21.51	22.69	26.10
Northeast (2)	82.83	37.32	26.44	20.89	14.30
East (3)	1.95	23.7	24.74	27.57	31.60
Middle South (4)	0.90	13.57	15.05	16.64	15.80
Southwest (5)	1.61	4.51	10.34	9.38	8.80
Northwest (6)	0	0.94	1.91	2.82	3.40

Fig.3 The share of crude steel production by regions in mainland of China



Vol.,m^3	1990	1991	1992	1993	1994	1995	1996	1997	1998
200-355	1.688	1.767	1.872	1.943	1.977	1.997	2.052	2.165	2.33

Fig. 4 The Evolution of Small BF(200-355m^3) Productivity in China Since 1990

Table 1 Progress of CC Ratio and BOF Utilization Efficiency in Local Steel Plants in China for Last 10 years

Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
CC Ratio,%	20.57	22.57	41.53	45.67	48.23	54.96	59.45	62.05	71.71	75.24	82.57
BOFUtilization Efficiency, t/t.d	25.90	26.64	26.64	27.32	30.63	34.39	34.39	36.09	39.83	44.65	49.80

Application of Rare Earths in High-Tech Industry

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Tu Hailing   Yao Jianming   Yu Chengzhou

Middle East has petroleum, China has rare earth

- are earth deposit: >80% of the world reserve.
- Well manage and use of the rare earth resources.
- Making the rare earth resource advantage to technology   advantage to economic advantage.
- Rare earth new materials with good properties, promoted the development of high-tech industry, advanced high-tech industry has been rapidly formed.

Application of Rare Earths in High-tech Areas

* Ni/MH Battery.

* Rare Earth Magnetic Materials.

Rare earth permanent magnetic materials.

Magnetostrictive materials.

Magneto cooling materials and refrigerator.

Rare earth macro magnetic resistance materials.

* Rare Earth Phosphor and Luminescent materials:

Rare earth phosphor materials for lamps.

Luminescent materials for display and halide light.

Rare earth laser materials.

Other rare earth phosphor materials.

Rare Earth Materials for photocommunication application .

* Catalytic materials for automobile exhaust gas.

Ni/MH battery – green battery

In year 2000, small scale secondary battery annual output of the world: 2 billion pcs.

In year 2005, Ni/MH battery demand of the world: 2 billion pcs

Hydrogen storage alloy demand: 20,000 tons.

Including mish metal alloy: 6840 tons.

Rare Earth Magnetic Materials

NdFeB   SmCo5   Sm2Co17

Potential Market for the Application of NdFeB Magnetic Materials

* Rare earth permanent magnetic electric machine

Energy-saving, small volume, good performance

Electric Vehicle

Household apparatus: inverter air conditioner, washing machine, etc.

* Magnetic levitation high speed train

* Automated High Speed Road System

Magnetostrictive Materials

TbDyFe, Pr2Co17, SmFe2, Tb(CoFe)2

The length can be varied with the magnetic field, magnetostrictive value containing the rare earth alloy is 100-1,000 times of non rare earth alloy

Applications:

Water sound detecting, Tape video camera tracking, micro machine. functional part for robot, ultra precision mechanical processing control

Magneto Cooling Materials and refrigerator

Low temperature: (<20K): Gd3Ga3O12(GGG) Dy3Al5O12 (DAG)

Room temperature: (~300K): Rni2, Ral2 such as Gd3Al2

Magneto coolant: high efficient, low energy consumption, pollution and noise free, low cost

Rare Earth Macro Magnetic Resistance Materials

Rare Earth High Density Data Storage Materials

Magnetic light storage materials

Electron capture light storage materials

Spectrometry

Rare Earth Phosphor and Luminescent Materials

Rare earth elements have a special electron layer structure,

Providing rich electron mobility energy level, producing a variety of absorption and emission spectrum.

Photoluminescence, visible light, ultraviolet excitation

X-ray emission, X-ray activation

Electroluminescent, exerting electrical field

RE phosphor, luminescent materials have entered into household application and have been widely applied in display and lighting.

RE phosphor for lamp

- Light source: lighting, duplicator light source, photochemical light source
- Energy-saving lamp RE tricolor phosphor
  Luminous efficiency is twice higher than incandescent lamp

Luminescent material for display

All kinds of screens: color TV, radar, computer, osillometer

Red phosphor: YVO_4:Eu, Y_2O_3:Eu, Y_2O_2S:Eu

Tendency

- High differentiate phosphor

Computer display demand is great

- Blue and green RE phosphor
- Spherical phosphor for high differentiate ,big screen TV

Other RE Phosphor Material

- Luminescent material for photo-electron information
- Plasma display phosphor
- Luminescent material for projection TV
- Long and short afterglow phosphor
- Organic electro-luminescent material
- Light conversion material
- Photo-electron conversion material

Luminescent material for RE halide lamp

RE halide lamp----new generation energy-saving light source

Used in stage, square, marine fishing, decorative lighting and so on

- RE luminescent material: Dysprosium halide, Holmium halide, Erbium halide and Scandium halide
- Tendency : From outdoor lighting to indoor lighting
  Requirement: smaller volume, lower watt and higher color redering performance

Commercialization of less than 20 watt RE halide lamp used as household decorative lighting

RE Laser Material

Close relationship between RE and laser, 90 percent laser material containing RE

Wavelength range: infrared------ultraviolet

kinds: Nd:YAG, Nd,Cr:GSGG, Nd:YAP, Nd:YVO4, YLF

- Application: photo-communication, medical treatment, military use, information storage, cut, weld and so on
- Advantage: Study on new type laser crystal
  $Nd:YVO_4$,Nd:LiSAF
- Problem:

1. Lagging behind the world level in Nd:YAG laser crystal manufacturing
2. Scattering work, repeating building in low level
3. crystal growth, quality of product and aftertreatment technique need to be improved

RE laser material

Base of laser technology

21 century important hi-tech functional material

Close related with national pillar industry

Photo-communication RE Material

- Photo-communication become important way of information transmission
- Photo-communication devices lower transmission loss ,building and use cost and enhance capacity and velocity
- Devices promising to be industrialized:
  optical amplifier, optical isolator

Catalyst for the Purification of Automotive Emission

- Automotive exhaust become one of the major pollution sources in big and medium-size city
- Major measures controlling pollution of automotive exhaust:

Lead free gasoline, Electric injection system, Automotive catalytic converter

- Active catalyst is the key part of automotive catalytic converter
- Addition of RE

1. Enhancing the toxic resistance to lead and sulfur
2. Enhancing high-temperature stability
3. Enhancing endurance to A/F ration of engine

Key High Technology Applied Field

- NH/MN battery and electrical vehicle
- RE permanent magnet and its application in new type electric machine
- RE luminescent material and its application in high differentiate TV and flat display
- RE photoconductive fiber and photo-communication
- RE catalyst and its application in purification of automotive emission
- RE inorganic pigment and coating

Prospect of Plastics Processing in Developing Countries

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1. The summarization of the current development in the plastics processing industry in the world

The plastic is developed at the fastest speed among three synthetical materials (plastic, rubber and synthetical fibre). It is not only applied to produce all kinds of commodities but also has replaced three traditional basic materials (steel, wood and cement) at great speed in many fields. In 1990's the global annual output of plastics broke 100 million tons, and exceeded the annual volume yield of steel for the period. Up to 1997 the global production of the plastic raw materials had attained 134.6 million tons. They show how rapidly the plastic industry and their processing industry develop and how huge the market prospect is. The development of the plastics industry both depends on the development of the plastics processing industry and extremely accelerates its development contrarily.

In the developed countries like Occident (include Japan) the plastic industry and the plastics processing industry start early and develop more quickly. In 1997 their output of the plastic raw materials approximately occupied 75 percent whereas the developing countries and the other countries and districts only occupied 25 percent. Seeing from the average annual consumption of the plastic materials per person, in 1996 Belgium was 144 kg per person per year, American was 143 kg per person per year. Whenas China was about 5.5 kg per person per year; Indian was 1.2 kg per person per year. The developing countries were lower than 10 kg per person per year in general. From 1993 to 1996, the average annual consumption of plastic and rubber machines per person in Canada was US$ 28.78, Italy was US$ 28.22, German was US$ 19.34, whereas China was US$ 2.1, Indian was US$ 0.1. The above conditions manifest that the plastics industry and the plastic processing industry of the developed countries are relatively flourishing. In German the plastics industry and the plastics processing industry are still the important stanchion of its national economy.

Compared with the developed countries the plastics industry and the plastic processing industry in the developing countries are developed later. There exists pretty gap. But due to the big dimensionality and the numerous population of the developing countries, especially the rapid increase of economy and the spreading of plastic applications, the developmental rate of the plastics processing industry in the developing countries looks very quick. From 1990 to 1996, the average annual increase rate of the global yield of synthetic resin was 4.65 percent, whereas China was 13.56 percent. The average annual increase rate of plastic products in china was 24.71 for the period. In Indian the average annual consumption of plastics per person is only 1 kg at present. But it schedules to go up to about 3~4 kg in 2001. From 1993 to 1996 the average annual increase rate of plastic and rubber machines' consumption had attained 33.6 percent. It can be foretold that the developing countries will be the biggest market of plastics industry in 21st century.

2. The challenges and chances faced by the developing countries in the plastics processing industry.

2.1 The effect of the trend of economy globalization

The economy globalization is that economic behavior as production, trade, investment and finance are large-scalely operated in the global area. It is the global allocation and recombination of production elements, and is the manifestation of high relying on and fusing each other for the world economy. After the World War II the economy of the cardinal developed countries got quick development. However since recent 10 years many evidences have displayed that the increase of internal requirements in those countries couldn't maintain the long-term winged growth of their economy in the future. Therefor a lot of enterprises in the developed countries and districts moved their market emphasis into the developing countries and districts step by step. The American Mulay Plastic Company, which is engaged in injecting shells of TV set and computer scope, has three factories in America. Recently it builded two new factories in Mexico. The population proportion of the developing countries is larger and increases more rapidly, whenas their economy is more laggard. So they are exigent to develop economy. Because their own technology is oppositely backward and the labor cost is cheap, they are urgent to introduce the advanced technology and equipment from the developed countries, and pursue extensive international cooperation. Hence the economy globalization is the consequent trend of the global economic development, and is developed swift. The challenges and chances brought by the trend to the developing countries are unprecedented. As an important component of the world economy the condition faced by the developing countries in the plastic industry and the plastics processing industry is the same.

In the developed countries the plastic application and the development of the plastics processing industry is more early so their relevant technologies are more mature and advanced. Whereas in developing countries more and more capacious markets are provided for the plastics processing industry with the spreading of the plastic application day by day. Meanwhile requirements to the plastics processing technology are also improved day by day. Thus wide chances are offered to the cooperation between the developing countries and the enterprises of the developed countries objectively. So on one side new competition and impulsion are brought to the plastics processing industry in developing countries and districts, on the other side new motivity is also brought to advance the development and improve the integral level in plastics processing technology.

In Brazil more and more cisterns made up of cement filled with asbestos using in civil residences and buildings were replaced by plastic cisterns made up of HDPE in recent several years. This may be the biggest new use of polyethylene in the world, which attracts many companies to pay close attention to. In many districts of China it has been regulated to replace the metal pipe by plastic pipe in the civil and commercial building step by step. The market also attracts more and more plastic factories and relevant equipment factories at home and abroad to participate at present.

2.2. The effect of the development in internet

Recently more and more people felt impulsion and chance brought by the information technology with the rapid development of the computer, especially the Internet technology. A lot of information including various technologies, market information can be transmitted and shared in the Internet. Thus it offers many developing countries an equal market opportunity with developed countries to a great degree. Meanwhile more extensive competition is confronted to the enterprises in the developing countries. For example, the enterprises in the developing countries can not only grasp the developments of related industry in the Internet but also choose suitable cooperative partner because many advanced companies have introduced their professional conditions in the Internet. Moreover they can open up their own market in the Internet.

It makes division of labor and cooperation with others convenient for the enterprises in different countries and districts because the information documents including the technical drawings and the product shape can be transmitted and shared in the Internet. Such as, the consumers of plastic products can sent their requirements of the products and the data of the products' geometric figures to the manufacturer. After receiving these data the manufacturer draws up technologic demands according to his equipment and poses some requirements to the mould, then sent the data to the mould designer in the Internet. The mould designer directly designs the required mould in computer in line with the data, and analyzes and perfects it with corresponding software, then sent the relative drawings to the manufacturer in the internet. Finally the manufacturer analyzes the receiving data on mould shape in computer and determines the processing technology. Any problems, which emerge in all links of the whole process and need consultation, including drafting price, modifying program etc, can be resolved through the Internet.

