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PLANNING AND IMPLEMENTATION OF RESEARCH PROJECTS 1/

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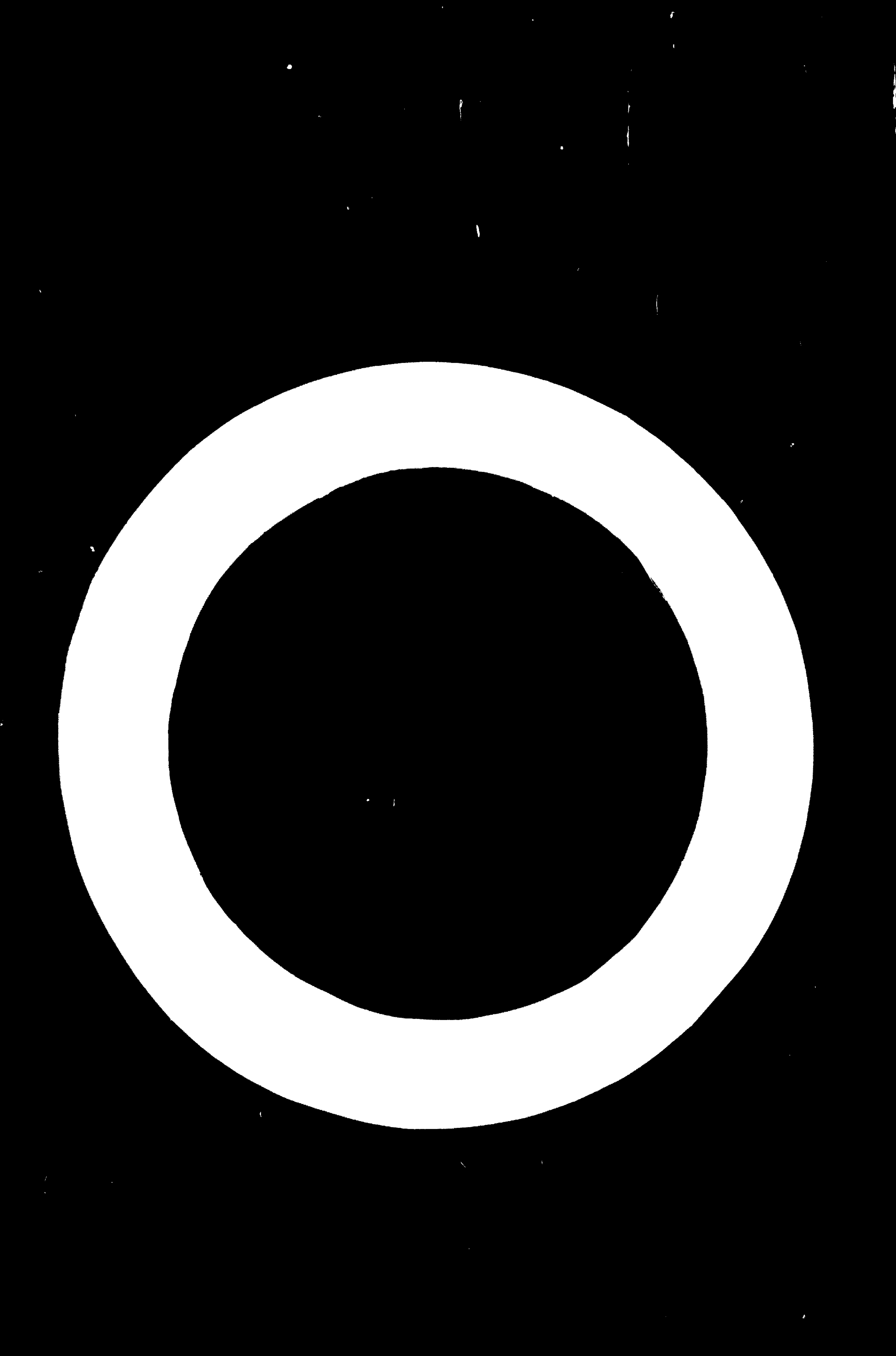


"PLANNING AND IMPLEMENTATION OF RESEARCH PROJECTS"

1 THE BASIC APPROACH

1.1 The Background

Nearly two-thirds of the world's population resides in the developing countries with a total Gross National Product of 12.5 per cent and having an average annual earning of only $ 135 per head. The remaining one-third of the world's population is in the advanced countries enjoying an average annual income of $ 1800 per head and a total Gross National Product of 87.5 per cent. By the time the developing countries proceed to make up this gap by intensive R&D, the gap would tend to become wider pointing to the need for a still faster progress in order to catch up. The growing gap between developed and developing countries in the amount of research and its application, and in their levels of technology is one of the major factors in the increasing disparity in living standards.

R&D, based on a scientific approach, offers the best hope for assisting the developing nations to speed up the processes of their development. There are, however, certain serious bottlenecks within the developing countries in carrying out effective and intensive R&D; insufficiency and imbalance in supply of trained manpower; lack of resources and institutions, lack of attraction to the professional careers, attraction to opportunities offered in highly developed countries thus causing brain-drain, and lack of social and psychological climate favourable to the adoption of the innovations are some of the problems one faces in developing countries.

Any meaningful R&D work has, therefore, to concern itself first with the basic questions what are the national requirements and national constraints; what are the industrial needs within the framework of national aspirations and goals; how should R&D propositions be identified and R&D plans be worked out to meet specific requirements; and what methodology and approach should be employed in implementing the Research Projects. Unless the concepts arising out of these fundamental questions become clear, the very processes of planning and implementing the schemes may remain too weak to serve the purpose.

1.2 The Scientific Approach

Notwithstanding the importance of R&D and the support it provides for industrial progress, planning and implementation of Research Projects cannot be based on only theories and ideas; they have very much to take into account the realities of the situation. Both planning and implementation present different problems in different situations. Solutions to these problems cannot be found in isolation; several parameters like specific place, time and pace of a nation have to be taken into consideration. In the developed countries, the major innovations in R&D are for saving labour and improving health and comfort; the primary materials are imported from the developing countries. In the developing countries, on the other hand, with abundant reserves of unskilled labour and primary materials, technologies to make the best use of them for advancement in the shortest time expending minimum resources are sought for. Thus, the parameters which influence planning and implementation of research projects in industrially advanced countries are quite often totally different from those which govern the planning and implementation in less developed countries. For example, the per capita production in India is only 8% of the world's average for power; 7% for steel and 17% for cement - the basic measures of development; this situation in India is perhaps true of many developing countries. The background with which R&D is approached in these situations necessarily brings in parameters quite often ignored in the planning and implementation of research projects in the developed countries.

1.3 Indigenous R&D capacity

A country without an indigenous scientific and technological capacity, has no means of being aware of its own needs, nor of the opportunities existing in science and technology elsewhere. In the context of the indigenous raw materials, climate, environments and socio-economic conditions obtaining in a developing country, technology imported from advanced countries cannot be a substitute; at best it could be complementary to the indigenous R&D. Building up of an indigenous R&D capacity at all levels, whether it be at the national level, association level or individual industry level, thus becomes a primary task. The building up of indigenous R&D capacity would involve the creation of

(a) suitable machinery for planning and decision making;

(b) an adequate network of scientific and technical services in the various disciplines; and

(c) mission-oriented R&D Establishments.

1.4 The Purpose of Planning and Implementation

The task before a developing country is not merely to get better results within the existing framework of economic, social and industrial institutions but to mould and refashion these so that they contribute effectively to the realization of wider and deeper socio-economic values. The crux of economic development of nations as a result of industrial progress, in particular, lies in achieving the specified industrial R&D objectives expending minimum resources and within the shortest possible time. The Research Projects which form the components of the R&D objectives, therefore, have to be planned, pursued and implemented in the most efficacious manner.

The object of planning is, therefore, to clearly identify the industrial needs of today and tomorrow and to assign priorities on the basis of both the needs and the resources. The object of implementation is on the one hand to ensure that the necessary wherewithal in terms of finances, manpower, equipment, etc., are made available, the work is pursued by the right men in the right manner; and the findings of research are translated into productive stream with the least possible delay at minimum cost.

contd.2

2 CONCEPT OF TECHNOLOGY TRANSFER IN PLANNING R & D PROJECTS

2.1 The Complete Orbit

Industrial R&D work is a close-ended effort in which the entire orbit is visualised; such of the links in the orbit as are already available from elsewhere are taken in to form the orbital loop and such of the links which are not already available are produced by those who are charged with the task of industrial R&D. At one extreme end there have been cases where the missing links in the loop are those which call for basic or fundamental research of a very high order; and at the other extreme end are cases where most of the links of the loop have been readily available, and all that an industrial R&D unit need to do is to put them all together to get a complete loop. Thus, industrial R&D, though complicated in its nature depending on the basic concept of the complete orbit, covers several varieties of situations which have to be met with. Every link in the orbit is essential and each link represents some transfer of technology. The transfer may be conceived as from one link to another or as direct links forming complimentary components of the total orbit.

2.2 The Means of Transfer

Like in trade and commerce, irrespective of the affluence or otherwise of a country, international collaboration in science and technology has become necessary. Technology has to be transferred from one country to another. Technology has also to be transferred within the same country from one level to another or from one point to another. Technology transfer can take place in one or a combination of various ways, such as dissemination of information through published literature, conferences, lectures, various communication media, movement of people, discussions, visits, etc, through the processes of standardization, through foreign investments and associated transfer of know-how, through input of machinery and equipment, and various technical cooperative programmes through licensing know-how, patents and trademarks.

2.3 Transfer from Overseas

In most developing countries, technology transfer from overseas is very often tied up with financial aid. Many times, under these aids, excellent projects are got completed. It is not, however, always that a second project of the same type can be put up without importing the know-how again. This is because the system of technology transfer and limitations of the normal channele of commercial transfer and the best means of overcoming them have not been understood. Within a given society technical change involves a process of invention, innovation, and imitation as the means of diffusion of the new techniques. But accepted technology transferred to another society involves commercial risks, needs adaptation so that the transfer becomes more an innovative than an imitative process. Therefore, for the transfer of technology to take place effectively, the transferee should be competent and equipped enough to receive, assimilate and utilise the new technology and adapt it to its own conditions and also adapt itself to the requisites of advanced technology; the transferer should also be willing and cooperative in this process.

The process integrates a large number of complementary elements, intimately connected in effective transfer. To establish modern technology in a developing country, changes are needed in social systems and attitudes, knowledge and human skills and the physical implements for embodying modern technology. In practice, large firms seem to have relatively little difficulty in gaining access to required techniques. The main problem appears to relate to small and medium sized firms which may require institutional help to identify and adapt the most appropriate technologies.

In matters of details, the system for transfer of technology could considerably vary from country to country depending upon the political and economic set up of the country. It could vary from situation to situation depending upon the environmental conditions. For example, one of the ways of transfer is from a foreign enterprise to its branch or to its wholly sub-sidised firm in the developing country. This leads to direct foreign investment as part of the transfer of technology. Many of the developing countries do not participate in such enterprises and have probably only very limited control over the functioning of the enter-prise. The second form of technology transfer may be a foreign organization selling the use of the process/manufacture of the product to a producer in the deve-loping country through a licence. This method does not generally give the licenser any control over the manu-facture of the product, its quality or in safeguarding that the process is not utilized in a third country. On the other hand, it results in continuous payment of royalties by the licensee, which in turn could lead to adverse balance of payments. The third method often used is by providing turnkey projects according to which the foreign enterprises undertake to build all the installations and machinery required for working the process and also to give performance guarantees for a certain period.

