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THE ROLE OF RESEARCH AND DEVELOPMENT WORK AND PILOT PLANTS IN THE CREATION AND TRANSFER OF METALLURGICAL KNOW-HOW IN DEVELOPING COUNTRIES AND REGIONS [1]

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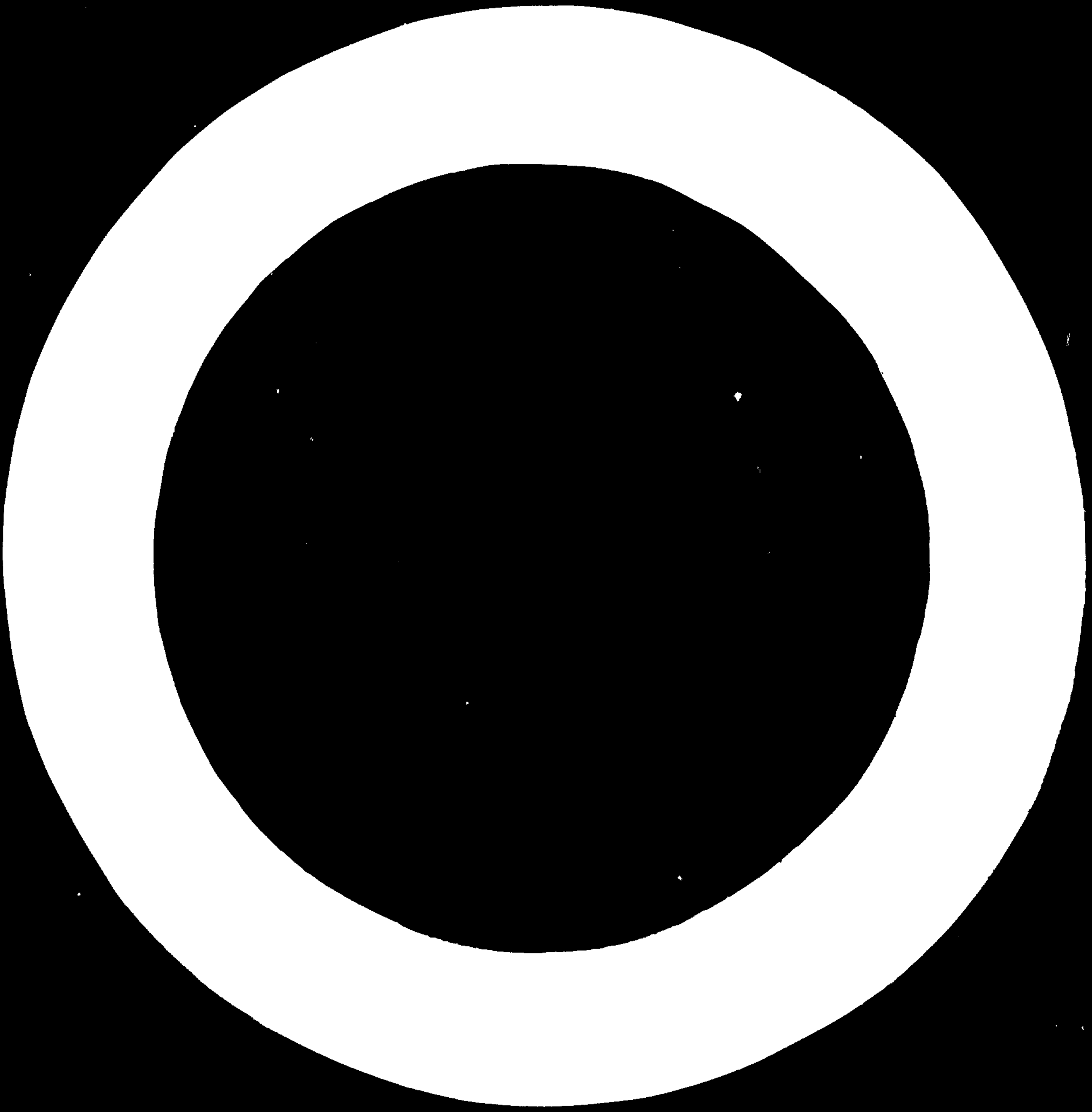

THE ROLE OF RESEARCH DEVELOPMENT WORK AND PILOT PLANTS IN THE CREATION AND TRANSFER OF METALLURGICAL KNOW-HOW IN DEVELOPING COUNTRIES AND REGIONS

The scope of the paper is as vast as the problems posed in the creation and transfer of Metallurgical know-how and a paper such as this can only present and focus attention on some ideas for discussion and cannot embrace all the facets of the subject.

Pre-requisites for Science & Technology

1.0 No one can question of the application of science as a significant factor in the wide surge that is taking place in the world over, particularly in the field of metallurgical science and technology. In the broadest sense, all countries are developing, each moving along its unique path. The problems facing individual countries reflect in varying degree the state of imbalances which characterize the world situation - imbalances in the kinds and abundance of fuel and mineral resources, imbalances in the per capita income and capital resources; imbalances in the state of educational development and in the restraints imposed by tradition etc. Each country must therefore, devise means of adapting itself to the state of imbalances that exist for formulating its own scientific, technological and relevant man-power policies.

2.0 Despite the fact that Asia experienced evolutionary developments in the past, events have shown that they are isolated blossomings which are not enough to establish development as a self-generating, self-sustaining process. This would, therefore, indicate that there is a critical stage at which the right combination of knowledge and understanding of the scientific, technical, social and economic aspects is to be built up to render a self-sustaining process possible - the so-called 'take off' stage. Once it gets properly started, the process has every chance of propagating over a wider front. The beginning of such a process of evolution requires a fertile social environment, as does also its continued propagation; a situation very analogous to a transplanting operation which demands careful preparation of the ground.

3.0 In the past, development was relatively slow and was always pushing at an unknown frontier of possibility. For the developing countries, this frontier lies on a distant horizon and the thrust towards it must be carefully planned and programmed.

Essential Aspects of the Application of the Science

4.0 The basic pre-requisites that are common to all the developing countries are the creation of general conditions favourable to the application of science and technology to development including the implantation of basic sciences and the provision of the foundation for the promotion of basic and applied research, both creative and adaptive and emphasizing above all the social and human factors involved, so as to create a social climate for actively promoting the changes associated with developments.

5.0 The planning of Government support for developing science and technology and of the national structures required for the purpose is also important as also the supply, distribution and utilization of the human, financial and institutional resources for the purpose of research and development; the planning of research programmes in harmony with national development needs; the consultation mechanisms of the scientific community and the follow-through in the production sector of the economy, i.e. the practical application of research results.