3. The exploration on the developmental prospect and strategy of the plastics processing in the developing countries in the future

From the above analysis we can see, although the development of the plastics processing industry in the developing countries is comparatively backward and faces great challenge at present, it is full of extremely big chance at the same time and has fairly extensive development space and good market prospect. The hinge is how to adopt correct developmental strategy and guiding ideology to bring their superiority into full play in the future, and catch up with the level of the developed countries.

3.1 Directly introducing the advanced technology of the developed countries

According to the statistics of *the investment report in 1997* of UN, at present there are more than 70 percent patents and other technology transfers controlled by transnational corporations with the developed countries at the core. Whereas the industry base of the developing countries is still weak and the technology of the plastics processing is relatively laggard. Under the conditions it is the most effective method to directly introduce the technology from the developed countries. It is also a most direct way to improve the processing level by digesting and absorbing. However thinking over their own benefit the developed countries don't offer the latest technology, or though the technology is the latest it needs generous manpower and material resources to digest and absorb. Hence there always exists disparity between the developing countries and the developed countries if relying on the method.

For China as an example, it is always introducing plastic processing equipment and technology from the developed countries, and develops very quickly. Util 1996 its output of the plastic products had stepped into the second place in the world. The consumption of the plastic and rubber machines even ranked first in the world. But China still imports 5 ~ 6 million tons of plastic materials and US$ 130 to 200 million of plastic machines annually at present. Compared with the developed countries the quality of the plastic and the plastic machines produced by China is lower, and the variety standards ad types aren't complete. It has been estimated to spend 10 to 15 years to keep pace with the technologic level of the developed countries 20 years before. But up to now the difference hasn't reduced and even has the trend to amplify. The developing countries have to pay significant attention to the situation.

3.2 Absorbing the direct investment of the international capital

The scale of the transnational investment is bigger and bigger in the process of economy globalization. So it can not only decrease the excessive impulsion to the relevant industry market of their own countries by absorbing the direct investment of the international capital, especially that of the transnational corporations with strength of the same industry. But also it can make full use of the abundant fund to carry on technology innovation and creation, and to open up the international market.

While introducing the international capital, the developing countries should firstly combine the requirements of their own development to evaluate and select several technology fields to throw into with breakthrough, and form the position with unique technology and absolute superiority in the world. Such as for the developing countries, which take agriculture as dominant factor, they can center on the agriculture and field film to make all-round series programming and research, and form a large-scale manufacture. For the countries with numerous population and poor resources they can centralized exploring the technologies of plastic building materials and simple and easy plastic dwellings.

It should be noticed to effectively administer the quality of the direct investment of the international capital to avoid the impulsion to the economy security of their own countries, and to prevent the economic retrogress controlled by the international idle fund just like the southeast Asia financial crisis.

3.3 Encouraging innovation and pursuing the leaping development in technology

One advantage brought by the economy globalization to mankind is decreasing price due to international communication and competition and liberating the labor force. How to build their own knowledge innovation system and accelerate the escalation of industrial structure as faster as possible in the developing countries is the most essential outlet for them to seek long-term development and avoid the developed countries to excessively monopolize technology.

In this aspect, scientists of China adopted surpassing thought to invent the plastics electromagnetic dynamic moulding processing technology, finally obtained the surpassing development. This is a successful instance. For a long time past, the basic principle of the plastics moulding processing is that the plastic is softened and melt depending on common actions of externally heating and shear heat of machines, then is passed through the mould with certain shape to cool and mould. Its driving, gearing, heating and cooling devices exist respectively. Therefor the traditional plastics processing equipment possesses some shortcomings such as big volume and weight, high energy consumption, high noise and shallow area for suitable materials. In 1989 scientists of China abandoned the customary thought of ameliorating original equipment, led the vibration field into the whole process of the plastics moulding processing, and invented initiated plastic electromagnetic plasticating extruder, plastics electromagnetic dynamic injector and plastics electromagnetic dynamic mixing equipment in the world. Compared with the traditional equipment, the new one can save energy by more than 40 percent, reduce volume and weight by about 70 percent, decrease the manufacture cost by 50 ~ 60 percent or so, lower the noise to 70 db. It extremely improved the working environment. At present the plastics electromagnetic moulding technology is still in the lead position in the world. It has acquired its own knowledge property right.

3.4 Paying attention to the continuous development

Primarily the concept of the continuous development is propounded in accordance with the problems caused in the process of the global economic development such as environmental pollution, destruction of the ecological balance, population explosion and resources shortage. In 1987 the world environment and development fund society of UN posed the concept of continuous development in the report of *Our Common Future*, i.e. satisfy the requirements of contemporary, but not threaten the ability to satisfy the peoples' demands. In 1992 the continuous development had struck root in the hearts of the people after the meeting. Up to now it has been the basic motif of development in each country of the world.

There exist serious partialities in the current allotment of the global resources. Although the population of the developed countries only occupies 25 percent their consumed energy, metal, wood and rice relatively occupy 70 percent, 75 percent, 85 percent and 60 percent. More seriously, the developed countries want to divert some industrial with grisly pollution and high energy consumption into the developing countries and districts on purpose in order to protect their own resources and environment.

The developing countries should pay attention to continuously develop while programming and developing the plastics industry and the plastics processing industry. That is because most of plastics come from petroleum which storage is limited in the world, and it will engender great environmental pollution due to the petroleum resins' antidegradation. It should be the task attached importance to by the developing countries how to effectively deal with and reclaim the waste plastics, and to explore the degradable plastic varieties.

The Role and Position of Rare Metal Materials in Developmetnt of Modern Mankind Civilization

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Abstact As viewed from a series of unique and valuable preperties of rare metals, a bief account of the role and position of rare metal materials in many sectors of national economy, high technics and defense is gives.

Keywords *Rare metal materials Role Position*

1. Introduction

Rare metals, including more than 50 elements in periodic table of the elements, are usually classified into 6 categories[1] technically according to their physical and chemical properties, existing states, production technology and other charactristics, e.g. light metals, such as Li, Be, etc.; refractory metals, such as Ti, W, Mo, Zr, Hf, Ta, Nb etc.; scattered metals, such as Ga, In, etc.; rare earth metals, such as Y, La, etc.; radioactive metals, such as U, Th, etc. and precious metals, such as Pt, Os, etc.

Being prossessed of many unique and valuable properties, rare metals are now standing at prominent place in the field of materials and thus become a kind of the core materials in many sectors of mational economy. Their important position and wide applications in the modern mankind civilization are shown fully in Fig.1 and Table1. The rare metals, as the materials used on an industrial scale, have more than 50 years long history only, and have been develped rapidly sinece World War II . They are usually taken as important stratigical materials. The development level of the rare metal materials symbolizes the comprehensive development level of science and technology as well as economy for a country.

The rare metal materials are here mainly referred to those which have great application amount, e.g. Ti, W, Mo, Zr, Ta, Nb, Be etc. and their alloys.

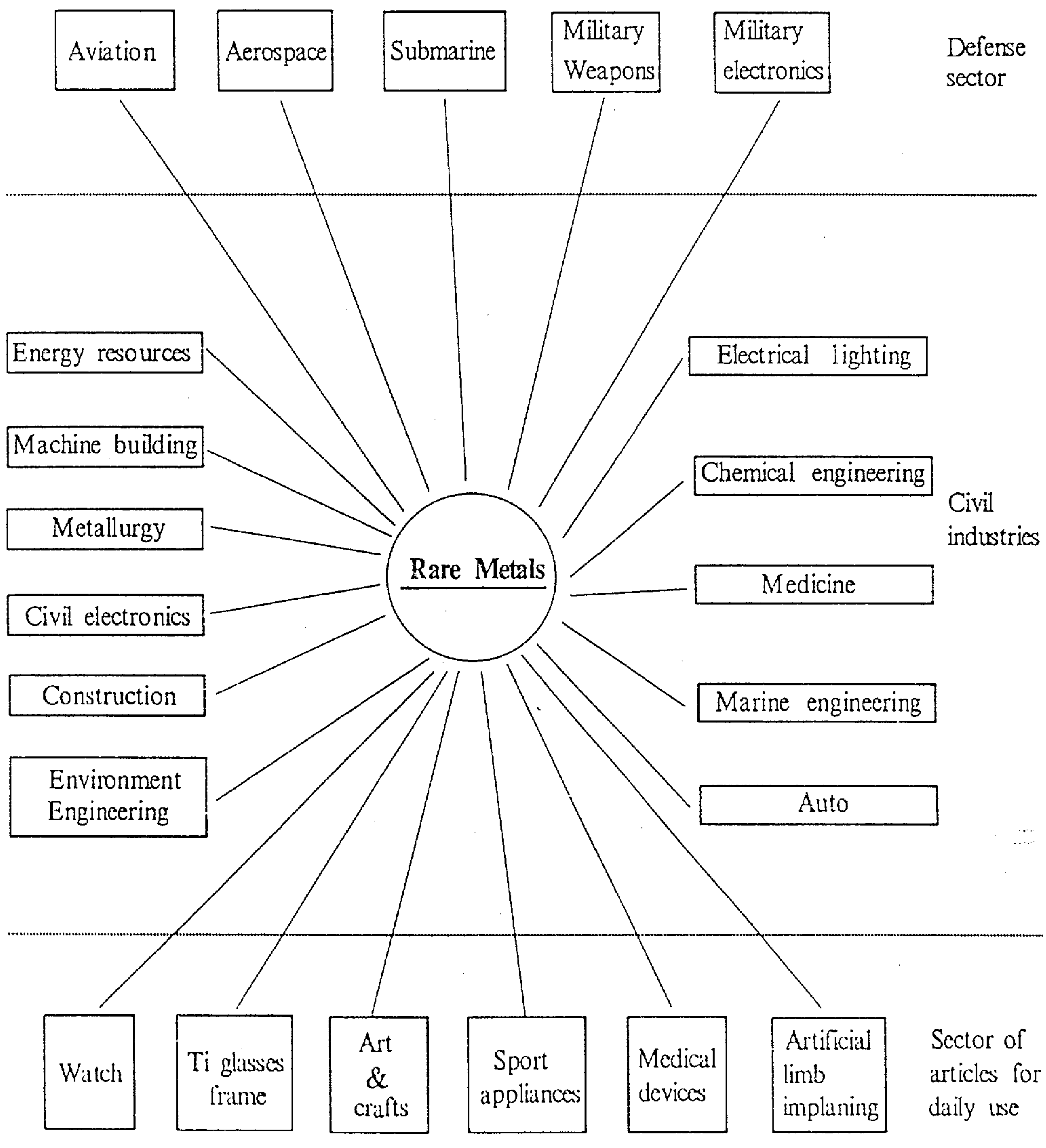

Fig.1 Close relationship between rare metal materials and national economy sectors

Teble. 1 Wide applications of rare metals

Application area	Application objeetive	Applied rare metals and their compounds
Metallurgy	Alloying elements in steel Special alloys Hard metals Cast iron Foundery	V、W、Mo、Nb、Ti、Y、La、Ce Mo、W、V、Ta、Nb、Ti、Zr、Li WC、TiC、TiN、TaC、NbC RE ZrO_2
Chemical Industry	Corrosion resistant materials Catalyst	Ti、Zr、Ta、Nb−Ta alloy RE、V、Mo、SiO_2、Li、Ti、Re、Platinum metals
Electronic industry	Integrated Circuit electronic components Electric vaccum materials	Si、GaAs、W、Mo、Ta、Platinum metals Ta、Nb、Ti、Zr、Sm、Nd、$LiNbO_3$ W、Mo、Zr
Optical, communication industry	Semiconductors, Microcrystal glass, Laser communication system	RE、GaAs、GaInAsP、Ge、SiO_2、ZnSe、ZnTe、CdTe、Te、In、Zr、GaP、InP
Magnetic material	Magnets	Sm、Nd
Energy resources	Electric contacts superconducting materials	W、Mo、RE Be、Zr、Hf、Gd、Si、GaAs、CdTe、Se、Ti−Nb、Nb_3Sn、V_3Ga、RE_2O_3、Ti、RE、Cs
Glass, ceramics	Electrodes	Mo、Se、Te、Zr、RE、Li、ZrO_2、RE_2O_3、Nb_2O_5
Aviation, Aerospace	Materials of air plane rocket, satellite	Ti、Nb、Ta、RE、Platinum metals

2. Rare metal materials have close relationship with civil industies

Owing to a series of unique and valuable properties, rare meal materials become the supporting materials of national economy.