2.4 Transfer Within the Country

Transfer of technology within the country is perhaps even more important. This transfer is naturally to be both vertical and horizontal, but what is most important is the proper interfacing and a proper national linkage so that, the know-how is transmitted from one level to the next and is absorbed and used. Therefore, R&D activities spreading in the required measure from one level to the next, covering not only the manufacturing industries but also the users, are important. Unless technology is transferred properly, technological advancement will not proceed at a pace at which it should, and any R&D conducted without being clear about its interfaces might become an infructuous expending of resources and efforts.

2.5 Interfaces in the System

The most important single factor which would contribute to the success of technology transfer - whether it be in a developing country or a developed country - is the creation of the proper interfaces in the system. In any given circumstance, every centre of technology has four clear interfaces - two in the vertical direction and two in the horizontal direction as illustrated in Figure 1(Page 8-A).

The upper vertical interface takes the inputs and the lower vertical interface delivers the output.

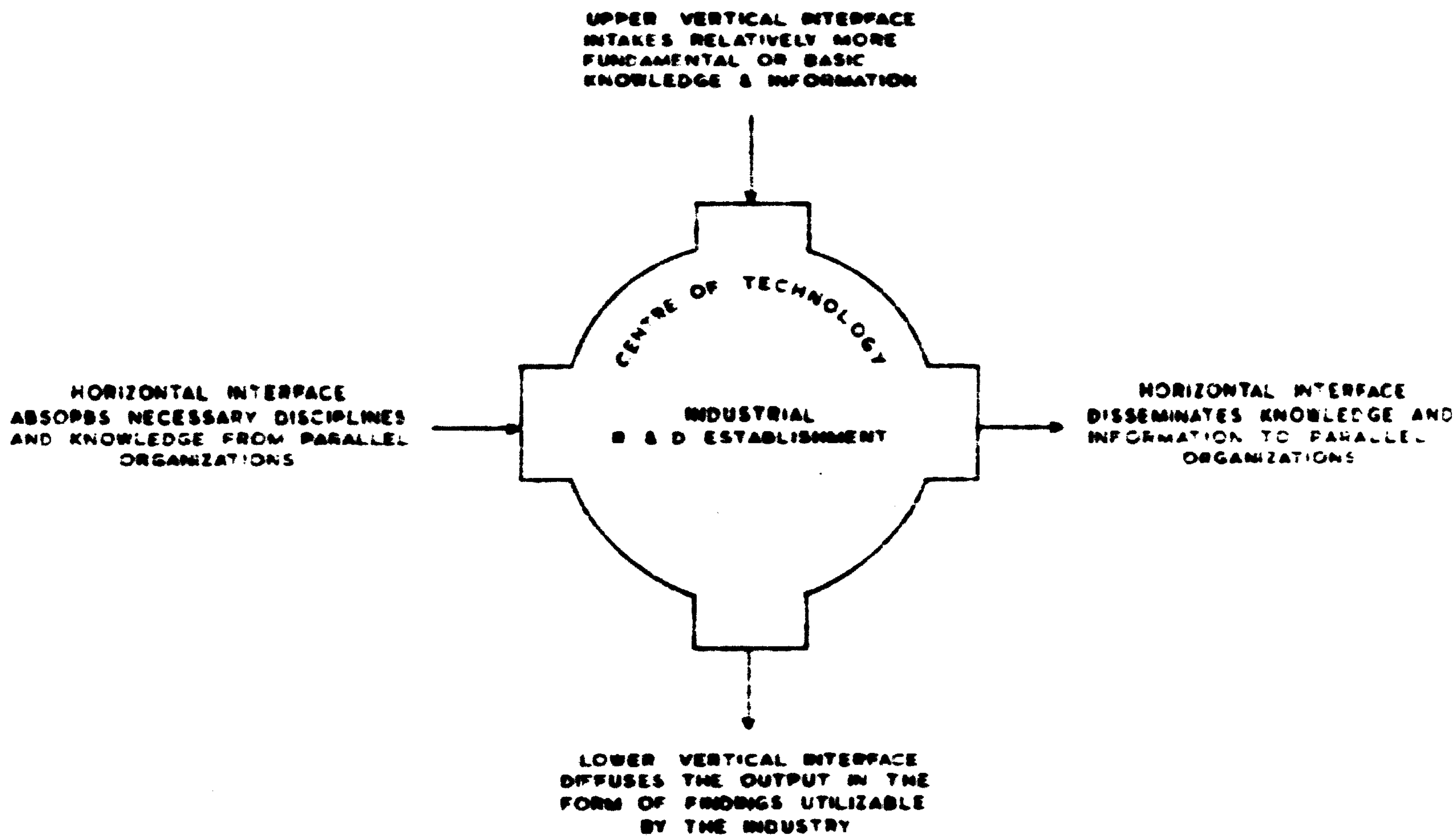
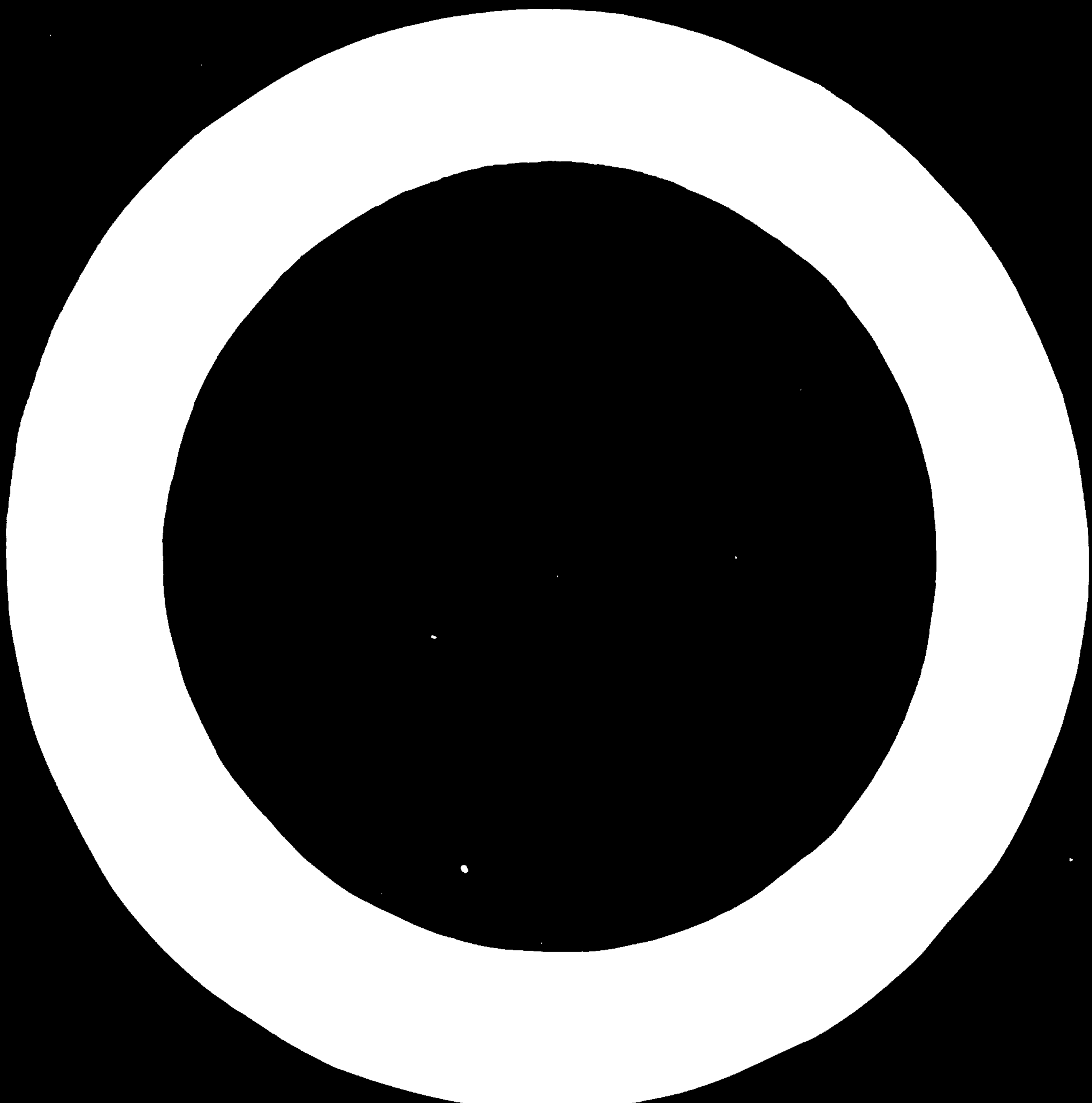


FIG. 1 THE TECHNOLOGY TRANSFER INTERFACE SYSTEM



At the upper vertical interface the relatively more fundamental or basic knowledge or information or the more sophisticated aspects of the know-how and technology are put in. These are processed in the centre and converted into more readily utilizable forms given out as the output. In reality this vertical transfer results in the pure science at the top face leading through successive interfaces to more applied forms of technology till finally the last output of technology results in a concrete hardware or a definite usable service to the society or industry.

In the horizontal direction, one of the interfaces feeds the centre with the scientific, technological, economic and social information generated under one context for application in its own processes and at the other interface disseminates the know-how generated within itself for application under other contexts.

Whilst this concept of interfacing is a basic one and the philosophy of interfacing is an essential pre-requisite in any effective system for transfer of technology, it is not always necessary that the centre of technology be a separate institution or organization. It is possible to bring about such a transfer even within the framework of a single institution. Again it is also important to emphasize that these institutions need not necessarily be those devoted only to technology transfer; they could just as well be universities, information centres, technological institutions or industrial establishments.

2.6 Information System in the Transfer of Technology

Information system is an important aspect in the system for transfer of technology. Effective utilization of available knowledge is possible only when the capacity to collect, store, retrieve, interpret and use all the available knowledge has been created. For example, a group of research laboratories in USA recently spent about $ 250,000 to perfect equipment for translating written matter electronically. After five years of work, they discovered that USSR had already investigated the same problem and that results of their work had been available all along. There are many such instances and these are the situations which turn both faces and budgets red; research teams traditionally seek to side step them by scurrying through current journals and by initiating each new project with insufficient literature search. A thorough literature search is a gigantic task. Thirty million technical books already on the shelves are being added to at the rate of almost 600 a day. In addition, about 100,000 special journals are published every year - 35 per cent of them carrying some 3 million articles dealing exclusively with science and engineering. By extrapolating the growth rate of scientific literature, it may be conjectured that by the end of the present century the total number of scientific journals published would reach nearly one million. Thus the system of collection and compilation, translation, and transmission of information published, - literally in millions of technical and scientific papers, books, journals, conference proceedings in hundreds of different disciplines and in many languages - is perhaps one of the most important factors in the development and transfer of science and technology.

Thus this determines the imperative need for an adequate and competent information service. This would greatly help in identifying the specific Research Projects, and hence the use of scarce research resources can be greatly improved. The building of this service should include not only details of work in progress throughout the world, defined by economical zones according to an appropriate coding system, but also details of R&D organizations, establishments and expenditures. This would not only assist the researcher but also facilitate the determination of priorities.