6.0 Based on the systematic surveys conducted by the U.N. Agencies of the scientific inputs and infrastructural facilities in the developing countries like Burma, India, Indonesia, Iran, Japan, Laos, Malaysia, Mongolia, Nepal, Pakistan, Philippines, Singapore, Thailand, Republic of Vietnam etc., it has been established that the expenditure on research and development, as % of the GNP, for all the above countries is below 0.5% excepting in Japan where it is of the order of a little over of 1%.

7.0 The prolific breakthroughs and the first new 'highs' reached in several industrial sectors of Japan, particularly in the field of iron and steel, are indeed staggering. Japan launched a massive input of technology in the post-war period in several fields of iron and steel technology. At the same time, they strengthened the research and development base to absorb and adapt these technologies to achieve maximum returns. Due to extremely limited availability of indigenous raw materials in the country and consequent necessity to depend entirely on imported iron ore and coal, maximum attention was paid to the use of preparation of the ore burden in the blast furnace and efficient utilisation of specialised techniques such as fuel injection, oxygen enrichment, high blast temperature, high top pressure etc. These efforts have produced maximum reduction in the coke consumption per ton of pig iron and increased productivity per useful volume in the blast furnace operation.
In 1960, there was hardly six L.D. converters and today, they have 73 L.D.converters and their combined capacity had reached 73 million tons per year. They have built ultra high power electric steel making furnaces to lower the cost of power unit electricity and improve the heat efficiency. During 1970, Japan has made considerable strides in continuous casting techniques and the total capacity has reached 12% of the world's total production. Automation and high speed operation of rolling mills have advanced to a great degree. In the use of computer, Japan's steel industry has achieved maximum utilisation. There are 200 computer system in use

in the steel industry alone. Japan today has surpassed several European countries including U.K. in steel production and ranks third in the world despite the fact that Japan has to import all the basic raw materials for the iron production from overseas and develop her own long term planning to sustain their production. All these evidently show their ability to select, absorb and improve the borrowed technology.

Determined & Aggresive Approach

8.0 In both China and Japan, the phenomenal growth of their industrial complexes show another pointer in how to choose the technology and how to adapt it and gain completely mastery. For instance, Japan imported a great deal of scientific knowledge and a fairly large amount of technical know-how and even engineering plants from the United States, especially after the World War II, (Tables 1,2,3,4 & 5). They also took a great deal of pains and scientific study to build into their industry, the capacity to develop their own technology. The germanium, silicon and semi-metal alloy industry is a fitting example. Japan today is in a position to export their technology to the United States which although highly developed are buying their technology and know-how. This would show that a determined and aggresive approach is required to choose what is required and to produce a technology that can be utilised indigenously and also to be exported. Such results are not noticeable anywhere in developing countries because of the difficulty in attracting a group of highly competent, highly motivated and highly creative technical personnel in the industry and in providing the right incentive and environment.

Role of U.N.Agencies

9.0 The application of science and technology to development and transfer has also been actively engaging the attention of the

Table No.1

Introduction of Iron-making Techniques (Class-A)

Licensees	Techniques for (Authorization year)	Licensers
Japan Special	Sand iron refining by Philipon process (1954)	Societe Central (France)
Hitachi Metal	Sponge iron making by Wiberg process (1960)	Stora Kopper-Bergs (Sweden)
Sanyo Special	Sponge iron making by Wiberg process (1961)	Stora Kopper-bergs
Yawata Steel	Direct iron making by R-N process (1962)	R.N. (U.S.)

Source: Japan's Iron & Steel Industry, 1963
published by Tokyo Foreign Service, Tokyo

Table No.2

Introduction of steel-making techniques (Class-A)

Licensees	Techniques for (Authorization year)	Licensers
Nippon Kokan	LD Process (1956)	Osterreichisch-Alpine (Austria)
Mitsubishi Steel	Vacuum casting (1958)	Leybold-Hochvakunie (W.Germany)
Japan Steel	,,	
Kobe Steel	,,	
Yawata Steel	Vacuum Melting (1959)	Dortmund-Hoerder (W.Germany)
Fuji Steel	Molten Steel vacuum degassing (1961)	Ruhrstahl A.G. (W.Germany)
Nippon Kokan	LD-AC process (1962)	La Centre Nationale du Recherche Metallurgique (Belgium)

Source: Japan's Iron & Steel Industry, 1963
published by Tokyo Foreign Service, Tokyo

Table Nc.3

Introduction of Rolling Techniques (Class-A)

Licensees	Techniques for (Authorization year)	Licensers
Fuji Steel	Strip mill rolling (1951)	Armco International (US)
Yawata Steel	Hot rolling of silicon sheets (1951)	Armco International
Yawata Steel	Metal surface peeling (1956)	Union Carbide (US)
Misshin Steel	Sendzimir mill rolling (1956)	Tadeusz Sendzimir
Yawata Steel	Manufacturing cold silicon hoop (1957)	Westinghouse (US)
Kawasaki Steel	Manufacturing oriented cold silicon sheet (1958)	Westinghouse
Yawata Steel	Manufacturing oriented cold silicon sheet (1958)	Armco International
Nippon Stainless	Sendzimir mill manufacturing and rolling (1961)	Tadeusz Sendzimir
Nippon Yakin Iwai & Co.	Planetary mill rolling (1962)	Tadeusz Sendzimir

Source: Japan's Iron & Steel Industry, 1963
published by Tokyo Foreign Service, Tokyo

Table No.4

Introduction of Special Steel Manufacturing (Techniques (Cla[illegible])

Licensees	Technique for (Authorization year)	Licensers
Sumitomo Metal	Continuous casting (1955)	Concast A.G. (Swiss)
Sumitomo Metal	Metal forming by hot extrusion process (1956)	Compagnie du Filage (France)
Osaka Special	Manufacturing zinc free cutting steel (1958)	Inland Steel
Sanyo Special Mitsubishi Steel	Continuous Casting (1961)	Mannesmann A.G. (W.Germany)
Nisshin Steel Aichi Steel Takasago, Tekko	Manufacturing stainless Steel (1962)	Armco International

Source: Japan's Iron & Steel Industry, 1963
published by Tokyo Foreign Service, Tokyo

Table No.5

Introduction of Secondary Product Making Techniques (Class-A)