The excellent corrosion resistant properties of many rare metal materials open up their great prospects of wide applications in chemical industry, environment engineering, marine engineering, metallurgical industry, energy engineering and transportaion sector etc. It is reported that the annual loss, caused by corrosion only, reaches 33 billions USD in China. The applications of Ti and its alloy have got active benifits. For example[2], while graphite electrodes are replaced by Ti anodes in 5000 electrolytic tanks in Chinese alkali chrorine industry, the duration of anode servie is increased by 40 times, the annual electric consumption is reduced by 400 millions kwh, and 10,000t/y of graphite are saved. In the marine environment, the corrosion resistance of Ti is much better than those of steel, Al, Cu alloy etc., see Table 2. The submerged depth of the deep submersible vessel made of Ti−6Al−4V can reach 10,000m, which becomes "the pioneer" of mankind ocean−conquering.

Table. 2 Comparision of corrosion resistarce properties of different metal materials in sea water

Metal materials	Ti	Stainless steel	Cu−Ni alloy	Al alloy	Steel
Corrosion resistance to pores	Excellent	poor	Good	Good	Good
corrosion resistance to gaps	Excellent	Good/poor	Excellent/Good	Good	Good
Homogeneity of corrosion resistance	Excellent	Poor/pores Corrosion	Excellent/good	−	poor
Intercrystalline corrosion resistance	Excellent	sensive	Excellent	−	Excellent

The electric and thermal properties of W, Mo, Ta, Nb etc. open up for themselves extensive application ways in electrics. electronics and glass making. Although W wires have been used as buble filaments for 100 years in electric lighting, they are still one sort of inreplaceable materials up to now, and their annual consumption occupies 40% of processed W materials. Replacing of graphite electrodes by Mo electrodes in melting process improves glass quality (transparency) obviously. Ta becomes the key material of electronic industry, 70% ~ 80% of which are used as electric capacitors. High purification of Ta provides the possibility to make capacitors lightened, miniaturized and more reliable, and thus promotes the communication devices, such as movable telephones etc., to be lightened and miniaturized.

Being possessed of superhard and wear-resistant performances of carbides and nitrides of W, Mo, Ti, Ta, Nb etc., they become ideal and main starting materials for producing cutting tools, drills, wear-resistant components, dies and coating layers widely used in machining, metallurgical sectors etc. The annual consumption of W used for producing cemented carbides in the world reaches more than 50% of total output of W. Machining with high speed, high efficiency and high precision in machines building is dependent on developing of new type of cutting tools, which make above-mentioned machining to come true see Fig.2.

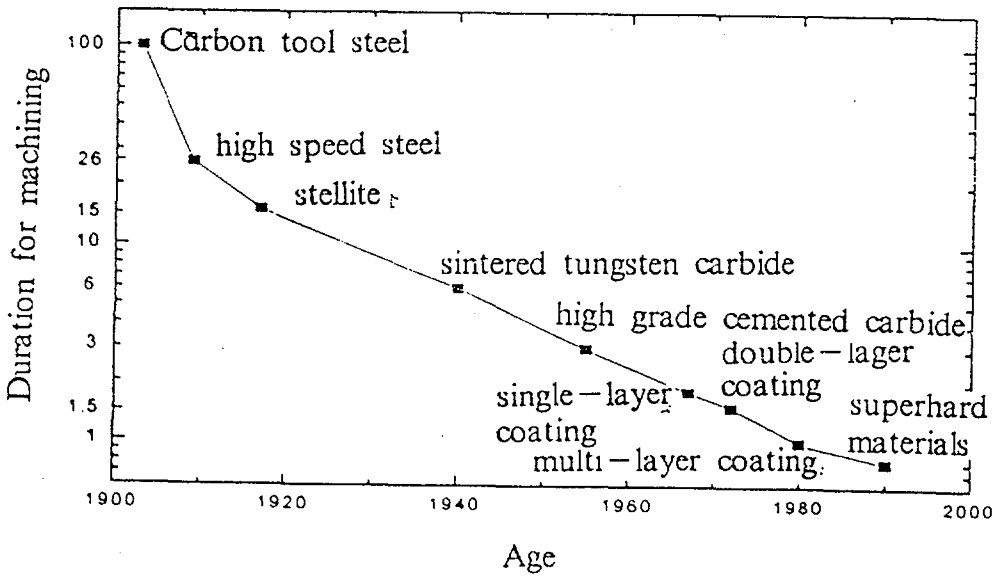

Fig.2 Machining efficiency of different cutting materias and their development in the 20th century

Rare metal materials are going right to the scope of the articles for people's daily use step by step. People's demand for high grade articles of daily use is urgent day by day. More and more increase of Ti-made aiticles for sports and extertainment, such as Ti-made golf heads and poles, bycicles, skis, tools for mountain-climbing etc. is taken as typical examples. The annual consumption of Ti for golf sport reached several thousand tons in the world, the consumption in USA was 1350 tons in 1995, and increased rapidly up to

4000 tons in 1996, which amounted to 18% of annual output of Ti in USA.

3. Rare metal materials are the key materials of modern high tech. development

The modern high technics, such as information, new energy resources, superconducting, space, biological, marine and new materails etc., have much close relationship with rare metal materials. This is because the development of high tech. requires the supports from rare metal materials on one hand, on the other hand, the demands of high tech. drive their own development of rare metal materails.

Information technics is one of the most active technics in the scope of modern high technics, it is based on integrated circuit, which has made great progress since about 1958, especially, since 1978, see Table 3. Component size has been reduced by one million times, and price per bit cut down by one million times since the mid of 1990' s. This is the results of enlarging of monocrystal diameter, reducing of line width and increasing of yield. Followed to come, a series of challenging problems of the materials required for integrated circuit, such as the materials of interconnection, specific resistance layer and superconducting layer etc. Taking the interconnection for example, although aluminium and ploysilicon have been used as the materials of interconnection in integrated circuit for long term, aluminium can be no longer used in microsize components because of appearance of aluminium film degeneration and serious electric leakage etc. owing to sharp incresse of DRAM

Table.3 Devolopment of microelectronic technology and applications of super high pure rare metal materials

Age	1978 ~ 1983	1986 ~ 1993	1996 ~ 2000
Tpye	VLSI	ULSI	ELSI
Integration level	$2^{16} \sim 2^{19}$	$2^{21} \sim 2^{25}$	$2^{26} \sim 2^{29}$
MOS Memory Bit	32KB	1(MB) ~ 16(MB)	64(MB) ~ 256(MB)
Components per chip	65536	2097152	100millions ~ 500
Si chip size (mm)	100 ~ 125	150~ 200	>250
Microprocessing (μm) (Feature size)	3 ~ 2	1.2~ 0.5	0.3 ~ 0.2
Refactory metals and their function		Nb, Ta, Mo, W, Re Interconnections, specific resistant layer, superconducting layer, gate, etc	Nb, Ta, Mo, W, Re Interconnections, specific resistant layer, superconducting layer, gate, etc

density and draft reduction of line width which enters submicrometer size range. The problems mentioned above can be settled by the way that the silicides produced though common sputtering of pure and/or superpure Mo, Ta, Nb, W, Re, etc. with Si are used as the materials of interconnection and MOS gate.

A lot of rare metal materials are now the key materials in atomic industry. Zr, Hf and their alloys are used as the structure materials of fusion reactor, U. Th etc used as fuels, Be and its compounds used as the materails of neutron deceleration and reflecting, Hf, Dy, Sm, Eu, Gd etc and their alloys used as cooling materails. The successful key to a complete fusion reactor is dependent on whether or not the structure materials can be supplied, which are able to endure extremely serious operation environment in reactor. The first wall materials are one of the key materials. Through many years research, refractory metal materials, such as Mo, TZM, Mo$-ZrO_2$, Mo$-$RE etc. have been selected successfully as the component materials used for manufaturing tiles, divertors, limiter elements and inboad cooling supports etc. Fig3 shows the plasma facing(first wall) components in Tokamak JET.

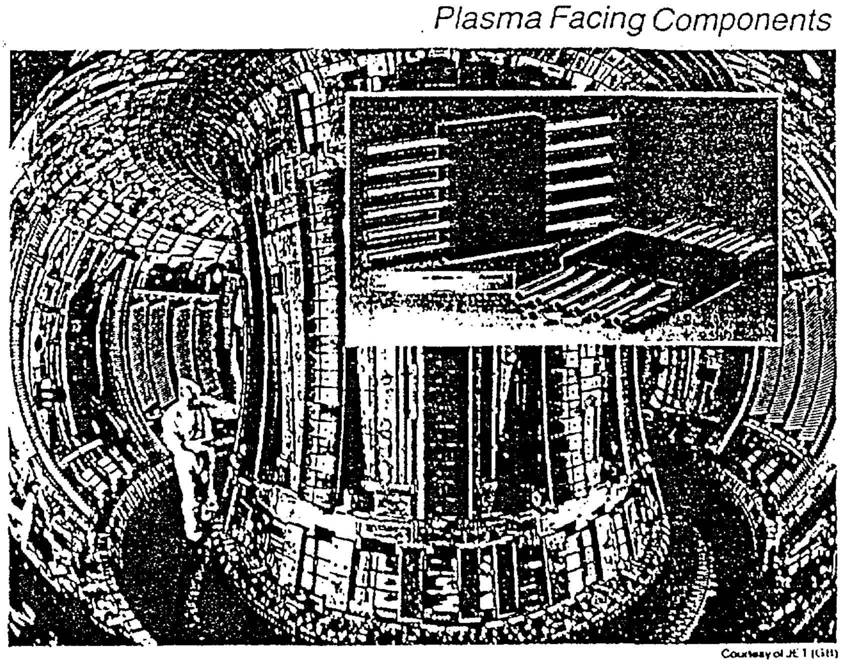

Fig.3 Mo components in nuclear fusion reactor JET(GB)

Superconducting technics attracts close attention of science and engineering community because its progress promotes the great development of a lot of high technics, such as energytechnics, electrotechnics, transportation thchnics, scientific research and medical technics etc. Rar metals, such as Nb, Ti etc. are the main starting materials for Low Tc superconducting materials of NbTi and Nb_3Sn, commercialization of which have come true. They have found successful applications in the fields of superconductive magnets, MRI, microwave resonators, fusion reactor and research for magnetic suspension vehicles. At the present time, superconductive industry market with 2 billions USD per year have already appeared in the world. The main is low Tc superconductive materials market. It is predicted that the superconductive industry market will reach 7.6 billions/year, 37 billions/year and 244 billions/year USD by 2000, 2010 and 2020 respectively[3].

4. Rare metal materials are the strategical materials of defense

The applications of rare metal materials have particularly colse relationship with the development of millitary science and engineering. Modern aviation and aerospace industries can not be developed successfully without rare metal materials. Taking Ti and it alloys for example, they are now the key and supporting materials of advanced aviation and aerospace. It is reported that lowering of petrol consumption is considered as one of the most important goals for modern aircraft engines. The expenss of petrol consumption amounts to 40% in aviation field. About 50% of the efficiency and performance raise of turbine engines is from materials improving. The proportion of the contribution of materials improving to the aircraft performace raise reaches about 2/3. Thorefore, the application of Ti and its alloys in aircrafts building are more and more owing to their high strength－to－weight ratio. The more advanced the airplances, the more the Ti consumption, see Table.4.

Table.4 Consumption comparision of materials for advanced military aircrafts(%)

Type	Design age	Ti Alloy	Structure steel	Al alloy	Composites
CY－27	1969	17	10	60	－
F－14	1969	24	17	39	1
F－15	1972	27	6	36	2
F－16	1976	3	3	64	3.4
F－18	1978	13	8	44	12
F－117	1983	25	5	20	10
F－22	1989	41	5	11	25

Zirconium is usually called "the first metal of atomic age". It is the inreplaceable materials for developing of nuclear power submarines, 80% of processed Zr materials are used as fuel clad, vessel pipes, pressure tubes, grills, plugers and structure materials in muclear power reactors, see Table 5.