2.7 Optimization of R&D Effort

In every given situation, there are always two possible alternatives - one would be to start developing one's own technology through completely indigenous R&D efforts and then to use it; the other would be to apply the available scientific and technological knowledge in whichever quarters it might be be available and to assimilate and use it as a base for further development and innovation. The former is most often very expensive and time-consuming but could occasionally result in a completely new technology not hitherto known; but the latter has the advantage of immediate utilization of the readily available knowledge and experience, thus making the R&D effort confined essentially to the adaptation of the available know-how to the given circumstances and for the further development and innovation. Which of the two alternatives is better suited depends entirely on the several parameters involved in a given situation but whichever is the alternative adopted, the R&D planning and the "trimming" of Research Projects have to fully take into account these considerations.

contd.3

3 R&D PLANNING AS RELATED TO INDUSTRIAL BASE

3.1 Industrial R&D an Integral Part of Industry

For any meaningful and successful Industrial R&D, the industrial R&D work has undoubtedly to be an integral part of the concerned industrial activity in a country. Whilst the purpose or the role that Industrial R&D has to fulfil is substantially the same in any industrial activity, the industrial activity itself is so varied and complex that a single definition is rather impossible.

3.2 The Influence of Status of Industry

The organization and management of the industry greatly differ - it could be an industry owned by the State; it could be an industry in which both the State and the private enterpreneurs are participants; it could be a cooperative industry where several agencies have pooled their resources and experiences; it could be an industry owned by a private business house or an individual. Some of the industries could be small and some big. Whatever may be the type of the industry it should have an R&D base - it could be a base of its own; it could be a base shared by others or it could be a state-owned national base. In general, in most of the developing countries the following three predominant situations are prevalent:

(i) There might be a large number of small industries that cannot individually afford an R&D base of a worthwhile size or strength; sometimes these industries cannot afford even one man or one equipment. In order, therefore, to be able to have an R&D base with a reasonable capacity to serve the industry, the industries with similar or common interests join together to establish a joint R&D base, or the R&D services are provided to them at national level.

(ii) Quite often the disparity in the size of the industries within the same industrial activity could be so large that the larger industrial organization can afford to have their own R&D unit and become bigger and bigger and grow stronger and stronger. Such a growth is a definite advantage in certain situations in certain countries, whilst in certain others such a growth could lead to imbalances in social, economic and political affairs. When cooperative effort is resorted to with the disparity of the cooperating industries being wide, the cooperative effort in R&D becomes more difficult and quite often a moderating force such as governmental involvement or participation might become necessary to keep the cooperation alive.

(iii) In the relatively less developed and the developing countries many industries owe their origin and technological allegiance to foreign organizations either because they are offshoots of such industries elsewhere in the advanced countries or because they have obtained the know-how and technology from them. Such industries quite often become technological parasites on the parent company and leave the entire responsibility for the R&D to their principals; sometimes even R&D needs arising out of purely local situations are also referred to the principals for a solution.

3.3 The Nature of Management Support

An important negative point in many of the firms is the inadequate active management support for the R&D function. R&D can be looked upon either as an essential vehicle for effecting improvement in technology and productivity and for achieving import substitution for the benefit of the company or merely as a status symbol, if not a necessary evil. When the latter is the case, the research activity inevitably suffers and should be guarded against.

3.4 The Indian Trend as an Example

For example, India started in the industrialization race rather late, perhaps only after independence in 1947 in the true sense; in view of the existing situations, it became necessary for her to adopt some short-cuts to develop. This involved building large public sector enterprises on imported technology, resorting to foreign collaboration on an extensive scale, simultaneous development of a large group of industries, and multiple development of units in the same industry. Likewise, the private sector companies which have foreign liaison or capital have provided an efficient means of bringing in technological R&D competence. In this process, the country has built up a considerable technical infrastructure; the government laboratories have begun to lay emphasis upon industry oriented research in recent years and have also been trying to evolve technological forecasting to meet the technological needs of the eighties. Industry, on the other hand, has tried either to build its own centres or to associate itself with various laboratories and universities to get their R&D work done. Many industries have already established their own R&D units - some of them large and well-equipped and well-manned. Many other industrial houses have plans to establish design and research centres. As a corollary, many engineering consultancy units have also sprung up in recent years for aiding translation of scientific research into commercial technology.

The status of small scale industries in India as evident from Table 1 below is perhaps typical of developing countries.

TABLE 1

PLACE OF SMALL SCALE UNITS AMONGST THE FACTORIES REGISTERED UNDER THE FACTORIES ACT IN INDIA

(Year 1966)

	All factories	Small-scale factories	Percentage contribution
Number	34,573	32,050	92.7
Employment (in thousands)	2,861	1,351	47.2
Investments in fixed assets (in million rupees)	29,670	3,350	11.3
Gross Output (in million rupees)	56,870	19,690	34.6

Source: Central Statistical Organization, Government of India

This situation at once emphasises the need for cooperative R&D work and also participation of government in this effort. This could be the case with almost all developing countries. Purely in technical terms, therefore, one could say that the technological gap between a developed country and a developing country could be considered as narrowing down in this process itself. But, given the point from which a developing country starts on the process of development, it is even more behind an advanced country in research and development than in the volume of industry.

3.5 Pattern of Research as Related to Industrial Trends

Again taking the Indian case as an example, a sample survey recently conducted by the Industrial Credit and Investment Corporation of India (ICICI) indicates that in keeping with the functional and financial limitations, the pattern of research undertaken by the companies seems to concentrate largely on the omnibus group of activity called 'Import Substitution'. Under this nomenclature, activities relating to simple process improvements, substitution of raw materials, designing and manufacturing simple components for the machinery installed, are included. At times improvements in quality and testing are also included under this category. Small firms with a sales turnover of upto Rs 50 million per year devote their attention mainly to this type of activity. As they grow in size, the firms tend to adopt more capital-intensive R&D like process modification, product adaptation, diversification in production, etc. Product innovation and development seem to be mainly confined to very large business groups as seen from Table 2 below:

TABLE 2

PATTERN OF RESEARCH UNDERTAKEN BY ICICI SAMPLE COMPANIES

Range turnover	Number of Companies			
	Import substitution	Product improvement & adaptation	Process modification	Product Innovation
Rupees				
Up to 10 million	9	3	2	..
10-50 million	22	14	18	2
50-150 million	14	13	14	4
Over 150 million	10	10	10	8

The table shows that import substitution is undertaken by R&D departments and centres of all the 55 reporting companies. However, it is interesting to note that 8 out of 10 companies with a turnover above Rs150 million also concentrate on product innovation as against only 2 out of 31 companies below a turnover of Rs 50 million.

The pattern of R&D activity undertaken by the companies also differs from industry to industry. The chemical industry seems to have made significant strides in import substitution, product innovation and process adaptation and improvements. Illustrations in this respect can be cited from dyestuff, caustic soda, fertilizers, cement and ceramic industries as also those based on raw materials of forest origin. In the field of electrical and electronic industries too, product development, replacement of copper by aluminium and development of technology requiring high degree of manual skill, have been achieved. In the field of metallurgy, progress has been made in developing alloy compositions which minimise the need of imported alloying elements. In the field of engineering are instances of development of tools and engineering products, special purpose machines, process refinements and simplications and increased sophistication in the fabrication of equipment, mostly achieved by employing indigenous talent.

With the type of developments taking place as indicated above, a developing country finds that the scope and objectives of R&D organizations keep continually shifting in emphasis and with this the planning, the programmes and the priorities on Research Projects.

contd.4

4 TECHNOLOGICAL FORECASTING AS A TOOL IN PLANNING R&D

4.1 Planning and Technological Forecasting

The industrial objectives arising from the national requirements, overall economic plans and national aspirations, policies and programmes have to be directly linked to a system of technological forecasting. This system has to be considered in its entirety and not in pieces. An R&D organization should have been ready yesterday to meet the problems of today. Undoubtedly, finding solution to today's problems would become the priority concern of an R&D organization, but irrespective of what happened yesterday or what is transpiring today, the primary responsibility falls on the R&D organization to get ready to meet the challenges of tomorrow. It is here that the technological forecasting becomes an important constituent of planning activity in any R&D work.

4.2 Forecasting Systems

Two types of Technological Forecasting are possible - the Nominative Technological Forecasting, and the Normative Technological Forecasting.

4.2.1 The Nominative Technological Forecasting: This is of an exploratory nature. It identifies the basic features of a selected technological system in its entirety projecting the technological changes over a period, say 5, 10 or 20 years and thus outlining the required strategy in research approach. In other words, it projects the needs and the technological possibilities, and defines the optimum directives with reference to the general framework.

4.2.2 The Normative Technological Forecasting: This is in the nature of setting concrete goals. It identifies the basic requirements in technological terms to fulfil the needs of the society in its entirety, projecting these needs over a period, say 5, 10 or 20 years and relating them to the socio-economic strategy of the nation.

Normative technological forecasting is thus related to the socio-economic objectives to be realised within a set time and takes into account the developments necessary for achieving the set socio-economic objectives.

4.2.3 Technological Forecasting becomes complete in a given situation when both Nominative and Normative systems are injuncted and integrated in such a manner that the resultant forecast takes into account the weightage given to each of the aspects by the society or the nation. Perhaps, in most of the developing countries, the socio-economic aspect may get precedence to the nominative technological forecasting, but when unusual and totally different local conditions warrant or when national priorities demand immediate or early break-through in any particular direction, the nominative system would get the same weightage.

4.3 Survey, Data Collection and Analysis

The basis for any such technological forecasting therefore, requires extensive surveys, collection and analysis of data with a view to being able to provide a coherent studied and rationalised framework for the future. Usually systematic and scientific data are meagre, specially in developing countries. The lack of such data presents the first hurdle in any system of forecasting. This enjoins on the developing nations to cultivate the necessary attitude and understanding towards scientifically and pragmatically assimilating the available data relevant to the national socio-economic and geographical environments and deriving such assistance from foreign sources as would augment the national settings. Gradually a sound scientific base gets built up. The survey and data collection activity could cover the entire spectrum of activities with which an industry is connected. The field covered may be scientific, technological, marketing, managerial, economic, social and in certain cases even political as all these would ultimately have a bearing on what an industry should do tomorrow.

4.4 Discussions and Seminars

Another essential pre-requisite for effective technological forecasting is intensive discussions and seminars amongst those concerned and interested in the field. The discussions could be at personal levels or in groups, committees, conferences etc, representing the whole spectrum of science and technology, drawn from industry, universities and government. Such meetings would help provide cross-fertilization of ideas towards identifying the R&D needs, advising on selection of problems and helping avoid duplication of work done elsewhere in the country or abroad. The industry's representatives would also make feed-back loop into the industry to inform them of the capabilities of the R&D establishments. An important aspect which is often forgotten is that technological advances in a particular field are quite often catalysed or accelerated by the technological advances and the techno-economic developments even in the fringe areas of allied and also in other parallel fields, for example, anyone who is concerned with one building material would have not only to have a thorough knowledge of what is happening in that particular field but also in the field of other building materials, as otherwise he may be left behind in the keen race which is a necessary part of today's progress in the world. Yet another point of importance is that these discussions and seminars must be so organised and conducted that they serve the purpose of feeding the technological forecasting. They should cover as wide a range as possible while retaining the depth necessary for the purpose.

4.5 Reference from Industries

A powerful means of getting the necessary inputs for the technological forecasting is from the references that industries make and from the references those engaged in technological forecasting pose to the industry. These again could be by way of personal visits, inspections, studies, communications, discussions etc. An important aspect which has to be kept in view here, specially in the case of developing countries, is the fact that an industry might be in such a stage that it itself might not be aware of its own problems and may not have any appreciation of what R&D can do for it. Similarly, those engaged in R&D activity might have a limited understanding of what are all the parameters which have to be simultaneously considered to fulfil the needs of the industry. Both these will get sorted through these mutual visits and discussions.