Licensees	Techniques for (Authorization year)	Licensers
Yawata Steel	Strip galvanizing (1951)	Armco International (US)
Yawata Welding	Manufacturing shielded arc welding electrodes (1958)	Holding Intercito (Panama)
Fuji Steel	Infiltration of chrome into coiled strip surface at elevated temperature (1962)	Gass Alloy Steel (US)
Japan Arcos	Manufacturing Arcos arc wires (welding electrodes) for automatic welding machine (1962)	La Soudeur Electrique (Belgium)

Source: Japan's Iron & Steel Industry, 1963
published by Tokyo Foreign Service, Tokyo

U.N.Bodies, the General Assembly, Economic and Social Councils, the Advisory Committee of Application of Science and Technology etc. During 1960's and particularly in 1970's, greater emphasis has been given to define the role of science and technology in development and to identify the major pre-requisites that are essential for the creation of technology and its ultimate transfer to the industries. The United Nations Industrial Development Organisation alone has carried out several pre-investment service for the developing countries in the field of iron and steel and has also provided valuable technical system for the establishment of the basic industries and also in the form of technical assistance for setting up commercial integrated iron and steel plants.

Invention & Innovation

10.0 Research however successful, cannot by itself produce services, food, shelter or wealth. Its results have to be applied in practice. This in turn goes to skills, incentives and the commitment to innovation along the chain starting from research through development to production and finally marketing. The basic concept that has very successfully been defined and emerged out of the several conferences is that there is a distinct difference between 'invention' and 'innovation'. Innovation implies bringing into being new products or processes. In the complete chain of activities constituted by fundamental research, applied research and development (R&D), innovation represents the culminating stage at which the total scientific effort of the country is incorporated in a form of having a direct and clearly recognisable implications for the national economy.

A Multi-stage Process

11.0 Invention creates opportunities to design and carry out their implementation. It is innovations which ensure the use of an idea - the process by which the idea is translated into economy. The test for research and development is to what extent it is put to use in productive enterprise. Innovation is thus a multi-stage process needing considerable human resources and the magnitude of expenditure is usually much greater than the funds consumed during the first stage. The United States, Department of Commerce, has estimated that expenditure on innovation is about 10 times of the expenditure on invention.

Fear of Obsolesence

12.0 In the last two decades, considerable efforts have been made to reduce the time lag from the discovery of invention to its ultimate absorption in the industry in the form of innovation and this has particularly proved very successful in 'product' and 'processes' research. Industry today is also more conscious of the possibilities of obselence in the equipment or processes they are using and there is a constant effort made by the industry to go in for new equipment and new processes to complete in the international market. Large organisations are constantly endeavouring to keep abreast of the latest advances in the application of science and to find effective use of utilising them.

Multi-stage Technological Activity Chain

13.0 The industry is also conscious of the fact that every new product coming to the market embodies many man hours of valuable research and design and in particular the amount of research and innovation of work preceeding the appearance of new type of equipment or machinery. This will be evident from the fact that in the production of a new piece of equipment or process, there are several stages involved such as preparation of product, first sample producing, few sample testing, introducing changes in the design, preparation for commercial production and finally commencement of production.

Need for Institutional Structure for Development

14.0 Technological activity is only one major link in the chain of activities and there are other links that are equally important such as the commercial aspects of management, market survey, legal aspects, patenting, developing, building and maintenance work etc. The modern concept of R&D is, therefore, quite different from those that prevailed before in the sense that innovation is no longer left for the inventor to carry out. At an appropriate stage, the inventor needs the support of a multi-disciplined team of innovators. A separate institutional structure may also be necessary for promoting innovation working closely with research institutions in which economists has a significant role to play.

Classification of Research Activity

15.0 Future historians will no doubt record the importance of research in our culture and the broad and steady stream of new products and new processes and new materials which it has contributed to our economy. The society is primarily concerned with material goods and objective phenomena and the major trend of research strategy in the world has been directed towards 'product' and 'process' development. Industrial research can, therefore, embrace problems covering a wide spectrum ranging from adaptation, substitution, adhoc improvements to process and product development, design of proto-type and final production and marketing strategies. Yet these activities are only one part of what might be called a total economic system.

16.0 During the recent past, it has been recognised that there exists an important economic activity called 'services' which do not, of themselves lead to physical end product, although they may well and usually do facilitate the manufacture of goods by providing functions necessary to the creation of firm utilities. The services including the personnel services help to create an environment that facilitates the production of goods. R&D has not been as productive in this field as in the product area. As far as metallurgical research is concerned, the innovation chain is rather long and infrastructure that is required to produce and sell the goods is quite wid

Basic Vs Applied Research

17.0 There can be no two opinions on the need for basic objective research as it leads to 'concepts' and applied research to 'options'. Basic research provides considerable scope for undertaking applied research and leads to technological follow-ups in the productive section of the economy, producing drastic changes in manufacturing or consumptions habits. When a basic research makes such impact, the returns justify the inputs.

18.0 As for instance, the expenditure of billions of dollars on space explorations and moon landings has certainly provided enough impact on the industries by way of new products, new processes and patents besides satisfying the scientific curiosity. The gap between inventions and innovations is also reduced as we could see the commercial application of satilites in T.V. Transmissions, communication etc. This is exactly what is required to keep the expanding wave front of technology fully in propagation. This is possible only in highly developed countries like U.K., U.S.S.R., where the industrial infrastructure is adequate to absorb the scientific advances. In developing countries, the time lag is wider and widening further with the result that even the few impact the scientific community tries to create is rendered useless by the lack of the capacity to absorb.

19.0 For scientific research to be effective and viable, the research unit must have a minimum size. Size is necessary for two main reasons. Firstly, research requires the interaction of a multitude of disciplines involving an irreducible minimum of people and equipment. The industry is no longer interested to have a quantitative approach, but qualitative emphasis on the properties that are required to meet the rigid service requirements of the product. Secondly, in order to ensure a reasonable chance of success in solving problems within an acceptable period of time, several alternative routes may be required involving multiplication of facilities. Having said this, the minimum size, in terms of revenue expenditure, can afford to be much smaller than comparable laboratories in the developed countries as a result of a combination of lower scientific salaries, availability of highly qualified scientific assistants and the fact that some of the goals of research, e.g. import substitution, are so much more finite. Last but not least, is the limited extent of the competition in a closed economy which tends to reduce the risk.