Table 5. Application of Zr alloys in some typical nuclear reactors

Reator type	Fuel	Coolants	fuel clad materials	Max. operation temperature
PWR	UO_2	H_2O	Zr−4 alloy	593
BWR	UO_2	H_2O	Zr−2 alloy	558
CANDU	Matural UO_2	H_2O	Zr−4 alloy	578
			Zr−2.5 Nb alloy (for pressure tubes)	
BBЭP	UO_2	H_2O	Zr−1 alloy	

Be is called "the metal of nuclear age" and used for manufacturing of precious gyroscopes in navigation system, and beconses the neccessary material for producing of nuclear weapons owing to Be playing key role in enhancing the explosive anipersonnel power of nuclear weapons.

W heary alloy is one of optimun materials for armour−piercing bullets in moldern millitary weapons.

5. summary

Being possessed of a series of unique properties, rare metal materials find extensive applications in many sectors of national economy, high technics and defense, become their key and supporting materias and/or strategical materials, and play great role in the development of modern mankind civilization. Their developing level symbolizes the comprehensive actual strength of a country. Therefore, the development prospect of rare matal materials is bright.

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China's Cement Industry — Present State and Strategy of Development

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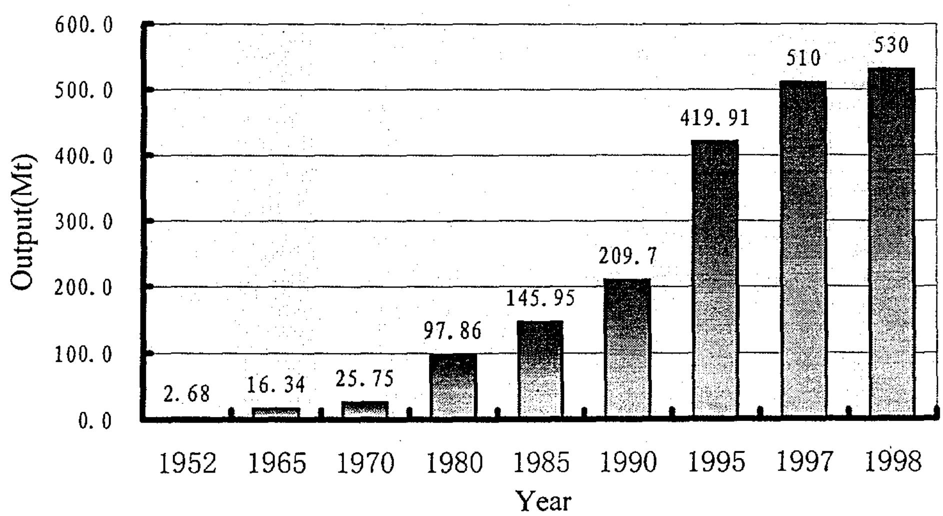
The history of China's cement industry can be traced back to 1889 when the China's first cement plant was built in Tangshan, Hebei province. The rapid development of the cement industry has been seen for the past 40 years. Now, China's cement industry is the largest in the world. In 1998, the annual cement production reached as high as 530Mt, about 1/3 of the world total output. However, China's cement industry is characterized as one of the worst in China for its high energy consumption, low efficiency and serious environment pollution. This paper will provide information about the present state and the strategy of development of China's cement industry.

1. Present situation

1.1 Cement production and quality

According to the statistics, the production of cement in China has grown at an average rate of 15% since 1950. The output of cement in 1997 reached 510 Mt and 530 Mt in 1998 (see Figure 1). However, 80% of the total comes from vertical shaft kilns, only 20% from rotary kilns among which about 35% is produced by new-dry process. The quality of China's cement is generally low, only 10% of the cement is 525# or higher grade, 60% of 425#. It should be mentioned here that the strength grade of cement may be one grade lower if ISO standards are adopted because of a lower w/c ratio specified in the Chinese standards. At present, there are 8435 cement plants with 2.55 million workers. The average capacity is only 60,000 t, about 1/10 of advanced countries. It can be seen that the development of China's cement industry is therefore in the form of quantity expansion, as characterized by such a small capacity and large quantity of the low-grade cement.



The production of China's cement industry

1.2 Cement varieties

In China, the varieties of cement are normally classified into two major groups, ordinary cement and special cement. There are six types of ordinary cements and more than 60 special cements falling into six series according to the main composition. The six ordinary cements are Portland cement, ordinary Portland cement, Portland-blastfurnace slag cement, Portland-flyash cement and composite Portland cement, which amount to 98% of the total cement production. The six series of special cements are silicate cement, aluminate cement, sulphoaluminate cement, fluoaluminate cement, aluminoferrite cement and other cements. According to the function and performance, the special cement can be divided into seven categories: rapid hardening cement, dam cement, oil well cement, expansive cement, decorative cement, high-temperature cement and other cements. However, the production of the special cement only takes 2% shares of the total in comparison with 5-10% for some developed countries.

1.3 Technology and equipment

As economically underdeveloped and a vast territory, China has developed a large amount of small cement plants that are dispersed in small towns and countryside with outdated technology and equipment. Various process technologies, such as shaft kiln, wet kiln and new-dry process can also be seen in China. However, about 90% are shaft kiln or outdated rotary kiln process. There is no doubt that there is a big gap between China's cement industry and that of developed countries.

1.4 Fundamental research

Researches on cement materials in China is however fruitful. In the aspect of clinker physical-chemistry, the phase diagrams between CaO, Al_2O_3, Fe_2O_3, SiO_2, MgO, $CaSO_4$, CaF_2 have been partially established. The mechanisms of mineralization of composite mineralizer have been thoroughly studied. Researches on chemical stability of pure clinker minerals, mineral formation process, crystal structure, hydration mechanisms and hydrates are well advanced. The achievements have played an important role in developing all types of Chinese special cements. For example, studies on formation and function of hydrate ettringite have guided the development of various expansive cements, some of which have been exported to countries of European, Asia and Africa.

1.5 Standards and testing

Chinese government has attached great importance to cement standards and quality supervision. There are 97 relevant standards ranging from composition, products, to testing methods and equipment, to meet the requirements of production, quality control, transportation, application and trade. However, the Chinese standards are different in many respects from ISO standards, which has made difficult for the import and export of cement product and technology. The Chinese government has decided to adopt ISO standards. A new cement standard, GB/T1767-1999, will be effectively based on ISO679. Similar work is underway to revise cement product standards GB175, GB1344, GB12958.

In 1987, China set up a national center for quality supervision and test of cement at China

Building Materials Academy (CBMA), the largest and comprehensive research institute in China in the fields of building materials and inorganic non-metallic materials. CBMA was established in early 1950's. It now employs 930 scientists and engineers, among them, there are two academicians of China Engineering Academy, 36 professors, and 285 senior reserachers. The main objectives and functions of the center are:

- quality surveying of state key cement enterprises;
- regular and irregular national examination of cement product;
- issuing of certification of quality product and of production license, international comparative test;
- arbitration of quality dispute;
- quality control of cement products for state key project such as Three Gorge dam, and
- formulating and revising national standards for cement and testing equipment.

Apart from the national center, there are provincial and local centers as well as enterprise's self-examination, forming a national network of quality supervision.

The national center has laboratories of $1614m^2$, equipped with advanced research instruments. It is a national center of cement science and technology and has successfully organized four international conferences on cement and concrete from 1985 to 1998. The center has a close academic connection and exchange with research institutes of America, German, France, Britain, Japan, Canada, India etc. It has taken part for more than ten years in comparative testing activities organized by a French cementitious materials center. There is a key laboratory of cementitious materials supported by the State Building Materials Bureau. There are also other three national surveying and testing centers in CBMA.

2. Strategy of development

2.1 New technology and modern production line

A steady growth in cement demand can be expected due to a national development program of infrastructure such as highway, high-speed railway, underground tube, hydraulic engineering, port, dam, river bank, residential and public buildings. It is predicted that the demand for cement in 2010 will be increased to 800Mt. However, cement production dominated by the backward shaft kiln techniques will bring about serious problems in energy and resources consuming and environment pollution as well as low quality. The Chinese government has decided to make great effort to develop new dry-process of precalcining kiln, high efficient grinding techniques and dust collecting equipment; to build large- or medium-sized plants with a capacity of over 1000 t/d; to eliminate the backward mini shaft kilns. It is the government decision to reduce 100Mt shaft kiln cement by the end of 2000.

2.2 Strengthening fundamental research to develop composite cement

One of the key projects of fundamental researches is to make use of industrial wastes such as blast-furnace slag, flyash, coal spoil in cement as main or important ingredients. This requires deep understanding of the relationship between composition, structure and potential activity of these materials. A new generation composite cement will be made from cement clinker together with the processed mineral materials, with high performance not only in strength but also durability. In this way, the demand for the amount of cement clinker will be greatly reduced, which in turn will contribute greatly to the saving of energy and mineral resources and the reduction of environment pollution in cement production.

2.3 Developing new quality control system

The Chinese government has decided that by the end of 2000, a new national standard for normal cement (as mentioned previously) will replace the present one. CBMA has completed a four-year research project on the required new testing method, equipment and standard materials including a comparative study with relevant German and French institutes. The training work for the implementation of the new national standard has started and all the test equipment associated with the present standard should be replaced. It is our sincere hope that United Nations Industry Development Organization (UNIDO) and International Materials Assessment and Application Center (IMAAC) will provide guidance and help for this important work.

It is believed that with the development of new technology, new cement materials and new national standard and quality supervision system, China's cement quality will be significantly enhanced. By 2010, it will be seen that the need for cement clinker may be reduced to about 300Mt and there will be a great improvement on energy saving and environmental protection.

CORROSION SCIENCE, CORROSION ENGINEERING, AND SUSTAINABLE DEVELOPMENT

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The Chinese Academy of Sciences

Corrosion charge about 4% of nations' gross national product. Approximately, the thirty-percent steel produced in every year was thoroughly corroded and corrosion damage is five times damage by natural disaster. The natural environment was contaminated by corrosion failure and corrosion prevention methods. The energy consumption also increases by corrosive products' deposit. Obviously, corrosion affects the safety, integrity and reliability of components and structures. Therefore, Corrosion affects sustainable development.

Corrosion is an undiminishing problem. Each epoch has its new technologies and new corrosion problems. Environment, safety and reliability of equipment and structure are major public concerns since it has strong relation with sustainable development. More attention in the three aspects, corrosion science, corrosion control and corrosion management, in the 21st century, especially for the developing countries, should be paid to as followings.

For corrosion science, the topics about interaction between mechanical and corrosive environment, electrochemical reaction kinetics (steps), surface film behavior, corrosion products and their evolvement, to relate the lab testing results with practice, etc., should be consider as main problems.

As for corrosion control, pollution free paints, coatings and inhibitors, surveillance in various industries, and new materials development and surface modification technology for advanced technique should be pay much attention to. For the disposal of organic waste, supercritical water oxidation system is an emerging technology, or say, most effective method. However, the environment also is extremely severe for reactor material. Corrosion rate is very high and cracking happens sometimes which has been restricting the technical application. In radioactive waste processing, the aim is to guarantee corrosion protection for about 1000 years, not like general technical plants and equipment in the span of 5-30 years,

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at most 100 years sometimes. Many effective inhibitors, like lead pigments, chromate pigments, are toxic. Although researchers in many countries have made many intensive researches in past 20 years, there are no entirely satisfactory replacements for either red lead or chromates. Many traditional solvent components of paints also are unacceptable. Therefore, the research for effective and economic alternatives continues and is research priority since non-toxic inhibitor and solvent become public concern. In other word, to develop pollution free paints, coatings and inhibitors is required.

About 40% of all failures were the result of human error. Corrosion problems can be worsened by inadequacies in human performance. The "people factor" should be reduced by corrosion management. In other word, corrosion management mainly focuses on the people although it accounts for the complex interactions between materials, environments, and people. Steel using increase very rapidly in Far East and China. Ten million tons steel was corroded thoroughly in China every year. In this sense, support services in the fields of information systems or knowledge based systems, data banks, and training or continuing education are extremely important and of great benefit to corrosion problems solving. Technology transfer also is expected since in developing countries, there are a large number of small and medium enterprises that have fewer resources for solving corrosion problems.