4.6 Special Studies and Communications

Notwithstanding the outcome of surveys, data collection and analysis, and the discussions and seminars, special studies and individual communications will be indispensable before arriving at the inputs for technological forecasting. The communications may be with the concerned industries and related interests within a country or with those knowledgeable in this field outside. The special studies might have to be sometimes wide or sometimes deep depending upon individual situations.

4.7 The Need for Periodic Review of Forecasts

As a result of the endeavours made in the light of what has been discussed above, one would arrive at the necessary inputs for technological forecasting; some of the inputs would be of quantitative nature and the others would necessarily be of a qualitative nature. All these put together will enable to arrive at the forecast. A single forecast made at a given point of time and space, whatever be the period it covers, cannot be considered ever consistent. In fact, inputs, as the country develops, change both in terms of quantity and quality and the fore-casts would have to be reviewed and revised periodically to synchronize with the latest requirements, knowledge and experience assimilated. At the same time, such revisions should ensure the imperative continuity of the set of existing objects to avoid loss of resources, time, capital, manpower etc, already put in. Any violent change considered essential should be thoroughly weighed with its inherent overall effects before arriving at a final decision.

contd.5

5 IDENTIFYING SPECIFIC RESEARCH PROJECTS

5.1 The Need

5.1.1 Whilst a sound technological forecasting, a clearly defined programme within the concepts of technology transfer and with adequate appreciation of the nature, character, type and size of the industrial base, would provide a rational basis for R&D planning, this base itself will still remain very broad and wide. In order to transform these into concrete steps, towards achieving the desired industrial progress, the most important process in the planning of Research Projects is identification of specific projects.

5.1.2 In general, many industries feel that the utilisation of the results of their own research laboratories or technical centres has been more satisfactory than that from outside agencies. One reason for this is, of course, the fact that these industrial laboratories work on products and processes that are identified in advance to be commercially worthwhile. But, there is also usually a close coordination between the marketing side and the research side in setting priorities for research with constant feedback from the market to the laboratory.

5.2 The Process

Identification of specific Research Projects is an art by itself and requires almost a similar type of exercise as detailed for arriving at a technological forecast. In any R&D work, there is invariably a temptation at some point or the other in the stream to branch off or diversify; it is not uncommon to find a research worker having started with a certain set research objective, ending up with a fine work altogether for a different objective. Whilst a certain amount of freedom is necessary for intellectual advancement even in industrial research, it is important to ensure that the movement is substantially straight towards the set objective instead of deviating on the way losing track of the main direction. Projects for R&D work would have, therefore, to be very clearly identified in specific terms.

Based on such an exercise an industrial R&D organization in India devoted to cement and concrete has, for example, planned a set of objectives for itself as given in Appendix I (Page 27).

5.3 Mission-Oriented Approach

Whilst identification of Research Objectives as discussed thusfar will enable the total planning of the R&D required, the process of planning for achieving concrete results will not be complete until individual "Missions" are identified. These would be Missions flowing out of the planned Objectives. These Missions would have to be even more directly tied with time and cost targets than the Objectives. For example, arising out of the R&D Objectives set out in Appendix 1, the same industrial R&D organization has worked out a set of Missions as given in Appendix II (Page 30). These are only the first set of Missions. There can be many more Missions. The question of giving up any Mission at any stage does not normally arise since it is directly linked with the Objective sought to be achieved.

5.4 Mission-Oriented Research Projects and Their Priorities

In order to fulfil a Mission, several Projects or problems may have to be tackled, some of them might be successful; some might not be successful; some might have to be abandoned half-way through - all for valid reasons. Notwithstanding what happens to the individual elements which constitute a Mission, the Mission by and large remains unchanged and stable. For example, if the Mission is to develop a crane of a large capacity within a certain time and cost target, one may have to tackle several problems - some may be interdisciplinary; some may be unidisciplinary falling essentially in the discipline of mechanical engineering, structural engineering, electrical engineering or metallurgy. As one proceeds, one might find that one has to give up a certain line of approach and take another line of approach; emphasis on one discipline may have to be more than another and so on. This would be possible in the Mission-oriented approach. Two examples of R&D Objectives, the Missions flowing therefrom and the Projects through which the Missions are sought to be fulfilled are indicated in Appendix III (Page 33). The priorities can then be assigned taking into account the needs, the Missions to be fulfilled vis-a-vis the available resources.

APPENDIX I

FIVE YEAR PLAN
OF
PROGRAMMED R & D OBJECTIVES
of an Industrial Research Institute in India

(Ref item 5.2)

1 IMPROVEMENT IN METHODS OF QUARRYING IN CEMENT INDUSTRY

2 IMPROVEMENT IN FUEL ECONOMY IN THE MANUFACTURE OF CEMENT

3 IMPROVEMENT IN SIZE REDUCTION IN THE MANUFACTURE OF CEMENT

4 EVOLVING METHODS FOR THE CONTROL, COLLECTION AND UTILIZATION OF DUST IN THE MANUFACTURE OF CEMENT

5 IMPROVEMENT IN THE LIFE OF REFRACTORY LININGS IN CEMENT KILNS

6 FORMULATION OF RECOMMENDATIONS FOR OPTIMUM INSTRUMENTATION IN CEMENT MANUFACTURING PLANTS IN INDIA

7 DEVELOPMENTS IN CEMENT MANUFACTURING MACHINERY

8 IMPROVEMENTS IN METHODS OF HANDLING AND PACKAGING CEMENT

9 UTILIZATION OF INDUSTRIAL WASTES IN THE MANUFACTURE OF CEMENT

10 UTILIZATION OF NATURALLY OCCURRING BUT RELATIVELY LOWER GRADES OF RAW MATERIALS IN THE MANUFACTURE OF CEMENT

11 DEVELOPMENT OF FIBRE REINFORCED PRODUCTS SUCH AS ASBESTOS CEMENT PRODUCTS

12 DEVELOPMENT OF NEW CEMENTS

13 DEVELOPMENT OF RAPID METHODS OF ANALYSIS OF CEMENTS, CEMENT PRODUCTS AND THEIR RAW MATERIALS

14 REDUCTION IN THE INCIDENCE OF CORROSION OF STEEL IN CONCRETES OF SPECIAL COMPOSITIONS AND EXPOSED TO AGGRESSIVE ENVIRONMENTS

15 DEVELOPMENT OF SPECIAL CONCRETES AND SPECIAL CONCRETE MATERIALS

16 DEVELOPMENT OF METHODS OF DESIGN AND MANUFACTURE OF HIGH STRENGTH CONCRETE

17 IMPROVEMENTS IN THE DURABILITY AND WEATHERING OF CONCRETE

18 DEVELOPMENT OF DEPENDABLE NON-DESTRUCTIVE METHODS OF TESTING CONCRETE

19 FORMULATION OF RECOMMENDATIONS FOR THE MANUFACTURE OF READY MIXED CONCRETE IN CONDITIONS AS PREVAILING IN INDIA

20 DEVELOPMENT OF LIGHT WEIGHT AGGREGATES AND CONCRETES

21 IMPROVEMENTS IN THE MANUFACTURE OF PRECAST CONCRETE UNITS

22 RECOMMENDATIONS RELATING TO UTILIZATION OF PRECAST CONCRETE ELEMENTS IN CONSTRUCTION WITH PARTICULAR REFERENCE TO PREFABRICATION

23 DEVELOPMENTS IN CONCRETE MANUFACTURING MACHINERY

24 DEVELOPMENT OF RATIONAL METHODS OF DESIGN OF STRUCTURES REQUIRED IN A CEMENT MANUFACTURING PLANT

25 EVOLVING RATIONAL DESIGN PROCEDURE FOR STRUCTURAL CONCRETE

26 DEVELOPMENTS OF RATIONAL METHODS OF DESIGN OF MASS CONCRETE STRUCTURES

27 EVOLVING RATIONAL PROCEDURES FOR DESIGN OF CONCRETE PAVEMENTS

28 STANDARDIZATION OF IMPROVED METHODS OF TESTING CEMENT, CONCRETE AND RELATED MATERIALS

29 FORMULATION OF RECOMMENDATIONS ON SITE ORGANIZATION FOR CONCRETE CONSTRUCTION

30 RATIONALIZATION OF METHODS OF CONCRETE CONSTRUCTION

31 IMPROVEMENT IN THE METHODS OF DESIGN AND CONSTRUCTION OF FORMWORK, SHUTTERING AND SCAFFOLDING FOR CONCRETE CONSTRUCTION

32 IMPROVEMENT IN THE METHODS OF EXTREME WEATHER CONCRETING TECHNIQUES

33 FORMULATION OF RECOMMENDATIONS IN THE FIELD OF LOW COST CONCRETE HOUSING

34 DEVELOPMENT OF CONCRETE FINISHES

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APPENDIX II

PROGRAMMED R&D WORK

FIRST SET OF MISSIONS

of an Industrial Research Institute in India

(Ref item 5.3)

1 Utilization of High Magnesia Lime Stone in the Manufacture of Cement

2 Evaluation of the Incidence of Corrosion of Steel in Pozzolana Cement Concrete

3 Utilization of By-product Gypsum from Fertilizer and Chemical Industries in the Manufacture of Cement

4 Evaluation, Application and Standardization of EDTA Methods of Analysis of Cement and Cement Raw Materials Suitable for Adoption for Routine Analysis and for Quality Control Purposes in Cement Plants

5 Development of Rapid Instrumental Methods of Analysis of Cements and Cement Raw Materials

6 Design and Development of Improved Packaging for Cement

7 Development of Methods of Design and Manufacture of High Strength Concrete

8 Use of Chemical Compounds for Obtaining High-Early Strength Concrete

9 Evaluation and Standardization of Ultrasonic Pulse Velocity Method of Non-destructive Testing of Concrete

10 Development and Standardization of Quick Tests for Determining the Deleterious Constituents in Water for Mixing and Curing Concrete and Development of Necessary Kit.