Imperativeness of indigenous technology

20.0 During the last two decades, developing countries have learnt with practical and pragmatic approach that adequate investment in scientific research is essential to achieve progressive economic growth. In this, Japan stands foremost. Even the firms in Japan which imported most of the foreign know-how spent maximum on R&D efforts. It has also been realised the more they already know themselves, the more they can secure from others and more they can benefit. It has also been observed that the Japanese Industry spends as much as 7 yens for every yen spent on borrowed technology for adapting and improving the technology through indigenous R&D.

Pre-requisite for Industrial Research and Technology Development.

21.0 Some of the papers that were presented on the 'Problems of Transition from Laboratory Research to Industrial Applications', a Seminar that was organised by the UNESCO at Poona, during Dec.1970 emphasise the fact that a high order of impact on the economic growth of the developing countries can be effected only by adapting and assimilating and improving upon imported technologies and that for improving the efficacy of the R&D institutions, it is necessary to ensure proper identification of projects and collection and dissemination of the local and international market information. Large industries in the developing countries should be encouraged to establish integrated R&D and engineering and design facilities which will facilitate the expansion of these units on the basis of their own research.

22.0 In a developing country, the following pre-requisites to successful industrial research assume great significance.

1. Availability of trained laboratory researchers, engineers, technologists, technocrats/managers
2. Liaison between governmental and university R&D Institutions, industry and governmental planning and policy makers
3. A national science and technology policy for promotion of industrial research. Setting up of priorities for financial inputs in relation to national needs as regards areas of industrial research. Respective areas for R&D activity in industry, co-operative research associations, and government research institutes. Role of governmental priorities for R&D inputs
4. Incentives for indigenous R&D and for induction of technically trained entrepreneurs
5. Availability of project engineering and design organisations and plant fabrication capacity. Incentive for promotion of these facilities.

23.0 The following pre-requisites for technology development have also been often identified.

1. Identification of projects for R&D inputs and their priorities from the point of view of techno-economic considerations

2. Market Survey
3. Relation to national planning and needs and impact on economy and/or strategic needs in relation to established R&D inputs and is it worth it?
4. Time and techno-economic targets of achievement
5. Identification of prospective users of technology keeping in view capital investments needed for commercilizing the process intended to be developed
6. Consideration of obsolescence factors
7. Problems arising out of the objective of improving existing technology.

Planning of R&D allocation

24.0 Since in almost all developing countries paucity of funds is a common, all pervading malady, planning of R&D allocations of funds must be done with utmost care with following to serve as guide-lines:

1. Selection of particular solution/solutions of the identified problem out of the various possible alternatives based on techno-economic merits, level of technological expertise available, estimated capital investments needed, indigenous availability of raw materials and equipment etc.
2. Planning of laboratory and pilot plant work on a detailed time-targetting programme, organisation of PERT or CPM programmes for execution and evaluation of the R&D work in relation to time-targets prescribed
3. Execution of R&D at the Laboratory and pilot plant stages - Evaluation of work at various stages of development in relation to objectives of achievement
4. Regional and international collaboration in R&D activity.

Sponsored Projects

25.0 Government may subsidise such research by affording adequate incentives. Until such R&D base is established, the large industries in these countries should take advantage of whatever research centres that are available in a country such as the National Laboratories or NRDC etc. by funding sponsored research on problems connected with assimilating and the improvement of imported technology as well as problems of production, diversification and expansion.

Government Vs Research and Development

26.0 An important suggestion which has received strong support on several occasions is that Government should give directive to all public sector companies that they formulate definite and time targetted plans for absorbing the imported technologies. The Government should also permit industries in key sectors by funding research on important problems in research establishments in public and private sector industries and in other R&D institutions.

The Role of Pilot Plants and Units

27.0 Before we go to this aspect, particularly in the field of metallurgical processes, it is necessary to understand the difference between 'process' and 'product technology'. The quality of a technology can be evaluated both in terms of production cost and quality of the product, although there are a number of factors affecting both. While it is difficult to quantify, quality of technology has two major identifiable aspects. In a comparison of technologies for the manufacture of the same product, one which gives lower cost of production per unit value of output is a better one. It will lower the cost by reducing input - output cost by substituting cheaper inputs or by giving a product of better quality. Second, the lower the risks associated with the use of a technology, the higher will its quality be adjudged.

Approach of the Buyers and Sellers of Technology

28.0 Unless one is already using a technology, a buyer will be uncertain regarding the output costs and quality that he will achieve with it. The less the risk he has to bear owing to this uncertainty, the higher he will rate the quality of the technology. It will also be evident that newer technology which gives lower cost and better quality are less tried and therefore, less certain in the results. Usually a buyer of technology places a high premium on higher returns and greater certainty of the quality. A seller of technology will try to reduce the buyers risk, by giving output and performance guarantees by reducing the subjective risk he will improve the buyers judgement of the quality of the technology and charge more for it.

29.0 Alternatively, he will look for a technologically sophisticated buyer who can tackle the teething trouble on his own and possibly contribute to the technology purchased. When technology is characterised by the quality of the product, the product will be protected by patents, trade marks etc. In the case of homogenous bulk products, technology is characterised more by the manufacturing process and its costs than by distinctive product features. As far as metallurgical industry is concerned, process technology plays a very important part and in the light of the arguments mentioned above, pilot plants and prototypes are important. This will be particularly clear from the fact that extrapolation of laboratory scale researches to industrial practice is generally a difficult problem as the ratio of area to volume is far greater in laboratory tests than in industrial practice.

Basic use of pilot plants

30.0 Industrial research must incorporate an intermediate stage where the tests are made on a medium or semi-industrial scale, half way between laboratory and industrial production scale. At this stage, it is practically necessary to have available specially installed premises which will be called pilot section or plant, according to their size. As a matter of fact, the object is to have a plant available which will enable production to be made on a reduced industrial scale. These facilities are generally devised to allow easy modification of equipment and more numerous and precise measurements than is generally the case in normal production.

Benefits in connection with metallurgical pilot plant include determining technical and economic feasibilities, the conditions that affect recovery and quality of products, marketing prospects, and factors affecting geometry of equipment and the design of projected commercial size plants.

31.0 There are also other possibly significant benefits that may be derived from pilot plant operations. One of these is the opportunity for training personnel, including technologists and [illegible] labourers The use of trained personnel lessens the hazards for smooth operation of commercial plants when they are first placed in operation. Damages to expensive equipment are avoided, and contingencies that arise can be met more readily because of confidence and experience that the persons have derived from pilot plant experimentation. Thus, shut-downs during initial operation of new commercial plants are minimised. Another benefit is that a fairly indicative processing cost data can be obtained that permit estimation of operating costs for large plants. Such figures are one of the key items in deciding the break even points and whether or not to venture into commercial demonstration or operation on a particular scale of production.