Corrosion problems in next century, especially for the developing countries, should be as follows:

1. Corrosion of infrastructure
2. Corrosion in energy industry
3. Corrosion in advanced technique, for example, microelectronics and biotechnology
4. Corrosion in disposal of waste, such as radioactive waste and organic waste
5. Corrosion surveillance in industry
6. To relate the lab testing results with practice
7. Pollution free paints, coatings and inhibitors
8. Training & knowledge based system

As an example, corrosion of infrastructure is called "one of the most evident modern corrosion disaster". Bridges, roadbeds, overpasses in city, particularly in the snow belt where the use of road de-icing salts have most obvious problems. Corrosion of reinforcing steel in all concrete structures was revealed dramatically.

The progress at corrosion science, corrosion control and corrosion management in China, particularly in Institute of Corrosion and Protection of Metals (ICPM), were reviewed. At last, to develop a "International Corrosion and Protection Center" in ICPM under UNIDO or IMAAC is proposed.

ASSESSMENT AND APPLICATION OF POWDER METALLURGY MATERIALS IN DEVELOPING COUNTRIES

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Abstract The current progress of powder metallurgy (P/M) industry in the developing countries and the distance in P/M between these countries and the developed countries were discussed. The new techniques in the P/M field were also reviewed. Taking China as an example, the application of some advanced P/M techniques in the developing countries were analyzed. In light of these analyses and according to the developing trend of P/M in the coming 21st century, the strategies for these countries to enhance their P/M industry were proposed.

With little or no machining, powder metallurgy (P/M) is an effective material processing technique characterized by its near net shaping capacity. The distinctive advantage of this technique is its capability to effectively utilize resources with little material wasting, less energy consumption and slight negative impact on the environment. For example, compared with the conventional techniques, through P/M can be saved approximately 50 percent of energy and 40 percent of raw materials. For these advantages, P/M has been gaining more and more importance with the increasing shortage of natural resources as well as the increasingly serious environmental issues. At the same time, with the recent development, P/M has become an effective processing technique for producing metal-ceramic and metal-polymer composites. In this way various high performance structural materials, special functional materials, and the materials for extreme application conditions can be produced. Therefore the application of P/M has been greatly expanded into various area, such as machinery making, electronic, chemical, energy, aerospace, agriculture, food and medicine industries. By far P/M technology has created a large amount of social wealth as well as economic benefits.

The developed countries have been consistently paying attention to the development of P/M materials. With the progress of new P/M techniques and the improvement of the product quality, the P/M market share has been increased remarkably expanded and the variety of P/M products has been greatly expanded. At the same time, in developing countries, the development of P/M materials has also been greatly enhanced, especially with the progress of automotive industries in these countries. However, there is still a considerable distance between the developed and the developing countries concerning the varieties and qualities of the P/M products. The conditions of the P/M industries in the developing countries will be discussed in detail as below.

1. Introduction to the worldwide P/M product market

The total amount of the P/M production of the major developing countries and areas in Asia and Oceania from 1995 to 1997 was listed in Table 1. Under the impact of the Asian economic crisis, the sales of most of the major Asian P/M industries decreased in 1997 with the exception of Singapore and Taiwan. The statistic data in the early 1998 showed that the Asian P/M market has been recovering slowly with a slight increase, mainly in Taiwan province, China, and India. In China, the P/M production in 1997 was 16,495 tons, decreased 2% compared to that of 1996. Among the various products, Cu based products suffered the most serious decrease, which amounted to -32.6%, while Fe based products increased by 2.3%, totally 15,092 tons. According to the government statistic data, now there are 250 P/M enterprises in China, and most of them have annual sales below one million dollars.

The statistic data of the powder shipment of developed countries in 1996 and 1997 were listed in Table 2. Comparing Table 1 with Table 2, it can be seen that there is still a large distance between the developed and developing countries.

The distribution and the constitution of the P/M products in the developing countries and regions in 1997 is showed in Table 3. As we can see, the P/M products consumed in the automotive industry took up a considerable share in the market, but still relatively smaller compared with the developed countries (as shown in Table 4). In China, the major markets of the P/M products include the automotive industry, household electric appliances (such as the washing machines, air conditioners, and the refrigerator compressors) and agriculture. Now the automotive industry in China is developing steadily, the cooperation between the native enterprises and the overseas industries (for example, the General Motors, Chrysler, Citroen and Honda, etc.) has brought about a 13% annual increase in the automobile production. It can be predicted that by the year 2000, the annual automobile output will be approximately 3 million ones per year. At the same time, powder metallurgy components in each automobile will be increased from 3kg in 1996 to approximately 6kg by 2000. Hence, P/M industry in China as well as in other developing countries has a promising prospect.

2. Recent development in new powder metallurgy technique

In recent years, many new P/M techniques have been developed. Among these techniques the most representative is the Near Net Shape Process techniques (NNSP), including Metal Powder Injection Molding (MIM), Powder Extrusion Forming, Warm Compaction, Semi-Solid State Processing, Powder Thermal Forging, and Hot Isostatic Pressing (HIP). It is the introduction of these new techniques that the P/M now is really developing into a low-cost, high performance, multi-functional technique and gains great advantage over the traditional processing methods, such as casting and machining. Now P/M has aimed at products with a full density, high performance, high shape and size tolerance, more complex shapes, larger production scale and increasing variety. For developing countries, especially those with relatively few natural resources and more serious environment pollution, it is advisable to pay more attention to the development and application of these new techniques. Below we will discuss the current conditions of the P/M development, and its application in the developing countries with a special emphasis on China.

2.1 Techniques for powder fabrication

Powder fabrication is the first step of the P/M process. The properties of the powder can greatly influence the performance of the final P/M products. In addition, the powder itself can be the end product, which will be used as the additives or catalysts in chemical engineering, hot spray powder, brazing powder or solid propulsion fuel in aerospace industry, or abrasives in the precise machining and optical instrument manufacturing industries. The increasing demand for the powder quality has called for a variety of new techniques for powder fabrication. Rapid solidification, atomization, mechanical alloying, and chemical techniques for producing nano-powder represent the new frontier of the P/M technique development.

The atomization process is to shatter metal/alloy melts by gas/water stream to make metal powders. This technique can produce various metal or alloy powders with excellent quality by which P/M components with a high strength, high density, and high shape and size precision can be produced. Currently, the global production of atomized metal and alloy powders exceeds 300 thousand tons per year. The major atomized powder producing corporations include Osprey Metal Ltd. in Britain, Pyron Corp. in the United States, the Hoeganaes in Sweden and Pacific Metal Corp. in Japan.

The developing countries are well behind the developed countries both in the research area of powder fabrication techniques and the industrial application of the existent techniques. Taking the iron and steel P/M industries in China as an example, in the late 1980s when the economy of China developed very fast, the rapid growth of the automotive industry greatly stimulated the development of the iron and steel P/M industry. A large amount of money had been put up by the Chinese government to a series of large plants for reducing or water atomizing iron powder in Wuhan and Anshan. As a result, the production capability of iron and steel powder was increased to several ten thousand tons per year. However, there are a lot of problems concerning the powder quantity, variety, and quality. Firstly, the serious conflict between the supply and the demand, especially the insufficient supply of high quality powders, has greatly hindered the production of high-quality P/M parts in large scale. Secondly, manufacturing facilities in some P/M plants are far from modernized, which has considerable negative influence on the development of the P/M industry in China. Thirdly, the varieties of P/M parts are still by no means adequate. Some kinds of P/M parts still rely on importing from abroad. Therefore, how to build up a modernized large-scale industrial manufacturing system and how to develop the atomization technique are now real challenges for the powder metallurgist and entrepreneurs in China.

2.2 Metal Powder Injection Molding (MIM)

Metal Powder Injection Molding Process is a new Near Net Shape Process, which is quite similar to the injection molding process now widely used in the plastic industry. The technological process is illustrated in Fig.1. Firstly, the fine metal powders were blended with organic adhesives, then the mixture was pelletized and injected. Finally, the green compacts are degreased, and sintered to the final products.

As a Near Net Shape Process, MIM technique has unparalleled advantages over the conventional P/M forming techniques and machining as below. (1) It can near-net shape P/M parts with complicated structure characteristics, such as the outer grooves, external thread, conical outer surface, cross aperture, etc., hence eliminating the necessity of further machining. (2) Since very fine powder was used, even under ordinary solid phase sintering conditions, MIM parts with a density over 95%, refined and homogeneous microstructures and high performance can be produced easily. (3) The injection molding equipment is relatively cheaper, easier to control and easier to be automated than the conventional automatic die press, and the injection molds can be used for a longer period. (4) The energy and material consumption is reduced, because the injection materials can be repeatedly used, and the material utilization rate can be close to 100%. (5) It is applicable to large-scale massive production. The MIM products include stainless steel watch wrist buckles, watchcases, and automobile transmitting parts, etc. Several products are shown in Fig.2.

Currently there are about 120 enterprises conducting MIM P/M parts production, about 20 of them are located in Europe, 50 in North America, 50 in Asia (mostly in Japan). The global sales amount to approximately 4 hundred million dollars, half of the sales are conducted in North America, 1.6 hundred million in Asia, 0.4 hundred million in Europe, and the global sales are increasing at a rate of about 20~30% each year. China conducted it own MIM research in the 1980s, now more than ten research units are doing extensive work in this field. The products include Fe/Ni alloys, stainless steels, heavy alloys, cemented carbide, and ceramics etc. However, compared with other developed countries, the research conditions are quite backward. The most remarkable problem is that our research is still in the preliminary small-scale or laboratory stage, which is now seriously restricting the expanding of the application field.

2.3 Warm Compaction Technique

Warm compaction is a low-cost technique utilizing single-step press/sinter process. The principle of this technique is illustrated in Fig.3. Firstly, the raw powders and high-temperature polymer lubricants (0.6wt% or so) are blended. The blend is heated to 140 °C or so in a specially designed heater and then sent to a mold through flexible pipes and feed shoes for pressing. The flexible pipes, feed shoes, and molds are all heated and thermally insulated. Through one step warm compaction, the green density of Fe based parts can reach 7.3~7.5g/cm^3, and the final sintering density can reach 7.5g/cm^3. The obvious advantages of warm compaction technique include (1) The increased green compacts density, ordinarily 0.1~0.25g/cm^3 higher than that of the compacts under conventional cold pressing. The increased compact density leads to an increased compact strength. In some cases the compacts can undergo direct machining. (2) The ejection pressure and pressing pressure are reduced, hence the life cycles of molds are increased and cost is saved. (3) The final sintering parts have a higher density and better performance. Compared with the conventional P/M materials, the tensile strength, elongation, and impact toughness of the P/M parts produced through warm compaction are much higher. When the warm compaction technique is combined with double press/ double sinter technique, the final density of P/M parts can be further increased.

The operating cost of warm compaction is a little higher than that of the ordinary pressing/sintering technique, but is 15~25% lower than that of the double press, double sinter technique. Moreover, it is easier to control the shape and size of the final products by using warm compaction. Therefore, as a new technique, the warm compaction is quite promising to attain the industrial sized application. Currently, seven to eight P/M corporations have produced P/M parts with various shapes and weights by applying the warm compaction. Hoeganaes and Cincinnati Inc. are representatives of these corporations. Among all these products the most remarkable is the successful production of the 1.2 ton torque converter hubs in Ford's rear-wheel-drive E40D truck transmissions. In China, the research on the warm compaction and related techniques has not been completely carried out as yet. However, because of the rapid growth of the automotive industry, the demand for Fe based P/M parts will be steadily increasing. There is no doubt that the development of the warm compaction and related techniques will greatly precipitate the growth of the related industry in China.

2.4 Hot Isostatic Pressing (HIP)

Hot Isostatic Pressing is an important technique for producing P/M material. Now it is extensively used to near net shape P/M parts, cemented carbides, ceramics and intermetallic alloys. Combined with other related techniques, HIP can be used to make high performance P/M superalloys, P/M high-speed steels, and tool steels. Currently HIP technique has been fully developed, and based on its principle, several quasi-isostatic pressing techniques are developed, which can be conducted with much simple equipment and produce large isotropic materials with high productivity.