11 Strength and Behaviour of Reinforced Concrete Members Under Combined Bending, Shear and Torsion

12 Evaluation and Technical Appraisal of Design of Concrete Poles

13	Development of Design Methods for Concrete Dams to Resist Dynamic Forces
14	Technical Appraisal of Design of Concrete Pavements
15	Determination of Cement Content in Hardened Concrete
16	Development of Improved Grinding Aids for Grinding Cement Raw Materials and Clinker
17	Formulation of Guidelines for Collection of Dust and its Utilization in Cement Plants
18	Formulation of Recommendations for Increasing the Life of Refractory Linings in Rotary Kilns
19	Design of Totally Indigenous Preheaters
20	Development of Bulk Supply of Cement
21	Utilization of Calcium Carbonate Sludge Obtained as By-product from Sugar or Paper Industries in the Manufacture of Cement
22	Utilization of Fly Ash from Thermal Power Stations in the Manufacture of Cement
23	Development of Non-shrinking Cement
24	Development of High-Strength Cement
25	Development of Fibre-Reinforced Concrete
26	Development of Polymer Concrete
27	Development and Application of Ferro-Cement in Thin-Walled Constructions
28	Development of Light-Weight Aggregate from Fly Ash
29	Determination of Optimum Compacting Conditions for Concrete and Development of Devices to Achieve them

30 Development and Standardization of Accelerated Methods of Testing Concrete for Getting the 28 days Equivalent Strength of Concrete

31 Development of Asbestos Cement Products Using Indian Asbestos

32 Development of Ready Mixed Concrete

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APPENDIX III

EXAMPLES OF R&D OBJECTIVES, MISSIONS AND PROJECTS OF AN INDUSTRIAL RESEARCH INSTITUTE IN INDIA

(Ref. Item 5.4)

Example 1

OBJECTIVE	A	UTILIZATION OF INDUSTRIAL WASTES IN THE MANUFACTURE OF CEMENT
MISSION	A.1	Utilization of Fly Ash from Thermal Power Stations in the Manufacture of Cement
PROJECT	A.1.1	Utilization of Indian fly ashes - a technical appraisal
	A.1.2	Development of technology for use of fly ash with portland cement clinker in the manufacture of fly ash cement by grinding and blending processes
	A.1.3	Development of technology for use of fly ash as a replacement for cement in concrete making
MISSION	A.2	Utilization of By-Product Gypsum from Fertilizer and other Chemical Industries in the Manufacture of Cement
PROJECT	A.2.1	Development of technology for use of phospho-gypsum in the manufacture of cement
	A.2.2	Development of technology for use of fluoro-gypsum in the manufacture of cement
MISSION	A.3	Utilization of Blast Furnace Slag in the Manufacture of Cement
PROJECT	A.3.1	Development of granulation systems for the blast furnace slag
	A.3.2	Development of supersulphated cements using locally available materials

Example 2

OBJECTIVE	B	EVOLVING RATIONAL DESIGN PROCEDURES FOR STRUCTURAL CONCRETE
MISSION	B.1	Determination of Ultimate Strength of Concrete under Sustained Loading
PROJECT	B.1.1	Development of methods for estimating the true strength of concrete through studies on the influence of stress on the ultrasonic pulse velocity
	B.1.2	Development of methods for estimating the true strength of concrete through studies on the influence of stress on the frequency of vibration of concrete specimens
	B.1.3	Development of methods for estimating the true strength of concrete through studies on the microcracking in concrete under stress by direct observations
MISSION	B.2	Development of Rational Design Procedures for Reinforced Concrete Members Subjected to Combined Loading
PROJECT	B.2.1	Strength and behaviour of reinforced concrete members under combined bending, shear and torsion
	B.2.2	Evaluation of influence of factors connected with the bend strength of concrete

6 THE RESOURCES FOR IMPLEMENTATION

6.1 The Three Components for Proper Implementation

Having got a well formulated and mission-oreinted plan with time and cost targets clearly defined, the question of implementation of the plan involves three distinct aspects: (a) to find the necessary resources - finances, manpower and equipment - sufficient in quality and quantity to deal effectively with the Research Projects; (b) to organize and manage these resources so as to efficiently and economically arrive at tangible results; and (c) to translate these results into industrial practice. It has often been pointed out that to attack difficult research problems with less than a minimum of resources is like attacking the enemy in war without adequate forces; both result in casualities without advance. In order, therefore, to reach a scientific and technological balance sufficient resources support is necessary; and the responsibility to ensure this support rests on those who benefit from R&D work. Naturally, the government, the society, the industry and the individual have all their roles to play, the extent and nature of their roles depending on the individual situations.

6.2 Finances

6.2.1 Financing R&D

The method and extent of financing R&D is out side the scope of the present paper; all that is attempted here is to give a broad picture of the situation obtaining in India as a case study; the situation in many other countries might be similar.

6.2.2 The India Case Study

The R&D effort of India in comparison with that of some of the other countries is indicated in Table 3.

TABLE 3

R&D EFFORT OF INDIA AND OTHER COUNTRIES

Name of the country		GNP: Total in terms of million US $	GNP: Per Capita	Population in millions	R&D Expenditure: Total in terms of million US$	R&D Expenditure: Per Capita	R&D Expenditure: As % of GNP
Belgium	(1970)	25800	2670	9.8	238	24.3	0.92
Canada	(1970)	80160	3740	21.4	965	45.0	1.20
France	(1970)	148230	2920	50.8	2964	58.3	2.00
Greece	(1969)	8400	950	8.9	12.5	1.4	0.15
Indonesia	(1968)	61700	510	121.2	NA	NA	NA
India	(1970)	49500	90	550.0	235	0.43	0.48
Italy	(1970)	92850	1710	53.7	743	13.8	0.80
Japan	(1969)	167200	1630	103.4	2840	27.4	1.70
Korea	(1970)	10800	343	31.8	NA	NA	NA
Netherlands	(1970)	31280	2400	13.1	595	45.6	1.92
Philippines	(1970)	8250	304	36.8	20.6	0.56	0.25
Singapore	(1970)	1740	830	2.1	NA	NA	NA
Sweden	(1970)	32560	4050	8.0	487	61	1.50
Thailand	(1969)	4960	139	34.9	NA	NA	NA
UK	(1970)	121180	2170	55.7	2900	52.0	2.40
USA	(1970)	974220	4760	204.8	25400	125.0	2.60
USSR	(1970)	318000	1310	242.8	12100	49.7	3.80
W Germany	(1970)	171000	2880	59.4	3420	57.6	2.00

Source: UN Statistical Year Book, 1969, 1970 & 1971

The expenditure on R&D in India has increased from about Rs.280 million in 1958-59 to nearly Rs.2140 million in 1971-72 as seen in Table 4.

TABLE 4

ESTIMATED R&D ALLOCATIONS
(INDIA)

	Rupees in Million					
	1958-59	1965-66	1968-69	1969-70	1970-71	1971-72
Central Sector (including Universities)	276.6	791.2	1096.0	1212.6	1462.0	1827.4
State Sector	10.0	35.1	119.9	122.2	125.8	138.4
Private Sector	1.5	24.06	98.5	128.1	145.9	174.6
Total:	288.1	850.36	1314.4	1462.9	1733.7	2140.4

Source: "Report on Science and Technology" 1970-71 Committee on Science and Technology, Government of India

The Gross National Expenditure on R&D as a percentage of GNP is indicated in Figure 2 (Page 37-A) and a chart showing the comparison of R&D expenditure in India expressed as a percentage of GNP with that of other countries in Figure 3 (Page 37-B).

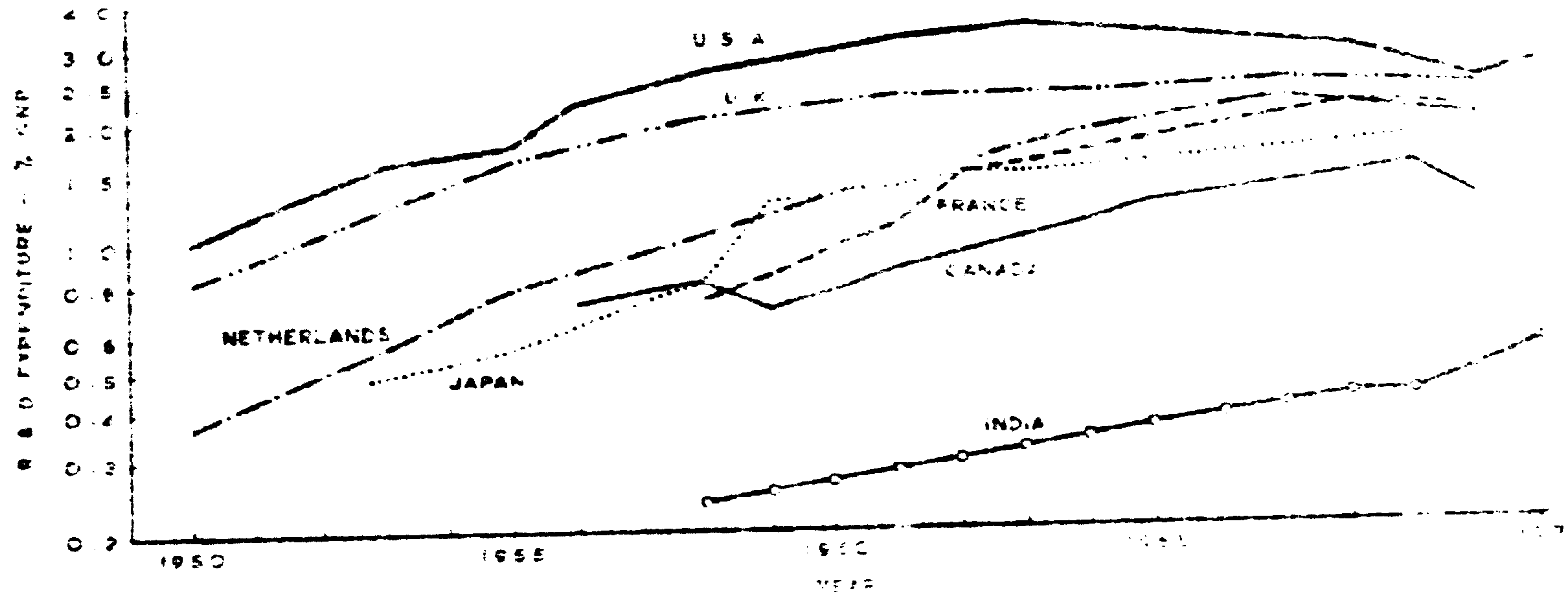
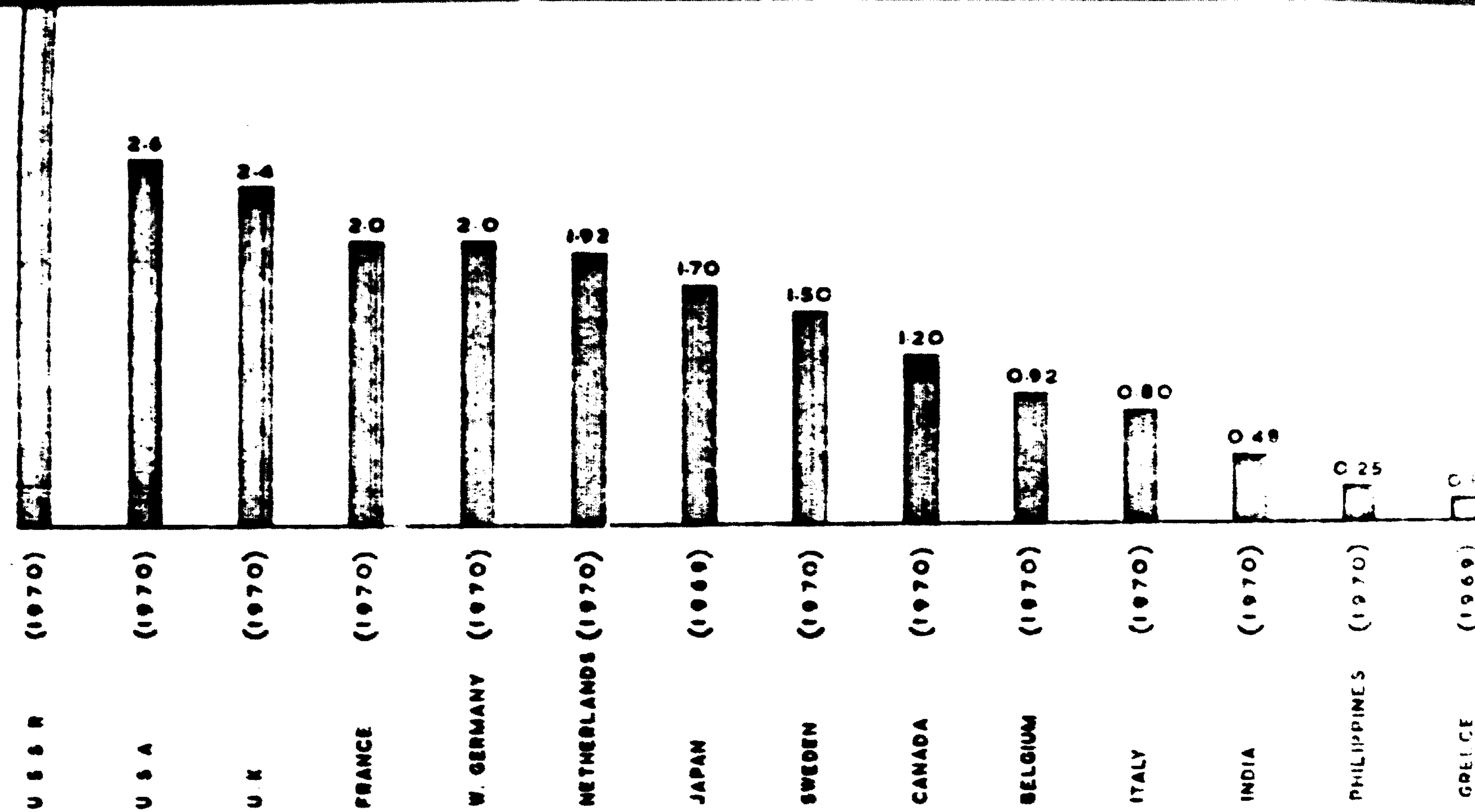