32.0 Pilot Plants also afford opportunities drastically to change treatment system at a cost much lower than if this had to be done in commercial size plants. Substantial changes sometimes are required in equipment and processes in commercial plants that use new processes or new types of ores. Such changes cause delays that are costly in production loss and in increased capital outlay. Adequate pilot plant experimentation before construction of commercial demonstration or production plants tends to reduce or eliminate such losses.

33.0 In conclusion, pilot plants can sometimes operate as perfect models and yield unarguable design data. Under any conditions trends in performance can often be established which give sufficient confidence for full scale trial. Whenever an element of a process can be used as a basis for the pilot plant, the results obtained are usually realistic without any corrections for scaling up. This will apply even when the process is complex as for example sintering.

Accountability of R&D

34.0 With the rapid growth of the nations' resources allocated to scientific activities, and more particularly to research, science policies of governments are being more and more challenged on economic grounds. Though it is no longer necessary to prove that 'science pays', nevertheless governments are under continuous scrutiny by parliaments and scientific committees in order to ensure that the investments in research are made in such a way as to optimize the probability of benefit. Here we have a new kind of cost/benefit analysis in which the uncertainty of the calculations increases as we pass backwards from prototype development, through applied research and oriented fundamental research to pure basic research, where the chances of success can hardly be estimated on an individual project basis.

Criteria for measuring research output

35.0 While criteria for estimating the research input are fairly well established, those for measuring research output are by no means generally accepted, and some leading figures in the world of research still assert that they do not know of any satisfactory method of measuring research output. The studies on 'efficiency of research' have not yet led to definite conclusions that can be used by science policy-makers, but knowledge in this field is accumulating rapidly and will certainly have to be taken into account in the near future.

36.0 When the problem is raised of the benefits accruing from research, most people think in terms of fairly direct economic returns from science-based productive activities, either industrial or agricultural. This should never be the only criterion. Too little has been said so far about the social benefits accruing from research and about the important cultural benefits to be derived from the improvement in working standards brought about by the inescapable demands of scientific research for qualities such as honesty, clarity, precision, persistence and a driving determination to achieve excellence. And these characteristics have in turn often influenced development in other fields.

From Research to Production

37.0 But let us now consider the chain of activity constituted by science, technology and production. One line of argument, based on past experience, contends that science and technology grow separately, though a symbolic relation between the two activities is recognized. This was one of the arguments that led the United Kingdom in 1965 to set up a new Ministry of Technology, with its own Advisory Council, in addition to the Department of Education and Science with its (Advisory) Council for Scientific Policy. It is worth noting however, that a Central Advisory Council on Science and Technology has been set up more recently to advise the British Government as a whole on the most effective use of the country's scientific and technological resources, whether in the civil or defence fields or in the public or private sectors.

38.0 A number of science policy-makers in the Soviet Union on the other hand, have assumed that the most fruitful approach is to combine various statistical indicators of the development of closely inter-related fields of knowledge in the complex of the 'Science-Technology-Production' chain. It is claimed that the comparison of the rate of development of a particular field of knowledge in each of the three links of the chain allows definite conclusions to be drawn.

39.0 This second approach implies on a direct casuality relationship between scientific research and technological development, apparently conflicting to some extent, with the 'symbiotic' view described above.

Double Feed Back System

40.0 The two views can however be reconciled by considering the relation between scientific research and technological development as a double feed back system. (Fig.1). As illustrated, there are independent inputs (of manpower, funds etc.) to scientific research and to technological development. The output from research is split into two parts, one of which feeds into cultural and educational channels while the other feeds into technological development. Similarly the output from technological development is split into two parts, one of which feeds into industry, to produce a marketable product or service, while the other feeds back to research in the form of new and improved instruments, equipment, techniques etc.

The Problems of Transfer of Metallurgical know-how and Production Entreprise

41.0 The creation and diffusion of technology is the main motive force for the industrial development and its ultimate result in the economic growth. The technological gap has been aptly identified as one which really marks out the poor countries of the world from the advanced countries. This technological gap is ever widening and the rich countries, because of their ability to apply the spectacular advances made in science and technology to productive efforts, are able to improve their economic position. Whereas the developing countries are unable to do so or at least unable to bridge up the gap in the foreseeable future. It has therefore, been recognised that