In recent years, as the HIP technique gets more and more sophisticated, its practical applications are also expanded, especially in the tool steel and superalloy fields. The annual expanding rate of North American tool steel market is approximately 10% and it is estimated that the United States has a market size of 4,500 tons or so. The Ni-Co based superalloy market is steadily increasing due to the demand of new jet engines such as the GE90, which was used in Boeing and Airbus airplanes. In China the research and application of HIP as well as quasi-HIP techniques have attained a considerable scale, but still have some problems such as the aging of the equipment and its limited application.

2.5 Powder Forging (PF)

It has been more than 30 years since the Powder Forging was first introduced as a new P/M technique. When compared with the traditional P/M, through PF can be attained a higher density, higher strength and higher processing precision. When compared with cold forging or precise forging, the PF has the advantage of higher material utilization rate, without the necessity of machining, and may be superior to invest casting in strength and automating possibility.

Currently some developed countries have already had their Powder Forging standards for approximately 100 kinds of structural parts. The typical PF parts are connecting rods, clutch gears and synchronizer gears. The world's major automotive corporations such as the General Motor, Ford, Toyota, and Volkswagen have already begun to produce connecting rods by PF technique. With the excellent application prospect and potentially large market, it is estimated the PF will be a new industrial sized applicable technique following the traditional P/M techniques. In China, the PF technique is also well behind that in the developed countries. Problems include small production scale, limited productivity, few varieties and under-developed production techniques

2.6 Powder Extrusion Forming Technique

Now the Powder Extrusion Forming Technique has been one of the most important processing methods for producing cemented carbide, heavy alloy and other important metal or alloy pipes, bars and special cross section materials. The basic technology of Powder Extrusion Forming is illustrated in Fig.3. This technique possesses several advantages: (1) This technique can process some metals or alloys that are hard to produce by using casting and machining. (2) Materials processed by extrusion usually possess more homogeneous microstructures with little or no segregation, therefore the mechanical properties are improved. (3) Powder Extrusion can produce composites homogeneously dispersed by a second phases without much difficulty. (4) In some special cases, when Powder Extrusion is used, the subsequent sintering and heat treatment can be saved and the as-extruded compacts can be machined to final products directly, thus the operating cost is lowered. (5) Compared with the extrusion of ingots, the extrusion of metal powders requires less equipment capacity, reduced extrusion temperatures and less energy consumption.

In recent years, with the great improvement in the extrusion automation and the controlling precision, the Powder Extrusion Forming Technique has made great advances. Now the metal bars with a diameter of 0.5~32mm, metal pipes with a wall thickness less than 0.3mm can be directly extrusion formed, ceramic parts with a honeycomb cellular cross-section structure can also be extruded in various shapes and sizes. It is reported that the Konard Friedrichs Corp. in Germany now can produce 32mm diameter cemented carbide extruded bars with three big coolant outlets. Its products include complicated parts used in electronic industry such as the printer heaters, automobile connecting rods and tail gas purifier etc, as shown in Fig.4. In this field, China has obviously lagged behind the developed countries in the world. As of now, we have not produced cemented carbide bars with large diameters, and in the composition design and elimination process of adhesives there are still some problems.

There are some other new P/M techniques, such as the spray deposition, spark sintering, microwave sintering and self-propagating high temperature synthesis, etc. They will be discussed elsewhere.

3 Strategies for the future development of powder metallurgy in developing countries

From the above discussion we can see, the P/M industry now is playing a very important role in the entire national economy. The developing countries have made considerable achievements in building up their own powder metallurgy industries, but they still lagged well behind the world's developed industrial countries both in overall developing level and in a series of branching fields. With the 21st century coming up, these countries should fully understand their standings in the world, take up all possible opportunities to develop their powder metallurgy industries, try to keep up with the developing trend in this remarkable area.

3.1 Strengthening cooperation and communication between developing countries

Each developing country has its own development advantages regarding resources, techniques, and labor markets. Obviously if these countries intensify their cooperation and communication with each other, they will have much greater development opportunities in the P/M field. Extensive cooperation and communication between these countries will definitely elevate the overall developing level of the P/M research and production, strengthen their individual competition capability in the international market.

3.2 Assimilating the advanced techniques from the western countries

Considering the current reality of the relatively backward P/M conditions in the developing countries, we believe that it is important for these countries to make efforts to introduce advanced techniques and equipment from industrialized countries. But first of all, the introduction of foreign equipment and techniques will be accommodated to the current conditions of these countries, meanwhile great emphasis must be placed on the assimilation of these introduced techniques, such as the combined introduction of hardware and software and the subsequent assimilation and absorption. Only in this way can these introduced techniques be turned into permanent productive forces.

3.3 Cooperating between Universities, research institutes and P/M enterprises, accelerating the industrialization of P/M products

As we know, powder metallurgy is not only a new kind of technique, but the integration of multiple disciplines. Any advance in this area requires the combination of advanced techniques, talented personnel, and increasing market. Universities and research institutes and researching institutes have the advantages on the exploration of new techniques, the cooperation of multi-disciplinary and preeminent research staff. They can provide with the scientific research achievements in related field, solve practical problems, and provide qualified personnel for the industries. Meanwhile the industries directly facing the P/M market are more sensitive to the demand and supply information. They are the feedback transmitters for product performance, quality and requirements. The cooperation between the two sides can make up a beneficial circulation of information, precipitate the industrialization of P/M, and help the P/M enterprises to occupy the market so that make much greater social and economic profits.

3.4 Building up applicable research and research achievements transferring departments, setting up corresponding intensified running mechanism

In the current world, the developing trend of powder metallurgy is in the newly established high technology fields, which has been vividly shown in the developed western countries. These countries have made considerable progress in the industrialization of scientific achievements, the strengthening of high-tech applications, and modernization of the enterprise management. While on the other hand, most of the developing countries are still at a relatively backward stage. What make up their current situation are the isolated research units, scattered manufacturing plants, small production scale, low efficiency and weak infrastructure in industries. Redundant production line and equipment introduction and construction as well as excessive production seriously wasted limited natural resources and energy. The number of the valuable research achievements is limited by the poor conditions of the fundamental researches. The lack of testing bases and low productivity transferring rate of research achievements also pose serious problems. To solve all these problems, we must take some basic measures, for example, setting up national key research laboratories, carrying out fundamental theoretical and prospective researches, keeping track of the world's scientific and technological front, building up national engineering research center, carrying out the study on scientific achievements transferring process, building up large united production body or transnational enterprises, carrying out intensified production and management. In addition, we must build up corresponding running mechanism to combine the research institutes, testing bases, and enterprises into a united body, realizing beneficial cooperation and communication. Only in this way can we improve our research achievements and produce much more wealth.

3.5 Developing powder metallurgy high technology

In the last twenty years, new materials, new techniques, processes and new equipment have been keeping emerging in the powder metallurgy field. This trends not only deeply influence the powder metallurgy itself, but also affect some other related technical areas and some influences are so great that a few fundamental changes have taken place. For example, the emerging of the rapid solidification and atomization techniques has made it possible to produce a series of ultra-fine powder, quasi-crystal powder, non-crystalline powder and nano-crystalline powder, then accordingly, a series of materials and products with extraordinary properties have be made. In the same way, new techniques such as Metal Powder Injection Molding technique and semi-solid state processing technique all help to produce many high performance, multifunctional special materials and products. The emerging of all these techniques, materials and products have greatly advanced the development of modern science and technology. For example, the nano-crystalline techniques, multi-functional materials and superconductive materials have revolutionarily changed the automation, remote control, artificial intelligence, and confidential characteristics in the aerospace, navigation and electronic industry. Therefore it will be of economic and social significance to fully develop powder metallurgy high technology, and the developing potential in this field is great. Because the powder metallurgy covers the high-tech study on raw powder preparing, powder processing techniques and other processes, and the high-tech products cover almost all-existing industries, the P/M high tech study will influence all respect of the complete society

By and large, the developing trend of the high technology is represented in the three aspects of new materials(including new powders), new techniques and new equipment. Among all the influencing factors, the fundamental research, interdisciplinary study and cooperation, as well as the extensive communication and cooperation are extremely important. Only when the high-tech industry have grown up, the Chinese powder metallurgy industries can occupy larger market share and attain full self-development.

3.6 Strengthening management, strictly controlling and improving product quality

Advanced materials and products with good quality is the safeguard for an enterprise to exist and develop itself. In the same way, only by producing advanced products with excellent quality to serve the society can the P/M enterprise win the confidence of consumers, take up its market share and then create much more wealth. Therefore, it is very important to pay close attention to the control and improvement of product quality. Scientific control is very important to the entire production process, and it is beneficial to realize the quality system step by step--- quality control system of the designing, developing, producing, installing, and serving --- ISO quality management and quality ensuring standard. It is necessary to collect information, to investigate the consumer's needs, and then improve the product quality. Track the world's new techniques and improving the techniques for production, analyzing and testing are also very important.

All in all, the 21st century is full of challenge and opportunities. In face of the challenges, the developing countries should take all possible opportunity to greatly improve their powder metallurgy industries.

Table 1 Asia/Oceania P/M production tonnes)

	1995			1996			1997		
	Fe-base	Cu-base	Total	Fe-base	Cu-base	Total	Fe-base	Cu-base	Total
Korea	16655	920	17575	18615	1144	19759	17710	1150	18860
Taiwan	12500	1900	14400	12000	1800	13800	14700	1800	16500
China	13741	1030	14754	14757	2081	16838	15092	1403	16495
India	4560	840	5400	5000	1500	6500	4650	1400	6050
Malaysia	3012	40	3052	3785	40	3825	3750	50	3800
Australia	2681	52	2733	2373	47	2420	2358	53	2411
Singapore	874	522	1396	996	462	1458	1060	510	1570
Thailand	357	0	357	433	0	433	346	0	346

Table 2 Powder shipments in North America, Europe and Japan (tonnes)

	1996			1997		
	Fe-base	Cu-base	Total	Fe-base	Cu-base	Total
North America	317997	75528*	393525	353166	87289*	440455
Europe	103258	14195	117453	123189	14847	138036
Japan	82200	3100	85300	84700	3300	88000

* includes other non-ferrous powders (stainless steel, Al, Tungsten, WC, Nickel, Tin)

Table 3 P/M end use sectors in Asia/Oceania (% in 1997)

	Automotive	Industrial machines	Electric machines	Other
Korea	46	20	16	18
Taiwan	25	12	55	8
China	46	20	16	18
Malaysia	26	0	74	0
Singapore	1	12	77	11
Thailand	36	0	64	0

Table 4 P/M production sector in advanced countries

	North America	Europe	Japan
Automotive	70%	80%	87.6%
P/M parts/vehicle	14.8%	7kg	6.53kg