FIG. 2 GROSS NATIONAL EXPENDITURE ON R & D AS A PERCENTAGE OF GNP

SOURCE : ANNUAL REPORT 1969-70, COMMITTEE ON SCIENCE AND TECHNOLOGY, GOVERNMENT OF INDIA

"PLANNING AND IMPLEMENTATION OF RESEARCH PROJECTS"
— Dr H C Visvesvaraya



(FIGURES IN BRACKETS INDICATE YEAR TO WHICH DATA RELATES)

FIG.3 CHART SHOWING COMPARISON OF R & D EXPENDITURE IN INDIA EXPRESSED AS PERCENTAGE OF GNP WITH THAT OF OTHER COUNTRIES

"PLANNING AND IMPLEMENTATION OF RESEARCH PROJECTS"
—Dr H C Visvesvaraya

As evident from Table 4, the R&D effort in India is financed mainly by the Union Government, bulk of the funds forming part of budgetary appropriations. The contribution of industry to R&D effort is very small in the overall financial expenditure. In fact, a recent survey has indicated that the private industry contributed only 8% of the total R&D expenditure whereas the rest, that is, 92% came from the public sector, unlike the situation obtaining in some of the relatively developed countries as indicated in Table 5.

TABLE 5

EXPENDITURE ON R&D BY GOVERNMENT & INDUSTRY

Country	Year	Expenditure as %-age of total R&D Expenditure	
		Government	Industry & others
Canada	1969	62	38
France	1968	50	50
India	1971	92	8
Japan	1969	28	72
Netherlands	1967	40	60
Philippines	1966	52	48
Sweden	1969	29	71
Thailand	1968	91	9
U K	1967	52	48
U S A	1971	54	46
U S S R	1971	(Unitary Control)	
West Germany	1969	42	58

Source: UN Statistical Year Book 1971
Report on Science and Technology 1970-1971
Committee on Science and Technology,
Government of India

In the above estimate expenditure of State Undertakings has been considered as part of the Government sector. Private industrial sector is estimated to have spent about Rs.146 million in 1970-71 and the public sector industrial undertakings Rs.42 million. Thus, R&D expenditure of Indian Industry (including the Public Sector) amounted to Rs.188 million in 1970-71. Viewed against the background of annual production, amounting to Rs.63,000 million, R&D expenditure of industries is indeed very small (about 0.3 per cent).

Another survey carried out by the Indian Chemical Manufacturers' Association reveals that in a large number of cases, less than 0.5% of the total sales is spent on R&D.

Most of the research by the industry is on routine development work and oriented towards import substitution. The factors responsible for the reluctance by the industry to invest in R&D are lack of competitive industrial environment, small size of an average plant and the high cost of research, inclination to rely on imported technology and dependence on foreign collaboration for supply of R&D, lack of sufficient incentives, etc. Similar situation exists in most of the countries in the region. In Japan, however, the industry accounts for over 72% of R&D effort.

TABLE 6

R&D EXPENDITURE BY SELECTED ICICI CLIENTS

(Year 1969-70)

	No.of Companies	(Industrywise : Revenue Account) Amount spent on R&D			
		Total Annual turn-over	Companies with no fixed budget	Companies with fixed budget	Total expenditure
		(Rupees in Millions)			
Chemicals (including drugs, pharmaceuticals & toiletries)	17	2916.6	60	110	24.0
Engineering	14	854.9	60	80	7.5
Cement	2	746.6	-	20	1.6
Electricals & Electronics	13	449.3	30	100	6.1
Wood, paper & pulp	3	126.2	10	20	0.9
Miscellaneous	6	248.0	30	30	0.8
	55	5341.6	190	360	40.9

In a survey conducted by the Industrial Credit and Investment Corporation of India (ICICI), covering some 100 companies engaged in the manufacture of electricals, electronics, engineering items, chemicals, paper and cement, of which about 55 companies furnished the requisite data, the problems that confront the companies in developing R&D were investigated to determine their trends. All the units included in the ICICI sample have routine

R&D cells; more than two-thirds have R&D departments staffed with qualified scientists and engineers. Ancillary facilities like workshop and library are also provided by these companies and in a few instances, they are also equipped with engineering and economic evaluation divisions for translating research into pilot scale, and then on to commercially viable projects. Although the objectives of the R&D departments appeared to be comprehensive, the companies, barring a few exceptions, seemed to prefer, in practice, confining to only those lines of R&D activities where the effect could most easily be traced back to the original investment. The trends are reflected in Table 6 and Table 7 where the Annual R&D Expenditures of these companies are analysed industry-wise and turnoverwise.

TABLE 7

R&D EXPENDITURE IN RELATION TO ANNUAL TURNOVER OF SELECTED ICICI CLIENTS

Range of turn-over	Number of Compa-nies	Total turn-over	Companies with no fixed budgets	Companies with fixed budgets	Total expen-diture
			(Rupees in Million)		
Up to 10	9	58.0	40	50	1.4
10 to 50	22	620.5	80	140	5.7
50 to 150	14	1286.0	40	100	13.3
Over 150	10	3377.1	30	70	20.5
	55	5341.6	190	360	40.9

Aggregate R&D expenditure by these companies on revenue account was of the order of Rs.40 million, while the ratio of revenue expenditure to expenditure incurred on capital account was less than 1:1. In developed countries the ratio between revenue and capital expenditure in running a research laboratory is reported to be around 1:3.

The other significant points that emerge from the tables in relation to ICICI sample are that:

(i) the annual R&D expenditure of the units is quite small in relation to their total turnover;

(ii) size of the unit seems to have a significant bearing on the scale of the R&D effort; the larger the size, the greater the expenditure; and

(iii) a majority of the companies seemed to have R&D budgets determined on the basis of the cost of an agreed research programme. In some cases, however, the size of R&D budget was related to the turnover of the existing product-lines.

It is also of interest to note that 36 of the companies accounted for about 50 per cent of the private sector's expenditure on R&D activity in 1969-70. This may mean either of two things: that only a few companies undertake R&D activity in the private sector or that the total private outlay is actually much larger than estimated; the latter possibility may arise because of the fact that many companies do not have separate budgets for R&D and do not show it as a separate item in their accounts.

Yet another important aspect of R&D financing that deserves reference is that industry in India has not incurred any massive, or even matching expenditure for adapting or developing the borrowed and imported technology further. Rapid industrialization of Japan in Post-war years is mainly ascribed to the fact that for every Yen spent on borrowed technology, Japanese industry spent about seven Yens on adapting and improving it through indigenous R&D as seen in Table 8.

TABLE 8

JAPAN'S EXPENDITURE ON TRANSFER OF TECHNOLOGY COMPARED WITH EXPENDITURE ON INDUSTRIAL R & D AND GROSS DOMESTIC PRODUCT

Year	Total expenditure on R&D	of which by industry	Payments for transfer of technology	Item 3 as percentage of Item 1
	(1)	(2)	(3)	(4)
		(in billion Yen)		
1955	56	29.3	7.2	13
1958	114	69.7	17.2	15
1961	245	153.8	41.7	17
1964	381	NA	55.9	15

Source: UNCTAD - II (TD/28/SUPPL 1)

Such a phenomenon did not occur in India, and the contribution of industry in relation to payment for borrowed technology has never been significant.

Against this background, it might also be interesting to know that in India in addition to supporting cooperative research institutions, the Government also provides certain intensive support to research activity within the private industry.

Under the existing provisions, a company is extitled to claim the following expenditure on scientific research as expenditure deductable fror the total for purposes of profit and tax assessments.

(1) Any expenditure on scientific research related to the business

(2) Any sum paid to an approved scientific association which has as its object the undertaking of scientific research or to a university, college or other institution to be used for scientific research.

(3) Any sum paid to a university, college or other Institution to be used for research in social sciences or statistical research related to the class of business.

(4) Any fees paid to research laboratories and consultancy services in connection with the business.

In addition, expenditure of a capital nature on scientific research can be written off in one year and the company can claim development rebate at 35 per cent on plant and machinery used for scientific research, if installed prior to 31 March 1970, and 25 per cent on equipment installed after 31 March 1970. Certain further concessions and incentives have also been extended from time to time.

6.2.3 Financing Development Work

It is at the development and marketing stage that finance becomes a much more important constraint since it takes a great deal more money to develop a commercial design based on a pilot plant operation, as compared to the original research, to develop a process know-how. Even when a research effort is successful in identifying a new product, sometimes the firms are reluctant to provide adequate finance for launching it. Some firms would rather hold the patent than utilize it fearing even the slightest chance of failure. The tendency to postpone commercial utilization or even abandon a new research result altogether is, of course, reinforced by the lack of competitive environment. In a situation of scarcity where almost anything would sell, the incentive to improve the quality of a product or a process is often absent, even when the know-how and the technology are readily available.

6.3 Manpower

The finance provided to R&D may not bear any fruit unless the right manpower - manpower devoted to research and talented with research-oriented bent of mind - is used for it. Finding the right manpower has been difficult everywhere, especially in developing countries where unusual problems have often to be dealt with. One has to meet with imbalances; there may be considerable difficulties in certain areas of work to find the right R&D personnel whilst exceptionally good personnel might be available in another area.

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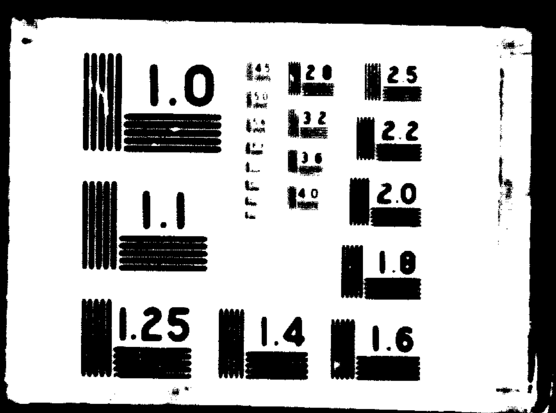


Again taking the example of India, see Table 9 below, the number of persons actually engaged in R&D work is only two per 10,000 persons against 38 and 21 per 10,000 in USSR and USA respectively and 36 per 10,000 in Japan. On the other hand it is estimated that the total scientific and technical personnel in India is about 18 per 10,000 persons. It is thus clear that mobilization of R&D personnel needs special attention for implementing the R&D Programmes.