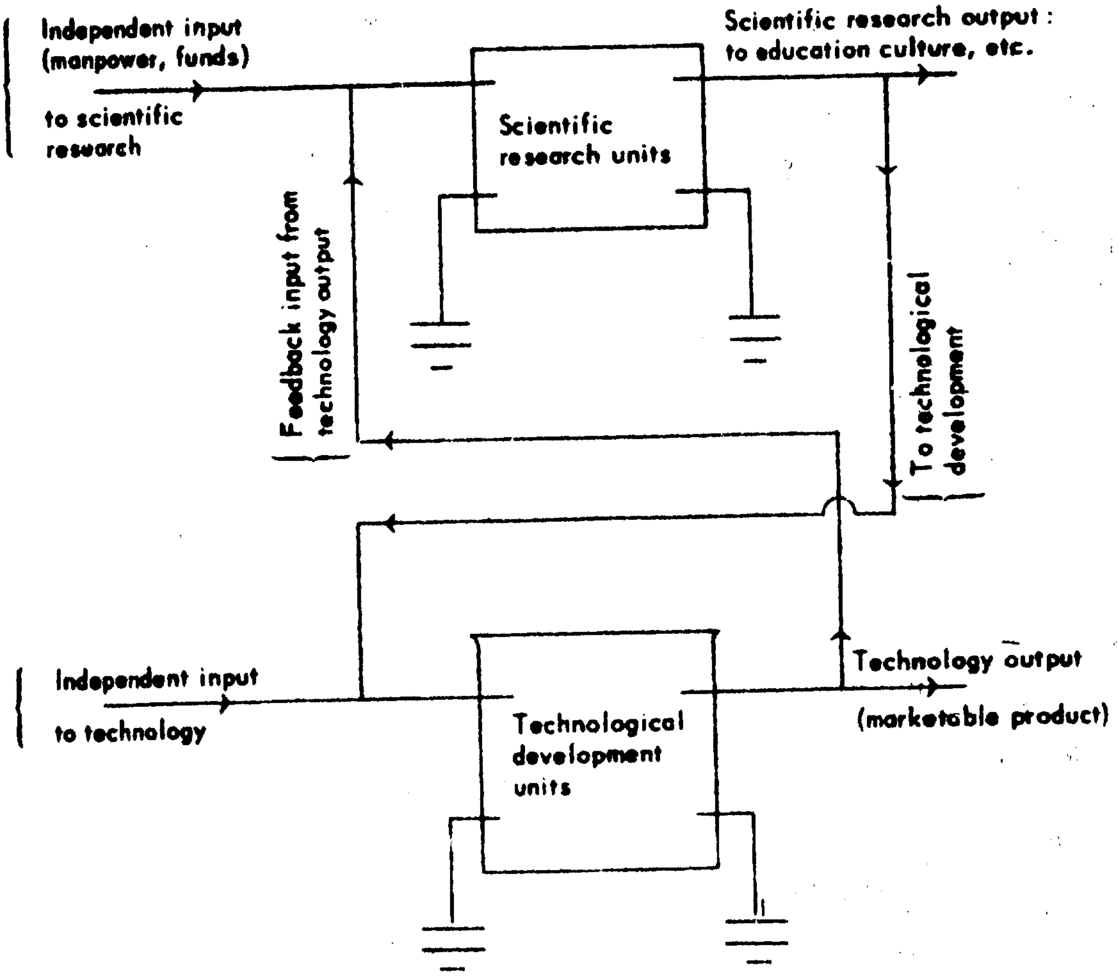

Fig.1 - Relation between scientific research and technological development: Schematic Diagram

Source: Conference on the Application of Science & Technology to the Development of Asia - Unesco Publication one of the major efforts by the developing countries should be to build a sound base for self sustaining growth in the form of major inputs for scientific and technological infrastructure to absorb the necessary know-how.

42.0 The experience of Germany and Japan in the post-war period would amply demonstrate that with a sound technological base, other constraints such as scarcity of capital and labour do not prove insuperable in the reconstruction of the economies. Developing a proper base for the growth of technological infrastructure of the country should thereforebe accorded the highest priority in any programme of industrial development and particularly in the metallurgical field.

43.0 Some of the policy makers assume that once a sufficiently large number of industrial plants are assembled and operated in a country, it can propel itself forward on its own. Even in our own country, this basic concept prevailed when the Government of India sanctioned 3000 and odd foreign collaboration for the import of plants, operational and maintenance know-how.
This concept is totally different as compared with that adopted by the developed countries which will be realised from the fact that side by side with the development of the industry, there is a parallel development of science and technology. When these countries reach the take off stage, they not only attain all the sustained growth but also a self-reliant technology.

44.0 The result of our own efforts for the last decade or so has also amply brought out in relief the necessity to have a close link of R&D establishments with the production units and it is this absence of communication link that has widened the gap or delayed the transfer of technology developed indigenously. This also reflects a great deal on the technological gap that exists between the R&D institutions in the developing and developed countries, which is any way does not convey the incompetence of the scientists and technologists in the developing countries. Several commercial aspects come in the way and before doing so, the well known concepts of the mechanisms of transfers could be discussed in brief.

Possible types of Transfer

45.0 Principally, there are two ways in which the technological infrastructure can be developed in the country, i.e. through transfer from advanced countries and through indigenous research and development. In the case of imported know-how, transfer is usually effected through foreign collaboration and licensing arrangements, generally involving payment of royalties, know-how fees, design engineering fees, import of capital equipment training of local staff and in some cases, even capital participation. Since an overwhelming proportion of the operative technology in the world is in the possession of the private industrial enterprises in advanced countries which have developed it, it is not open to the developing countries to draw upon it except through payment of necessary fees and other forms of payment and because of their strong position, and advanced countries are in a position to dictate terms. Consequently, the cost of transfer is invariably exorbitantly high.

Inhibiting Factors

46.0 Another inhibiting factor in the transfer of technology is the clause that the know-how cannot be shared with other agencies in the country. This is almost insulating the imported technology from the stream of research and development activity in the country and keeping its direction and links with the know-how of the exporting country. Such transfers therefore, really constitute 'pseudo' transfers, as they function merely as inputs for production with no impact in the research and development field.

In a developing country which seeks to widen the industrial process, the expenditure on the import of know-how will continue to grow rapidly.

47.0 Besides, the imported know-how does not contribute to the growth of technological base within the country, but leads continued dependence on foreign sources even where the know-how is repetitive. It is also the common experience that the know-how developed in other countries does not suit the requirements and the economic and social systems prevailing in the country and needs to be adopted through further developmental work, which will not be possible unless there is sufficient competence developed in the country. It is also a common feature that those industrial firms which are in possession of critical know-how link up sales with the know-how so that the import of know-how invariably leads to import of machinery and spare parts. In the absence of free flow of technical data, the indigenous capability for manufacture of machinery, equipment and instruments will not grow.

Efforts in India

48.0 As far as India is concerned, few activities have received such massive support from the Government as industrial research. During the last decade, the total number of scientific and technical personnel employed in R&D establishments has gone upto 75,000 as compared to less than 20,000 in 1958-59. The expenditure has gone upto Rs.1500 million compared to about Rs.300 million in 1958-59. Now that the sizeable infrastructure has been established, questions are often raised and opinions are expressed - what is the nation getting out of the heavy investments in science? Are the results commensurate with investment? Is enough liaison exists between research and industry? This not only applies to the conditions prevailing in India but can be generalised to many of the developing countries as would be evident from speeches of so many scientists from developing countries at the Unesco Conference held at Poona (India) meeting in Dec.1970. Scientists feel that men of affairs, administrators and industrialists do not appreciate their contribution in the true perspective. Industrialists feel that scientists are mainly working in an academic mood and are not realists. So a situation develops in which there is inadequate rapport between scientists on the one hand and administrators and industrialists on the other. There is actually some sort of hiatus between research men and industry. This is basically because of the lack of awareness of the mechanisms of science in relation to the industry.

Mechanism of Transfer

49.0 Mechanism of transfer can be better understood if we realise the fact that innovation chain is too long and has several critical joints and if any one of them snaps off, the process results in failure. Although one may approach the problem of transfer of technology to be a matter of approach, attitudes, aptitudes, problem of identification, resources, development judicious selections at every stage, understanding and participation of entrepreneurs and above all of good management, the mechanism of transfer can broadly be grouped basically into two categories, horizontal and vertical.