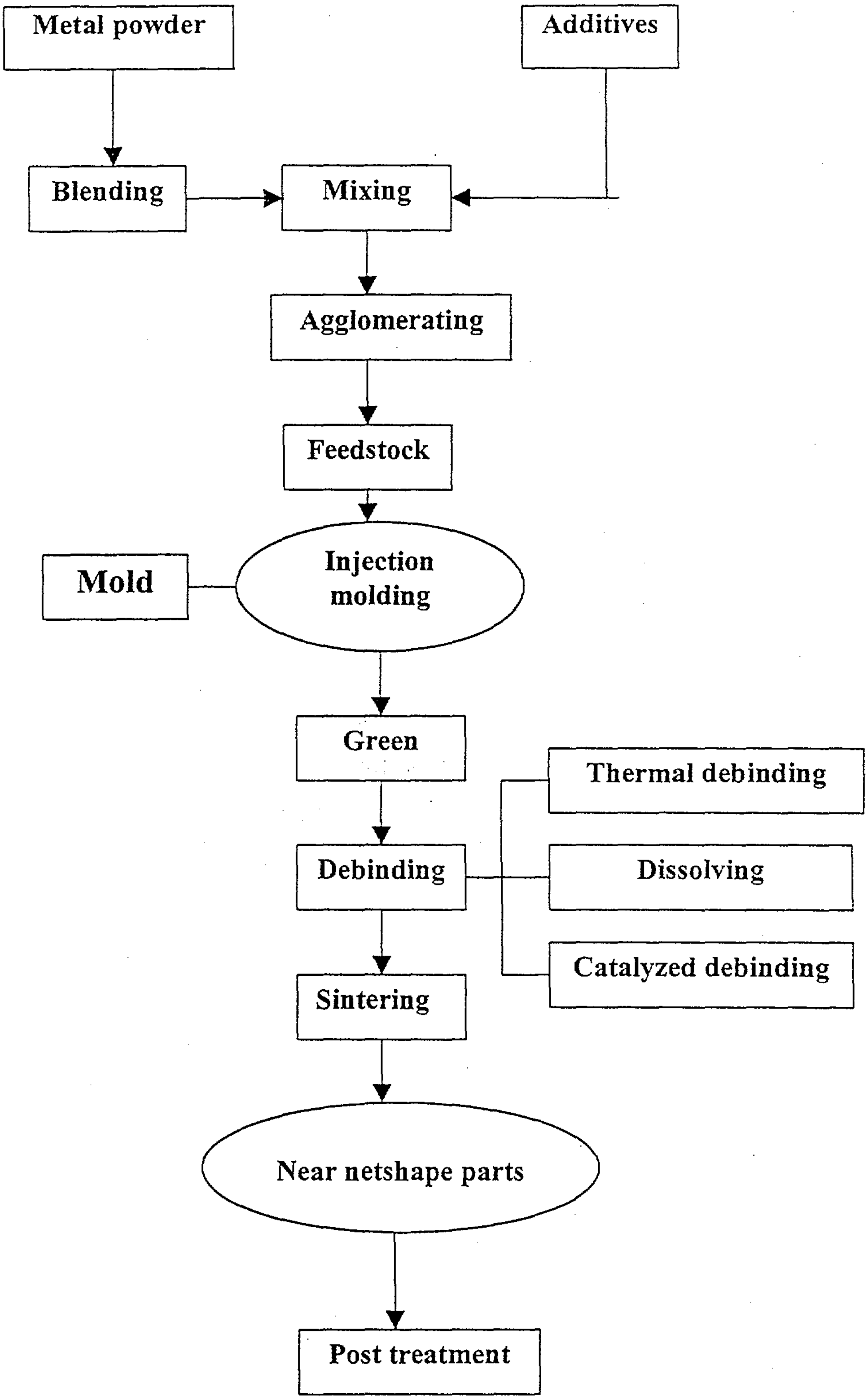

Fig.1 Illustration of MIM process

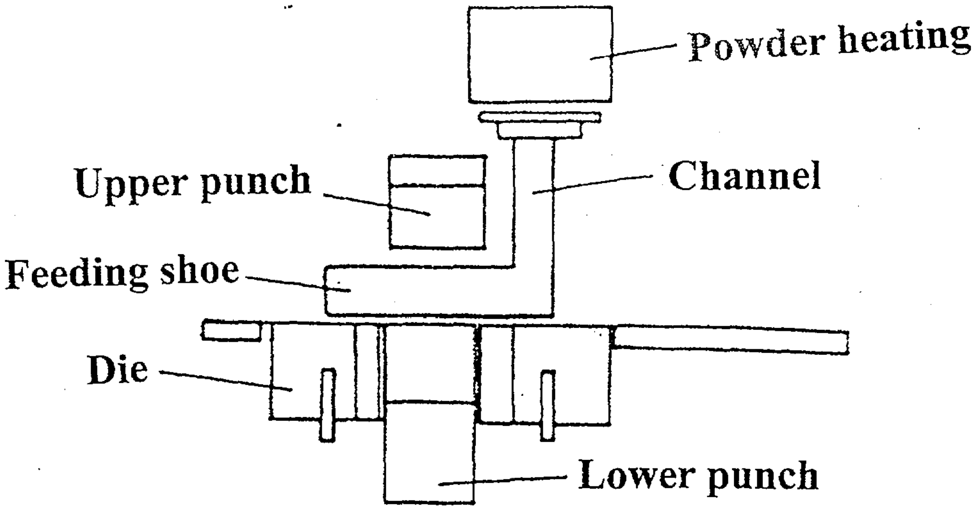

Fig.2 Illustration of warm compaction process

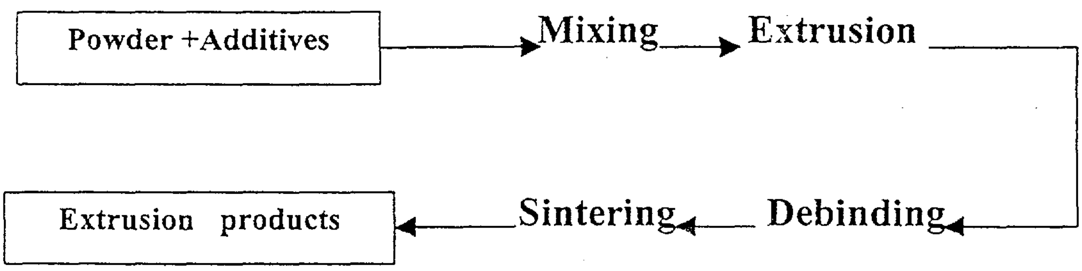

Fig.3 Illustration on powder extrusion process

THE CURRENT DEVELOPMENT AND OUTLOOK FOR ADVANCED SURFACE TECHNOLOGY AND ENGINEERING IN CHINA

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Ⅰ. Introduction

1. Advanced surface technology mainly includes:

   1) Coating technology (mainly referred to as PVD, CVD and thermal spraying technologies);
   2) Surface modification technology (mainly referred to as surface modification technologies with ion beam, electron beam and laser beam);
   3) Technology for surface testing and analysis.

2. Advanced surface technology is a booming technology and engineering which is new, interdisciplinary and multi-functional.

It is also an economic and effective method that can change the chemical composition, microstructure and provide new composite performance on the surface and near-surface zone for materials.

Surface technology is a crossing of various sciences involving electronic technology, vacuum technology, metallurgy, physics, chemistry, material science, etc.

Surface technology provides many new ideas, new materials, new appliances and new applications.

In China, surface technology is widely used in almost all industries such as metallurgy, power generation, petrochemical industry, machinery, light industry, auto-making, space & aviation, electronics, textile, building, and medical apparatus. Optimizing the performance of traditional materials and satisfying the critical demands of industries is becoming an import issue in China.

Ⅱ. Current development

1. Thermal spraying technology

Current situation:

Its application began twenty years ago, mainly for repairing parts and components in the early years. At present, it has been developed gradually into a vital link in the manufacture chain of certain high performance components.

The coating with good quality, high efficiency and low cost is required by the industry. New technologies such as LPPS (low pressure plasma spraying), EAS (electric arc spraying), HVOF (high velocity oxygen fuel) spraying, etc., are widely used in many fields.

The research and manufacturing systems of relevant equipment are preliminarily formed. More than 100 types of equipment for flame spraying, electric arc spraying, plasma spraying, LPPS as well as HVOF spraying, can be designed and manufactured in China.

As for the spraying materials, China can produce over 300 varieties of powders, including metallic, ceramic, composite, plastic and other functional material powders. Wires for spraying range over 100 types, including metallic/alloy, tubular core and ceramic flexible wires. The current annual consumption of spraying materials is around 1000 tons. Most of them, say 90%, are made domestically and can essentially meet the domestic demand for development.

In China many advanced thermal spray equipment were imported by research institutes, engineering units and Sino-foreign joint ventures, examples are TAFA JP5000, PlazJet 200 kW, GTV 120 kW plasma spray system and PT LPPS devices. The advanced devices lay a solid foundation for developing and exploiting thermal spraying technology in China.

Superalloy coated blades have been successfully developed and the application has started in air plane.

It should be noted that HVOF spray feature high flame velocity, making the coating in low porosity, and get strong bonding between the coating and the substrate. In kerosene fueled HVOF spray system efficiency is increased while cost largely reduced, which is very suitable for large area coating application. It is anticipated to become a focus and be used in large quantity within next five years.

For thermal spraying technology, more and more applications have been used in steel, power generation, automobile, textile, and aero engine industries.

2. Vapor deposition

(1) Current situation:

Novel synthesis and processing methods, mainly including CVD, PVD, PCVD, MOCVD, are used in China.

They provide a brand-new way to create materials with new structures such as over-non-equilibrium status structure and multi-layer structures with specific compositions.

Essentially, China has all kinds of equipment which are available worldwide, such as ion plating, magnetron sputtering, R.F. sputtering, EB vapor deposition and cathodic multi-arc deposition. Furthermore, some of the equipment made in China are exported to other countries, for example, the cathodic multi-arc ion plating equipment with 42 targets, which is the largest of this kind in the world.

(2) Film systems under research

a) New wear-resistant mechanical functional films

New wear-resistant mechanical functional films include Ti(CN), Cr(CN), HfN, ZrN, (TiAl)N, c-BN, diamond and diamond-like, β-C_3N_4 and other composite nitride/carbide and superhard films. Among them, (TiAl, V, Zr)N and HfN films are superior to TiN in quality. Films of boride and carbide are also promising. Due to the problems of inner stress and bonding strength, c-BN film still encounters difficult in metal machining. It appeared necessary to have an intermediate transient layer. In this respect diamond and diamond-like films are very promising. Recently, the thermal conductivity of diamond film has reached 12 W/cm°K, the highest value is 18.4 W/cm°K. The hardness for the diamond film has reached 10^5 N/mm^2. After solving the bonding strength problem between diamond film and substrate, the working life of diamond coated tool is 55 times that of the un-coated tool for cutting Al-22%Si alloy.

b) Physical functional films

Films for sensors, such as gas sensor, pressure sensor, temperature sensor, light sensor, magnetic sensor, integrated sensor, and intelligent sensor, have found actual applications in China.

Cold light reflection bowl with 24-layer films is a good application for gradient film.

Light conducting films of Se-As, Se-Te, light sensitive films of a-Si, a-Se, a-sulfide, and organic substances are used for electronic photographing, colored duplicating.

Magnetic recording films of γ-Fe_2O_3, Co-Cr are used for electronic information recording.

Films of Te/SiO_2/Al (Te: 5 ~ 10 nm) and TeO_x-Ge-Sn (Sn 100 nm) are used for re-writable laser disc/compact disc.

(3) Some of the vapor deposition technologies have found applications in industrial production.

a) VCD, DVD discs:

Developments of the players and discs get the benefits from thin film technology. China has set up production bases in Beijing, Shanghai and Guangdong. In 1996, 53.25 million discs were made in this country, and the output exceeded 100 million discs in 1997. The production speed has been raised from 2.5 seconds per disc in the beginning up to 1.5 seconds per disc till now.

For DVD, there are 23 player production lines at present. In 1999, China will import a production system which consists of 8 discs production lines and 1 parent disc production line.

b) Erasable laser disc/compact disc:

A LD/CD production line with an investment of 170 million RMB Yuan will be set up and put into operation in the second half of 1999.

c) Cold light reflecting bowl:

In China, production capacity is 80 million bowls per year. Actual export totals 30 million bowls.

d) Curtain-wall glass:

From 1992 to 1995, China had imported 25 production lines with total annual capacity over

20,000,000 m^2. Besides, 45 production lines were built domestically with total capacity of 40,000,000 m^2 per year.

e) Hardware and ornaments:

There are about 1000 factories with annual production value over 1 billion RMB Yuan.

f) ITO glass:

The growth rate of market demand is 20% per year. The global market capacity in 1998 was 5 billion pieces (about 0.4 billion m^2).

There are six plants with a capacity of 1.5 ~ 1.8 million m^2 per year in full production. Five more production lines (around 1 ~ 1.2 million m^2 per year) will soon been built and put into use. The annual capacity is expected to reach 2.5 ~ 3 million m^2 by the end of 1999.

g) Duplicator's photosensitive drum:

The industrial production is realized in the cities of Wuhan, Guangzhou, Tianjin, Shanghai and Guilin in China.

h) TiN coated tools

Lot production has been carried out in Beijing, Shanghai, Harbin, and Chengdu, etc. Generally speaking, supply has exceeded the domestic demand. At present, only a part of the products are exported to Pacific Rim countries.

3. Surface modification by three beams (electron beam, ion beam and laser beam)

A key national laboratory was set up in 1991.

The research items include:

a) Mechanism of reaction between three beams and the atoms on the material surface;

b) Optimizing the parameters of IBAD for high quality of deposited films.

c) Effect of metal ion implantation to metal surface on the microstructure and performances.

d) Laser is used for phase transformation hardening, alloying, cladding, and amorphous treatment.

Application:

Ion implantation is widely used in the production line for doping, microprocessing of integrated circuits. In a small lot production, China has successfully implanted N^+ ion into steel, Al alloy and Zr alloys, ions of carbon and boron into Ti alloys. In the early 1990s, China started the research on metallic ion implantation, with emphasis on materials' surface modification to improve its performance in wear and corrosion resistance. So far, a great deal of work has been done on surface modification by MEVVA ion source.