TABLE 9

R & D PERSONNEL PER 10,000 OF POPULATION

Country		Population in millions	Qualified R&D Personnel	
			Total	No per 10000 of population
Belgium	(1967)	9.6	14660	15
Canada	(1969)	21.1	40640	19
France	(1968)	49.2	134800	27
India	(1971)	550.0	95000	2
Italy	(1969)	53.1	42000	8
Japan	(1970)	103.4	366900	36
Netherlands	(1967)	12.6	50200	40
Sweden	(1969)	8.0	16000	20
U K	(1968)	55.3	151000	27
U S A	(1971)	243.0	519000	21
U S S R	(1970)	242.8	927700	38
West Germany	(1969)	59.1	149000	25

Source: 1) UN Statistical Year Book, 1968, 1969, 1970 & 1971
2) National Pattern of R&D Resources by NSF, 1972

6.4 Equipment

The R&D manpower requires the right kind of equipment in order to be able to compete in quality, speed and quantity in today's technological race. Even when financial resources are found, difficulties are often faced in finding the equipment and materials necessary. Certain countries have given special attention to this aspect in their trade and commerce and almost every developing country needs special attention to this aspect. In the long term, however, it is important that as far as possible and necessary, indigenous sources should be developed. Efforts to develop indigenous sources for R&D equipment should go hand in hand with the R&D work.

Talking purely in terms of the investments and returns, one quite often comes across cases where an R&D organization has had to possess expensive equipment, though its R&D needs might be such that this equipment is to be used only occasionally. Thus, in arming an R&D organization one has to consider whether the returns by way of a few real uses during the life of the equipment are worthy of the large investment on it or should some convenience or sophistication be sacrificed to make it multipurpose or undergo the inconvenience, delays and expenses by going to centres which possess these tools and obtain their services.

contd.7

7 THE ORGANIZATION AND MANAGEMENT FOR IMPLEMENTATION

7.1 Organization

Planning and identifying research projects and finding resources by way of men and materials are only some of the links in the chain of R&D processing. They are like raw materials which form the input in a factory where unless appropriate and efficient machinery is provided even the best of raw materials and resources may not lead to fruitful results. The most vital part in the R&D process is, therefore, the actual philosophy, concept and methodology adopted for conducting the research work; the organization provided for it and how the R&D men actually work. Further, in any industrial R&D activity, the ultimate success will depend on how actively the industry has been involved. Industry is the institutional vehicle by which R&D work is reduced to technology, and in a continuum of change, brought to a state where routine production of the articles of trade, commerce and defence is achieved. The key to successful implementation of R&D effort is the whole-hearted cooperation of the industry.

The involvement should not, therefore, be merely in the nature of being associated with Committees or Councils - the involvement should be at all stages and in all matters of relevance to the healthy progress of the activity. The R&D organizational structure should be organized along such lines as to provide representation of the whole spectrum of science and technology, drawn from industry, universities and government. This body would then be available to provide a feeling of ownership involvement to each of the constituents and enable a coherent studied opinion on all matters involving R&D.

It would automatically ensure that biased activities are not embarked upon and protection is provided against undue pressures from any quarter. It could stimulate new areas of emphasis since its advice would be heeded by the funding agencies. Last but not the least, it would pull together the scattered community of science and technology into purposeful activity towards industrial advancement.

7.2 Individual Research

Research is a state of mind - an attitude of enquiring into, almost dissatisfaction with, the present state of affairs. Much of human progress have come out of this enquiring attitude though the temptation to hark back to the oldon days is never absent from the human heart. Research can be conducted almost anywhere and on almost any problem provided the necessary pre-requisites are available, the most important and vital pre-requisite is undoubtedly 'the man'. Everything depends primarily on him and on his competence; if he is one who has a spirit of logical reasoning and keeps his ears, eyes and mind open, he can do research in any given circumstance. Even a cursory study of the history of science and technology will at once show that some of the world's greatest discoveries, inventions and contributions to scientific and technological advancements have come about under almost unbelievable environments and circumstances. What mattered in all such cases were the men behind the great achievements. Even so, to an extent this enquiring state of mind is combined with luck - for fruitful inventions - as the inventions of Archimedes, Newton and Fleming show. In these circumstances, therefore, an individual, no matter whether he had a systematic training in R&D or not, can sometimes do research no less in value than that in an organized R&D effort; but it is seldom possible to relate an individual research effort to an overall planning except in exceptional cases.

7.3 Institutional Research

In recent times, however, technological progress is not so much a product of a sudden discovery by an individual as a concerted effort and work of a team organised for a specific objective. Dispersed individual efforts are giving place to organized efforts pooling the intellectual talent of a group of research workers and the material support required by them. Even in such an organized effort the research has to be built round the men whilst simultaneously directing them towards definite needs and specific objectives. In fact, in the advancing world of today research and development, as many other things, have become capital intensive. Therefore, the stronger the base in such institutional research, the greater the support it can provide in the R&D process. The cardinal objective of any institutional research would be to identify the problems, engage R&D men who have the necessary skill and competence and to provide them the necessary R&D facilities integrated with an appropriate management concept. This could be achieved by an industrial organization having its own R&D unit; by several industrial organizations with common or essentially common interests, joining hands with several others to pool the resources towards a common R&D establishment; the needs of the industrial organizations could also be met by entrusting their specific problems to organizations who have developed the skill and the facilities to get the results through R&D contracting system.

7.3.1 Proprietory R&D Units: The general tendency is to think that an own R&D unit would provide all the necessary R&D feeding required by an industrial organization. This is not so in most cases, specially in developing countries where the industries are relatively smaller in size. The small industries cannot, in general, afford either to employ R&D personnel of the required calibre or to provide R&D facilities of the required order. Thus, the own R&D units cannot by themselves be expected to provide a total answer, but they would be extremely valuable from the point of view of transfer of technology from outside into the industry and for translating the needs of the industry to outside R&D organizations; thus, own R&D units, however weak, are essential in every industry.

7.3.2 National R&D Centres: Every government in the world, irrespective of its political system, has a responsibility towards R&D and would therefore have R&D establishments financed by the State. The fields in which this is done, the size of the R&D establishments and the financial support provided by the State, vary from situation to situation depending upon the individual circumstances, but the socio-economic conditions and the degree of industrialization, as indicated in Chapter 6 will greatly influence the extent and the form in which national R&D establishments are developed.

However, it is possible to distinguish four functional levels in the scientific and technological structure of a national institution. The first functional level involves the area of planning, decision and promotion. The second level includes the financing, coordination, and control of scientific and technological research at the national level. Depending on the volume and diversity of the scientific research conducted in the country. these functions are undertaken by one or more bodies whose sphere of competence is determined by the type of R&D they do and sometimes also by the sector for whose support R&D activity is conducted.

The third functional level involves the execution of research. The research is executed in those industrial and scientific fields that are of direct relevance to the industrial need in the institute where continuity of effort and magnitude of the activity justifies concentration of resources in that specific sphere.

The fourth functional level represent mixed group of activities indispensable for the application of research and technology to development. These are: (a) natural resources and environmental services; (b) the information and documentation services; (c) the standard reference service that deals with standards, norms and scientific instrumentation which perform most important tasks in relation to the dependable developmental effort; and (d) the extension and innovation service that performs the activity of harnessing R&D results for injecting them into production and services.

7.3.3 Co-operative R&D Establishments: The Co-operative or Associational R&D establishments can be based on co-operation between industrial units or between a group of industrial units and the Government of the country concerned. This co-operation at once brings with it the advantage of pooling of resources, thus making it possible for an R&D establishment to be able to have relatively more powerful tools of research and to possess relatively higher calibre of R&D personnel. Moreover, such co-operative R&D establishments can also function as links in the transfer of technology between the own R&D units in the individual industrial organization and the rest of the national network of R&D, such as Universities, Governmental Institutions etc.

7.3.4 Special R&D Centres: In any organized R&D effort today, science and technology demand a number of sophisticated tools. The use of these tools may be occasional; nevertheless, even to meet the occasional needs the use of these tools should be available. In an R&D establishment which has responsibilities in a fairly wide range of activities, such investments in specialized but infrequently needed tools would constitute a heavy capital investment with rather low returns. In such cases, the facilities provided in such establishments would have to be so planned from the very beginning that every tool involving relatively a heavy capital expenditure, is, as far as possible, made multi-purposed so that the several needs of the establishment could be met from the same tool; these have naturally their own possibilities and limitations which have to be carefully weighed.

Whatever be the tools, the tools themselves become out-dated or obsolete with time; trained personnel who will be required to operate the tool will become out-dated unless constantly under continuing education and training. For example, in a building materials research institute, equipment such as X-ray Analytical Units, Electron Micro-probe Analyser, Atomic Absorption Spectrophotometer etc., are all required, but these tools themselves would become obsolete and out-dated in course of time unless replaced by newer models incorporating more up-to-date improvements. If on the other hand, specialized centres for specific specialities could be developed to serve not only one but several R&D establishments, the tools would be used more frequently, they can be replaced as and when they become obsolete, newer technologies could be developed, technical personnel could be constantly kept trained in the newer specialities and so on. Even in advanced countries it is not unusual for one to find in many laboratories, tools of research which are out-dated and obsolete by today's standards. This will be more so in developing countries unless care is taken from the very beginning at the time of organizing R&D establishments.

7.4 Contract Research

Organizations have also attempted successfully contracting research as in other fields of contract, but this requires special skills in management as the managers of the contract have themselves to have required training to be able to identify and divide the problems, to identify the required skills and competence, to determine how and where a work could be got done best, to get the work done in pieces and to put the results together to provide the ultimate answer to the client. The contract system could also be a part of activity of any type of R&D institution engaged in its own direct R&D work provided the management is geared to this system.

7.5 The Inter-disciplinary and Multi-disciplinary Approach

In many parts of the world, specially in certain developing countries, there exists today a dichotomy in R&D work; the need for R&D is greatly felt but what R&D institutions produce are hardly implemented. A detailed study of individual cases leads one to the conclusion that this anomolous situation is substantially due to either of the following two causes:

(a) The R&D problem on which work has been done was not based on clearly identified needs of the industry and so the industry is not interested in this R&D work;

(b) The R&D problem is of vital interest to the industry but the R&D output is unacceptable because it is considered by the industry as academic, impracticable or uneconomical.

This latter situation results mainly when uni-disciplinary approach has been adopted on an issue which requires multi-disciplinary approach; here, the well known story of the description of a big elephant by five blind men is an apt anology.

In the uni-disciplinary approach, a given issue is looked at from the angle of a specialist who has hardly developed a capacity to appreciate the rest of the ingredients necessary for a total solution. In fact, the criticism by the industries is frequently attributable to the fact that those engaged in R&D have failed to take into account the total picture. Whatever the disciplines necessary - physics, chemistry, mathematics, materials science, structural mechanics, economics, productivity, comfort, health etc., have all to be simultaneously considered. Many of the breath-taking advances that are taking place today would not have been possible but for this inter-disciplinary approach. Missions to the moon and jumbo jets have amply demonstrated the need for inter-disciplinary approach; but since such examples might not reflect the majority of cases practically dealt with in developing countries, a simple example of a pile foundation for an industrial building in a highly aggressive soil might be considered; here, a geologist, a soil chemist, a cement chemist, a concrete technologist, and a structural engineer are all required to pool and integrate their specialised knowledge towards a common and total solution.

Progress in science and technology has become synonymous with increasing specialization. Simultaneously, an R&D problem is no more a problem of an individual specialist alone. No matter, therefore, how broadly or narrowly we define any discipline, in today's world most of the industrial R&D issues are of an inter-disciplinary nature. This means that the most effective way in which these could be tackled is by an inter-disciplinary and multi-disciplinary approach.