Vertical Transfer

50.0 In the vertical transfer, science leads to technology and technology results in hardware. The vertical transfer is quicker and more effective since R&D and production departments function under one management which provides the right feed back and results. The Bhabha Atomic Research Centre in India is a good example of built in Institutional R&D with a closed loop.

51.0 On the other hand, horizontal transfer occurs when the scientific or technological information generated under one context is applied by other firms which improve upon it vertically to meet their requirements.

Horizontal Transfer

52.0 Technology transfer from developed to developing countries which is mostly horizontal can take place in one or a combination of various ways as outlined below:

a. Flow of books, Journals and other published literature;
b. Movement of people between countries including migration and return of immigrants;
c. Foreign investment and associated transfer of know-how and equipment;
d. Import of machinery and equipment;
e. Technical cooperation programmes (multi-lateral, bi-lateral, official, and private) and
f. Licensing know-how, patents and trade marks.

Most of the developing countries adopt all the above methods in the technology transfer.

Essential conditions for successful Transfer of Industrial Technology

53.0 To adopt technology and particularly modern technology in an under-developed country, we need to change:

a. The technology;
b. The social system and human attitudes;
c. Knowledge and human skills; and
d. The physical implements in which modern technology is embodied.

Another important feature is the team approach to the transfer of technology.

Technology Transfer Centres

54.0 To facilitate the transfer of operative technology, a few have suggested that technology transfer centres could play a dominant role. These agencies should not be mere repositories of publication and other technical material but should have strong links with other national and international centres having sources to special technical information and operative know-how. This will ultimately help the various enterprises in the developing countries to obtain information on technical know-how which may be difficult for them to get through normal methods of communication.

55. The role of the Centres should be (i) to advise entrepreneurs, research institutions and other agencies on the most appropriate technology to choose from various alternatives and sources; (ii) to give expert advise on the adoption of imported technology to suit local conditions and also on its effective use by domestic users and (iii) to help in the rationalisation of the processes of inquiry and application to the possible in the region bearing in mind regional similarities.

SUMMARY AND CONCLUSIONS

1.0 Developing countries should realise that the major pre-requisites such as allocation of adequate finance and human resources, recruitment, training and maintaining requisite number of scientists and technicians in proportion and with the scale of specialisation and training according to the national development plan and current science policies are sine-qua-non for implantation and application of science and technology.

2.0 To optimise the limited resources, developing countries should evolve a national policy on science and technology which will ensure that R&D inputs lead to economic and social gains.

3.0 A co-ordinated development of institutional resources for science and technology is essential since the activities of the national research 'net-work' (Universities, Technological Institutes, Centres of Excellence and National Laboratories) are inter-related.

4.0 Conditions favourable to the evolution of the different types of research, fundamental or developmental or adaptive, should be encouraged so as to ensure a continuous exchange of ideas between neighbouring disciplines of techniques.

5.0 Achievement of technological competence is a major priori for achieving self-reliance and sustained growth of the technology. Developing countries should, therefore, build up a strong indigenous R&D base to help in the choice of technologies offered, to assimilate, implant and diffuse the imported technology. However, a certain balance in the distribution of the national efforts towards institutional build up in science and between research activities with different degrees of relevance is inevitable, since adaptation and first stage of application of new scientific or technological knowledge normally take place within a national technological system and not necessarily in the country of original discovery.

6.0 Developing countries should associate their scientists, technologists and management experts in the assimilation and implantation of imported techniques and patented know-how from the inception so that they could absorb the technology within their research and development frame-work and further the diffusion of technology.

7.0 Developing countries should also establish innovation research and promotion centres entrusted with a broad mandate for application of science and technology to development. Such bodies would be truly operational and would have to perform the role of national development agencies mainly geared to technological progress and innovation.

8.0 Since a combined effort of research scientists, technologists, economists and sociologists is a major pre-requisite for an innovation, these centres should employ specialists in the various disciplines to devise methods of transacting new technology into motive sector of the economy and evaluating their economic soundness. Such centres should also include Information and Documentation Units, Design Office, Experimental Workshop, Economic Units, Computer Centre and Training Unit.

9.0 The experience gained and the output of the centres should help the Government of the developing countries in determining the technological policy which can form a vital link between the National Science and Industrial Policy. Most important role of such system should be the feed back arrangements into the National Science and Planning Body.

10.0 While large industrial undertakings and associations of similar firms may be encouraged on work of innovations, medium size industries should receive some sort of protective incentive for developing indigenous technology and development expenditure for a new project or process could be borne by the Government of the developing countries.

11.0 It is also recommended that the Government of the developing countries which are in the initial stage of industrial development and aspiring a very rapid economic growth through industrialisation should ensure a free flow of imported technology. The expenditure on such account may be at least equal to or could be much more than that spent by such countries on their own research and development. However, efforts should be made to build up indigenous R&D base to absorb and adapt the imported technology.

12.0 Developing countries which have already established adequate industrial base in various sectors of the economy should spend more money on indigenous research and development in such sectors than on import of technology. They should also take steps to provide incentives for local industries in order to make them more self-reliant, in particular by granting those local industries preferential treatment of a fiscal and financial nature such as tax reliefs, subsidies etc. Such preferential treatments should be accorded to industries which intend to commercialise the know-how developed by their own efforts as compared to other industries which have been established with foreign know-how and which continue to depend for further development of imported technology. The preferential treatment would apply only in those cases where the industries concerned have developed technological know-how of comparable nature, efficiency and level as the alternate foreign technology.

13.0 In the field of iron and steel and other metallurgical fields, UNIDO has done valuable services in providing technical assistance covering a wide spectrum such as feasibility and pre-investment studies; negotiation of contracts for building iron and steel plants; evaluation ofprocess and projects including expansion and modernization of existing facilities; promotion (developing, implementing, evaluation) of manufacturing industrial projects; development planning on a national and regional level; production of ferro-alloys; technology of steel fabrication; provision of training; marketing, provision of facilities for industrial testing, development of research etc. Such useful forms of technical assistance should be considerably stepped up and more special fund projects should be organised for the developing countries with a minimum ratio of expert to equipment depending upon the technological competence of the developing countries.

14.0 Developing countries should also utilise the bi-lateral and institutional link between scientific institution of different countries. This may be effected by:

i. Exchange of scientists

ii. Greater assistance from UNIDO for dissemination of technological developments amongst the developing nations

iii. Sponsored research and development work amongst the national lines to take advantage of the available expertise and facilities amongst other countries

iv. Establishment of International Market Information Centres and setting up of National Agencies at different developing countries for exchanging information amongst R&D Institutions

v. Setting up of major pilot plants of national importance with the assistance of UNIDO for evaluating the technologies developed or imported.