Laser phase transformation hardening technology has been used in some regions, such as Dalian, Beijing, Guangdong Province, Xian, as well as Yiqi (China's First Automobile Works) in Changchun where production lines were built to treat the inner surface of cylinders and cylinder liners for automobiles, tractors and large diesel engines.

In Yiqi, the production line equipped with eight laser devices can handle 300 thousand jackets per year.

By taking the ratio of price to performance into consideration, the above-mentioned technologies is demanded to spread in the following fields:

1) Biomedicine: to make Ti-base artificial joints, kneecap, backbone, conduct orthopaedics and implantation of arm, finger, and toe.
2) Space and aviation: to make lubricant-free bearing, piston in reciprocating cryopump.
3) Precision & compact components: precision tools such as nozzle for optical fiber production, precision wire-drawing die, carving die for aluminum beverage can, etc. compact & high accuracy precision gears, micro-drill for IC boards, medical tools & devices.

III. Development and Outlook:

1. Within the next ten years emphasis for surface technology (thermal spraying, thin film technology and surface modification technology) shall be put on large scale application and production. Special attention should be paid to stability and reliability of the equipment, uniformity for large area deposition, as well as convenience and reliability for the control.

2. With greater demands in materials for modern industrial application, it is necessary to adopt combined surface technologies to get more delicate composite coatings. The importance of coating design will be greatly enhanced.

3. Good equipment and devices are essential guaranteed for the making of a good coating. The computerizing equipment for coating shall get rapid development in China.

4. With the development of space technology and wide application of industrial gas turbines thermal barrier coating would attract much attention.

5. Diamond coated tools will find wide applications in large scale integrated circuit board and automobile industry by the early years of the 21st century.

ENVIRONMENTAL IMPACT ASSESSMENT OF MATERIALS AND ECOMATERIALS DEVELOPMENT

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ABSTRACT

As a sustainable century, the sustainable development of society and economics in 21 Century is based on the coordinativity with natural resource and environmental endurance. It is very important to keep the balance among resource, energy and ecological environment during the production, application and disposal of materials. As a new boundary science, the ecomaterials is just created for the purpose. In the present paper, some consideration on the fundamental of ecomaterials will be demonstrated such as the ecomaterials definition and content of ecomaterials, as well as the development tendency, so as to enrich materials science and to promote the sustainable development of materials industrials.

KEY WORDS: Life Cycle Assessment, Environmental Impact, Ecomaterials, Resource Productivity, Sustainable Development

INTRODUCTION

A new boundary science named as Ecomaterials was founded in the beginning of 1990's between materials science and environmental science [1]. The purpose is to investigate the interaction between materials and environment. As serious pollution of ecological environment, it becomes more and more popular to protect our globe and to develop green technology. Scientists have noticed it makes a severe deterioration on the ecology from the production, application and disposal of materials, as well as expand the load of the earth. Therefore the task of ecomaterials is to quantitatively assess the environmental impact in materials processes; to study the techniques reducing the deterioration on the earth; and to develop environmentally beneficial products.

Because ecomaterials has been established for several years, it is still unpopular for most of scientists. Of course, there are a lot of issues unsolved like ecomaterials definition, objective, content, fundamental, and so on. This paper would like to contribute some fundamental consideration on ecomaterials, so as to share to others and to promote the development of ecomaterials.

UNDERSTANDING OF ECOMATERIALS

Many historical periods, in the development of human being society, were named as a materials, for example, stone time in remote antiquity, copper time and ironic time in primitive period, as well as polymer time in present. It is the materials that promote the civilization of humanity. In other words, materials science and technology is originated to meet the needs of social development. Table 1 demonstrates the appearance of some materials in 20 century. Like energy materials and information materials, evidently, ecomaterials emerges as the times require and develops as the mankind need.

With the excessive exploitation and consumption of natural resources, as well as the pollution and deterioration of global ecological environment, mankind has understood the importance and emergency to protect environment and to realise sustainable development. It is an impressed task for materials scientists to reduce environmental load in materials production and use.

Table 1 Appearance of some materials in 20 century.

1960s	1970s	1980s	1990s
Semiconductor Materials	Energy Materials	Polymers Materials & Ceramics Materials	Information Materials & Ecomaterials

Ecomaterials are the kinds of materials that have a coordinativity with ecological environment in manufacture and service processes, a possibility to be degraded by environment after disposal, or an ability to purify and repair environment. Besides the satisfaction performance, ecomaterials should have the characteristics such as less consumption of energy and resources, smaller affection to ecological environment and higher recycling possibility in the processes of production, application and disposal [2]. With prospective research and development, it is believed that the understand of ecomaterials will be continuously modification, as well as ecologically beneficial materials and products will be widely accepted [3].

FUNDAMENTAL STUDY OF ECOMATERIALS

It could be found from Table 2 that, up to now, the fundamental study of ecomaterials is primarily concentrated on the ecomaterials design; the assessment methodology on the environmental load in the production, use and disposal of materials; the database on the environmental impact of materials; the theory on the sustainable development of materials technology such as the resource protection and productivity, recycling use, cleaning production processing, etc.

Before the process to assess the environment impact of materials, it is first to select an index qualifying the impact. Several quantitative indexes on environmental load have been now suggested like energy consumption, resource consumption, environment affect factor, eco-indicator, environmental load unit, materials input per unit service, and so on. However, it is still in progress that a normalized quantitative index on environmental impact assessment could be widely accepted up to now [4].

Table 2, the fundamental study of ecomaterials.

→ Ecomaterials design
→ Assessment methodology on the environmental burden
→ Database on the environmental impacts of materials
→ Sustainable development of materials technology and product
→ Resource protection and productivity
→ Waste recycling and reusing
→ Cleaning production process

Except that single factor method is used for evaluating simple affection on environment from waste gas, waste liquid or solid waste, life cycle assessment (LCA) has been widely applied for evaluating a combined impact on environment in a process, an action or a product. It is a quantitative method that could assess the environmental impact of whole processes from cradle to grave. The study on LCA at present is major on the practical application in various fields, and the allocation determination of assessed objective [5]. The allocation has important influence to the result from LCA. From a small allocation, it is possible to get a false conclusion that the process, the action or the product has a maximum environmental load. From a big allocation, oppositely, another incorrect result could be obtained that the environmental impact of assessed objective is so small as to be neglected. By the way, one important progress on LCA methodology is that the procedure of four steps in LCA processing has been changed into three steps since 1996.

Figure 1 gives an environmental load analysis of three normal materials by LCA. To assess the environmental impacts of the materials shown in Figure 1, three methods like input-output, linear programming as well as analytic hierarchy process have been used in LCA implementation, and the same tendency of environmental impact had been derived for the materials. According to the analysis from cradle to grave, obviously, the environmental impact of 6063 aluminium alloy is much greater than AISI 4340 low alloy steel and high density polyethylene in both production and consumption, even under the same service purpose [6].

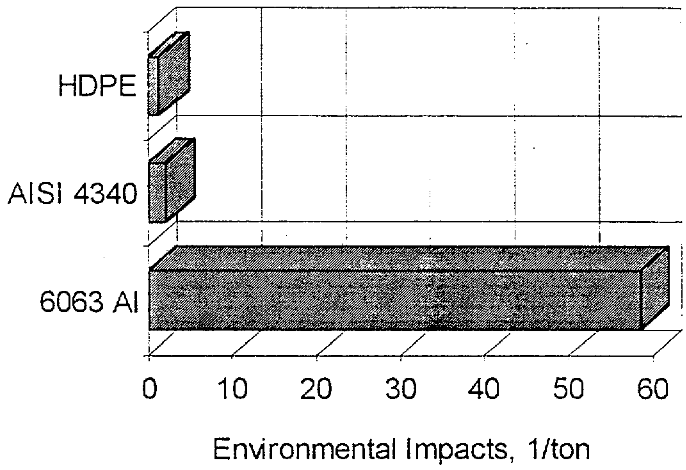

Fig. 1 Environmental load analysis of normal materials by LCA.

Study on the sustainable development of materials technology is another important field in the fundamental of ecomaterials. Based on natural resource, the goal of the study is to explore the coordinativity with the bearing capacity of environment; to keep resource balance, energy balance and environment balance, so as to realise a profitable development among society, economics and ecology. By the study, it is probable to understand the effect of the activities in mankind's developing materials on ecological environment variety, and the influence of environmental alteration on the quantity and quality of materials required from humanity life. In current, the content of studying the sustainable development on materials technology principally includes the resource protection and reproduction, the recycling and reusing of waste, harmful waste avoiding technique, control technique, remedy and restoration technique, and cleaning production, environmental education and management, etc. Correspondingly, to reduce the amount of materials transportation and to decrease the deficiency of materials flow are also the active approach to acquire sustainable development [7].

Design is one of the most important means to protection environment. It has been proved by many facts that avoiding the emergency of harmful waste is an active way to improve ecological condition. It is well understood that the design of product and processing is a key step to avoid pollution. Other is that traditional ending treatment is substituted with beginning prevention. Ecological design could make the product beneficial and compatible with environment at beginning, and delete the end treatment, so as not only to earn the environmental benefit, but also to obtain the economic benefit and the social benefit. At same time, the cleaning production stressed in processing design could make am important contribution to ecology by means of using clean raw materials, clean process and clean product.

APPLIED RESEARCH OF ECOMATERIALS

One of objectives in ecomaterials study is to attempt the compatibility and coordinativity. The main content of applied research in ecomaterials is to develop new ecologically beneficial materials and products with environment, as well as to modify the coordinativity of current materials and related products with environment. Up to now, a lot of progress (Table 3) has been achieved in the development and use of ecomaterials like natural materials, biomaterials, green packaging materials, ecological construction materials. It is popular that, for example, wood with various modification treatment is being used to substitute the materials with heavy environmental load for practice [8].

Eco-degradable material is also an important area in ecomaterials study, which includes bio-degradable polymer and degradable inorganic phosphate ceramics. The development of optical and/or biological co-degradable polymer, for instance, and industrial scale production are the highlines in bio-degradable polymer at present.

Table 3, Ecomaterials and Related Eco-products

Ecomaterials	Related Eco-products
Natural Materials	Wood, Bamboo, Stone
Bio-materials	Manufactured Bone, Man-made Links and Organs
Green Packaging Materials	Biodegradable Bag, Green Packaging Paper and Film
Green Construction Materials	Ecological Beneficial Coating, Green Housing Components, Biocompatitive Materials
Bio-degradable Materials	Bio-degradable Polymer
Environmental Engineering Materials Environmental Repairing Materials	Adsorption, Absorption and Catalytic Conversion Materials for Controlling Air Pollution; Neutralization, Deposition and Oxidation Materials for Water Pollution; Sand-fixed and Vegetation Materials
Environmental Purifying Materials	Filtering, Separation and bactericide and disinfectant Materials
Environmental Substituting Materials	Substitution Materials for CFC, Building Materials

According to above discussion, environmental engineering materials is one of ecomaterials, which is often used for purifying and repairing polluted ecological environment. The materials purifying environment normally has filter materials, separating materials, bactericide and disinfectant. The materials repairing environment could be divided into the materials harnessing air pollution like adsorption, absorption and catalytic conversion materials, the materials using for controlling water pollution such as deposition, neutralisation, oxidation and reduction materials, etc. By the way, sand-fixed and vegetation materials are also belong to big group of ecomaterials. In some case, there is an environmental substitution materials, too. It means that, to improve ecological environment, a ecologically beneficial materials is used to substitute the environmental harmful materials. For instance, some ecological beneficial refrigerant is being studied to substitute CFC. In fact, some natural materials like wood and bamboo used to substitute some construction materials with high environmental load is also belong to the environmental substitution materials.

SUMMARY

As one boundary science, it is sure that ecomaterials will be taken as one of leadership directions in developing new materials for next century. In order to maintain the balance among resource, energy and environment, as well as to realise sustainable development of materials technology, the contents of ecomaterials study mainly include to accomplish the assessment system of environmental impact, to search new processing, new technique and new method for reducing the environmental load of traditional materials in manufacture, use and disposal, and to explicate ecologically beneficial materials and related green products.

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Appendix D

The 2nd Meeting of the Advisory Committee and IMAAC Forum

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