15.0 Developing countries should also encourage setting up of R&D Boards for major mineral and metal based industries such as Iron & Steel, Aluminium, Copper, Corrosion etc. so that identification of technical problems in the relevant fields become easier and transfer of technology indigenously developed or imported becomes fruitful.

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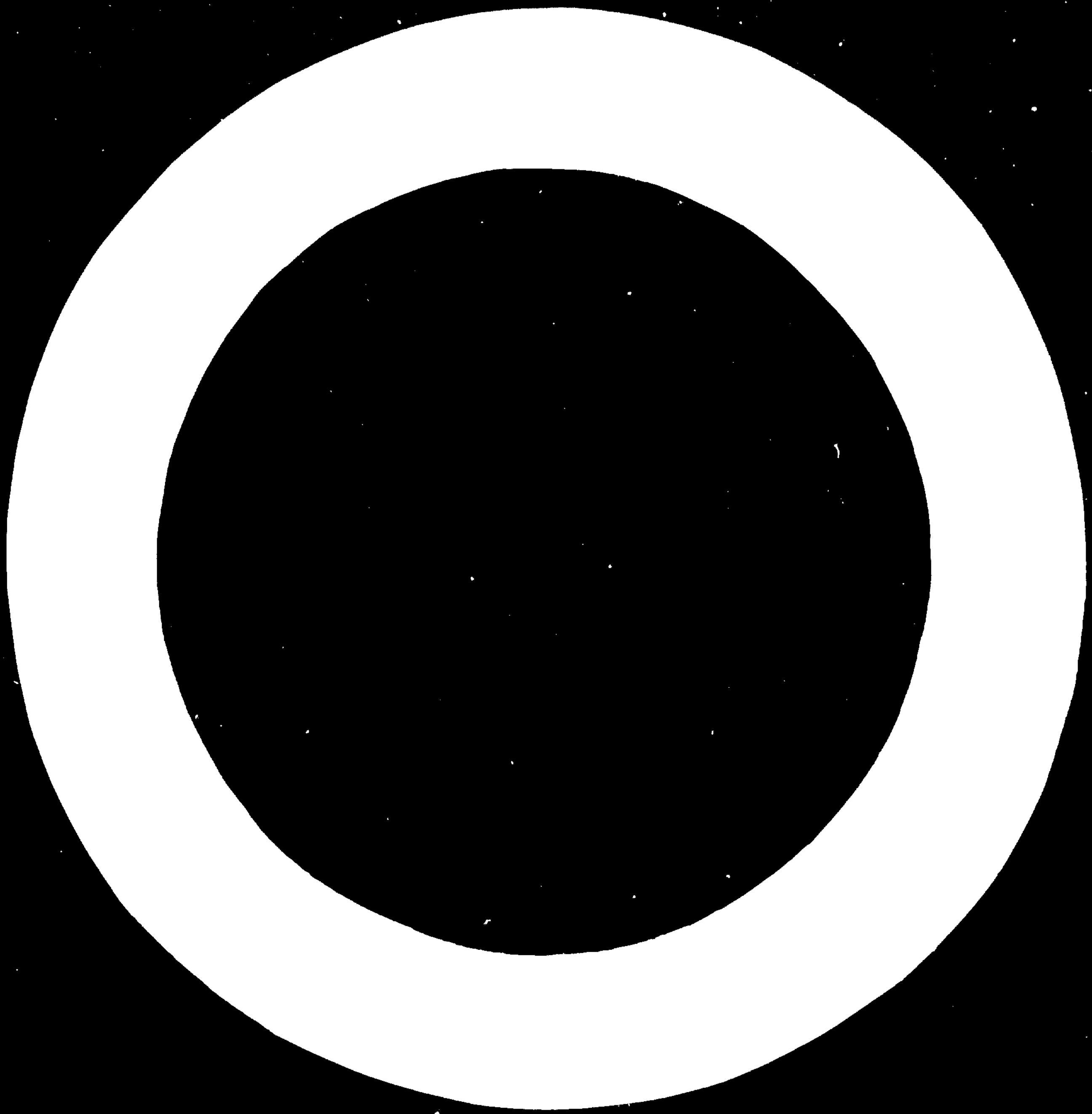
ANNEX

Experience of NML in Creation & Transfer of Metallurgical know-how

During its past two decades of existence, the National Metallurgical Laboratory has gathered a rich and wide experience in the field of creation and transfer of metallurgical know-how.

1.0 In the early years of its working, many of the problems tackled in the Laboratory were self initiated. However, quite a sizeable proportion of these projects have resulted into products and processes which have served well to their licencees. Included amongst these are processes for production of graphite crucibles, carbon free ferro-alloys, production of nickel-free heating elements, production of bimetals, production of wear resistant materials, as well as processes for surface finishing, metal protection against corrosion, electrolytic manganese, aluminising of steel etc.

2.0 An important feature of NML is its multi-purpose pilot plant for ore-beneficiation, wherein the equipment has been so chosen that practically any type of low-grade ore can be processed by any of the number of alternative ore-dressing processes available. This pilot plant has done yeomen's service in the development of mineral based industry in the country and has established processing parameters for such large industrial complexes as steel plants at Tisco, Bhilai, Rourkela, Bokaro and for the future steel plants at Vizag, Salem, and Hospet, as also for fertilizer plants utilising phosphate rocks, pyrites etc., and for the use of non-ferrous metal industry in private and public sectors. Based on through investigations and painstaking data collection, treatment processes have been developed in these pilot plants on the basis of which commercial plants have been successfully designed, constructed and operated.



into separate agreement to ensure this continuing contact with the industry.

6.0 In its attempt to transfer technology to industry, the Laboratory has identified some processes which make it essential to draw upon the services of established consulting engineering firms specialising in these fields. The Laboratory has taken steps to reach an understanding with some of these firms for the complex processes developed by the Laboratory. This is with an idea that the two together will share the process guarantee and engineering responsibility respectively. This convention should ensure sufficient protection to the interest of the would-be entrepreneur of products requiring considerable investment. In medium scale sector, however, there has been successful cases of transfer directly between the Laboratory and the entrepreneur without any formal participation of engineering agencies. The Laboratory has also built up an active cell for Design, and Engineering and the Cell is able to prepare adequate feasibility Reports for heavy capital projects.

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