7.6 The Three Life Stages of an R&D Establishment

Whatever might be the nature of an R&D establishment, it has three distinct stages in its life - the Initial Stage when it is being established; the Operational Stage when it is established and starts functioning as an R&D establishment; and the Implementation Stage, when the results of R&D start flowing out for implementation. The philosophy and concept of organization and management of these R&D establishments will determine the course they take and the contributions they make towards the objectives. Some of the problems highlighted hereunder in the various stages are more prominent when the R&D is financed by the State which is the case with many developing countries.

7.6.1 Initial Stage: The establishment of the R&D Centre is approved and things get moving. A Planning Officer or a Director is appointed together with the necessary administrative and technical personnel. The project report, plans, estimates, programmes are approved, details are worked out and the execution starts. Some staff are sent to other organizations or overseas for training; everyone connected with the R&D establishment is highly devoted anu enthusiastic. The staff are all dedicated. The buildings are inaugurated, the equipment and instruments are installed. At this stage the establishment finds no shortage of funds, no difficulties in staff appointments, no difficulties in getting equipment etc., and generally there is no substantial interference from the administrative or financial heirarchy in the progress. The initial investments are heavy and the operating costs are small.

7.6.2 Operational Stage: The institution is established; the ratio of capital investment to operational expenses become much less since there are no more buildings to be built and no more costly equipment to be installed; the staff would have returned after training and communications would have been established with other R&D Centres. The operating costs gradually become the key budgetary consideration, where relative priorities start getting questionned-whether an item 'x' is more important or an item 'y' and so on. Things are not as smooth as they were but R&D works moves on because the enthusiasm and dedication still continues in the staff.

7.6.3 Implementation Stage: This is a stage at which some R&D results start flowing. This becomes the crucial stage for the justification of the existence of the institution. Before the flow gathers momentum there is a great slackening in the enthusiasm and consequent continued support; the organization gets weakened. Due to loss of enthusiasm by those very agencies which have constituted the R&D establishment, creative actions are hampered and discouragement and frustration starts. A vicious circle sets in and it would be impossible to pass on anything to the industry not only because it has nothing to pass on but also because it has forgotten that it was for this very purpose that the institution was set up.

7.6.4 Paradoxical Situation: Quite often this paradoxical situation is explained away as due to lack of resources. This could surely not be the reason since plenty of resources were available to start with. The cardinal issue is that mere investment of money is not sufficient for the development of science and technology. Continued enthusiasm, support and vigilence are equally necessary as otherwise irrespective of the type of R&D establishment it would become an object of ridicule or at best a show-piece.

7.7 The Concept of Management of R&D

R&D demands rationality and flexibility. There should be no attempt to replace quality by quantity whilst there is nothing wrong in trying to press for more quantity as long as the quality is not likely to suffer. The concept of management is a vital factor for the success of any institutional research.

Organic conflicts arise as a result of the application to R&D establishments, the same rules and procedures which have been designed for administrative or production services, though the functions of the latter are very different from those required for essentially creative work pertaining to the former. The majority of organic conflicts occur for two reasons.

The first of these is that very often a pyramidal or vertical structure, a rigid heirarchical set-up based on rank, is imposed on an R&D establishment. This is the typical organizational form for government agencies but it is not the most suitable for a research centre. Much more fitting for the latter is a horizontal type of organization or a pyramidal structure with a broad base and little height. This allows for maximum communication between all levels of staff participating in the R&D and especially between the recent graduate newly recruited to the centre and the most senior researcher.

The vertical pyramidal structure is generally accompanied by a somewhat rigid and bureaucratic system of promotion, ill-adapted to the recognition of merits in R&D work, where anyone who possesses creative ability and knows how to conduct R&D is his own chief, regardless of age, seniority, personal charm or temperament. Moreover, the appointment of staff in the pyramidal type of organization does not often have the flexibility that is needed for R&D in that it presupposes entry at the lowest grade; this becomes a serious obstacle when it is desired to engage a brilliant researcher who is still very young or without a long list of achievements to his credit. The pyramidal structure may, by definition, give rise to the most serious quantity versus quality conflict possible. When such a thing happens, the best minds of the centre leave it in search of another organization directed with more talent and ability.

The second major source of organic conflict is in the rules and regulations that govern the general administration and in such things as time cards and attendance checks, the entry and exit register, the leave and vacation log, instructions for the transmission of memoranda and correspondence, recruitment procedures, procurement procedures, auditing procedures, allocation, use and control of funds for investment, buildings, equipment and operating costs. Instances are not uncommon where in an R&D establishment there is ample provision of all the most costly items needed for a research project - the equipment, the men and the buildings - but there is an extreme difficulty to tie small ends to make them work and so not only the research is not undertaken or slowed down if it is already on hand, but also the essential component - the researcher - himself becomes demoralized and deteriorates. To his rational mind, for which reason he was engaged in R&D, it is deeply incomprehensible that huge investments have been made which cannot be put to use for want of ridiculously small sums.

Whilst providing for the rationalities and flexibilities, a good R&D management should also provide for a balanced integration of all its faculties so as to direct them towards objective fulfilment, simultaneously exercising the necessary management controls in appropriate measure at appropriate points.

7.8 Matrix System of R&D Management

7.8.1 In order therefore to transform these concepts into practical propositions, it is essential to give thought to the management structure. The matrix system of R&D management perhaps provides the most efficient means of transforming the above concepts into practice.

7.8.2 In the matrix system, the organization is divided for convenience of administration and management, into Divisions based essentially on the different disciplines involved in an organization. The objective of these Divisions should conceptually be to provide excellence in knowledge and efficiency in service, which can be made use of for tackling the several Missions which form part of the Objective fulfilment of the R&D organization. The responsibility of the Chief of the Division will therefore be to manage the men, materials and the money including the equipment and facilities relating to the discipline with the assistance of the technical, financial and administrative controls as are conducive to a healthy and progressive management with a view to making the Division a powerful tool in the given discipline and a tool which will at all times be ready with latest science and technology to operate on a given subject. The Divisions themselves do not in general and in concept deal with any R&D problems.

7.8.3 To deal with the R&D problems, a separate set of R&D groups are established whose objectives are to achieve the maximum useful and pragmatic results at minimum cost in the shortest possible time and in any case within the fixed targets of cost and time. The groups or teams are formed by drawing personnel from the various Divisions of specialised disciplines. The responsibility of the Chief of the Group of R&D will be to manage men, materials and money relating to the particular R&D group assisted by such technical, financial and administr[illegible] conducive to a healthy and progressive [illegible] with a view to ensuring fulfilment of the Mission with which the group is charged.

7.8.4 A typical chart of the R&D Management with this concept based substantially on what a new and large industrial research institution in a developing country is adopting is given in Figure [illegible] (page [illegible]-A). Since the chart is self explanatory, it is sufficient here to mention that the concept indicated in the chart is to bring all the components of R&D management into an orderly arrangement clearly specifying what is expected in each activity constituting the institution. The chart emphasizes the balanced integration.

7.9 <u>Leaders for Research Management</u>

7.9.1 <u>Responsibility for Onerous Task:</u> The job of one shouldered with the responsibility of management of an R&D establishment is perhaps the most complicated and onerous one of all managerial tasks - quite contrary to the belief which many persons in other types of managerial positions hold.

7.9.2 <u>R&D Managers v/s Other Managers:</u> In order to get a true perspective of the problems of research and development managers one should not confine one's attention only to the technologist in the science-based industries whose case is similar to that of the design manager of an aircraft manufacturing company, the style director of a fashion house or the art director of a publishing house. His influence in each of these cases, is directly dependent on the time-scale and he is paid to promote the products for the future.

TYPICAL MANAGEMENT CHART

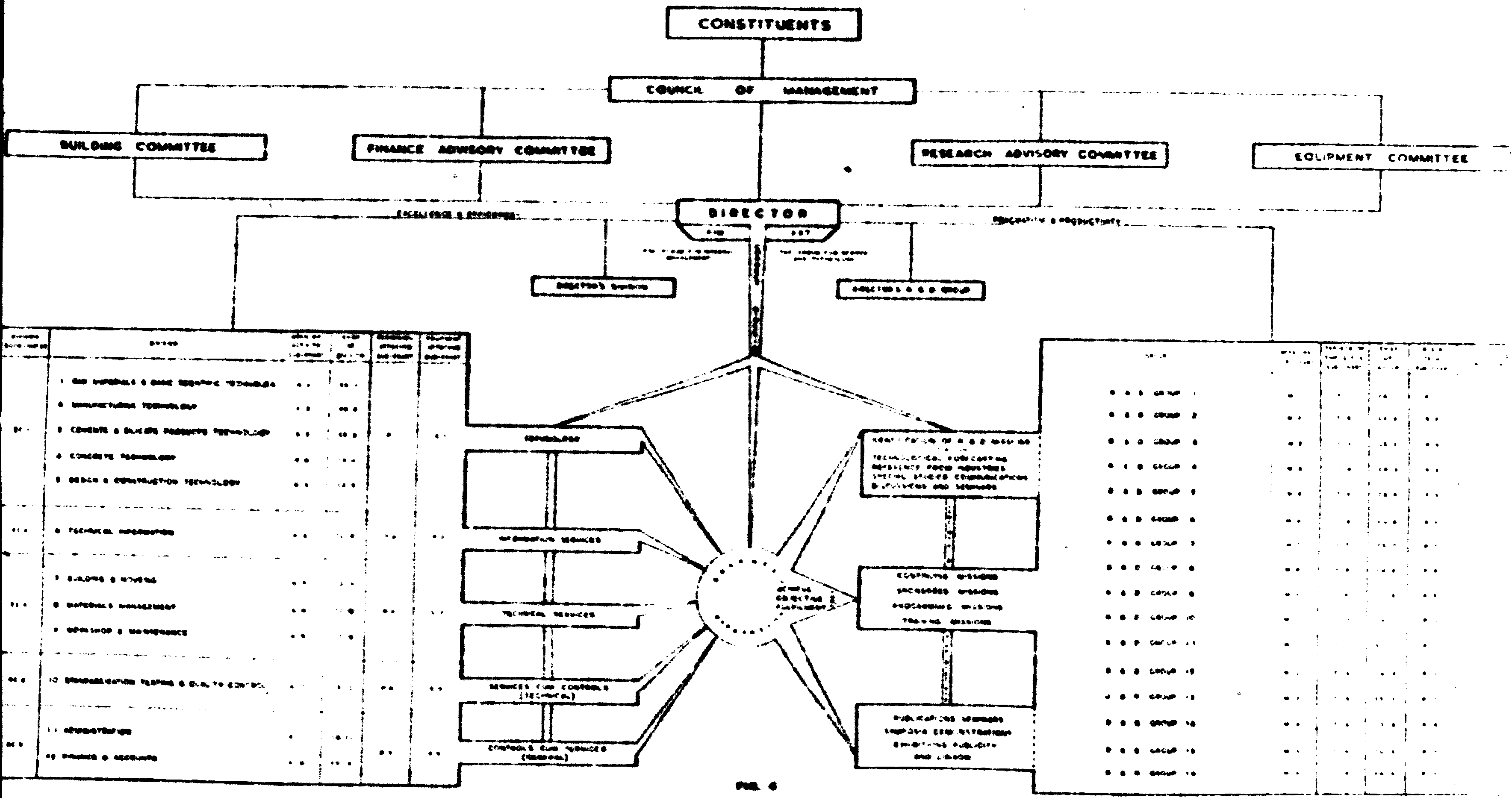
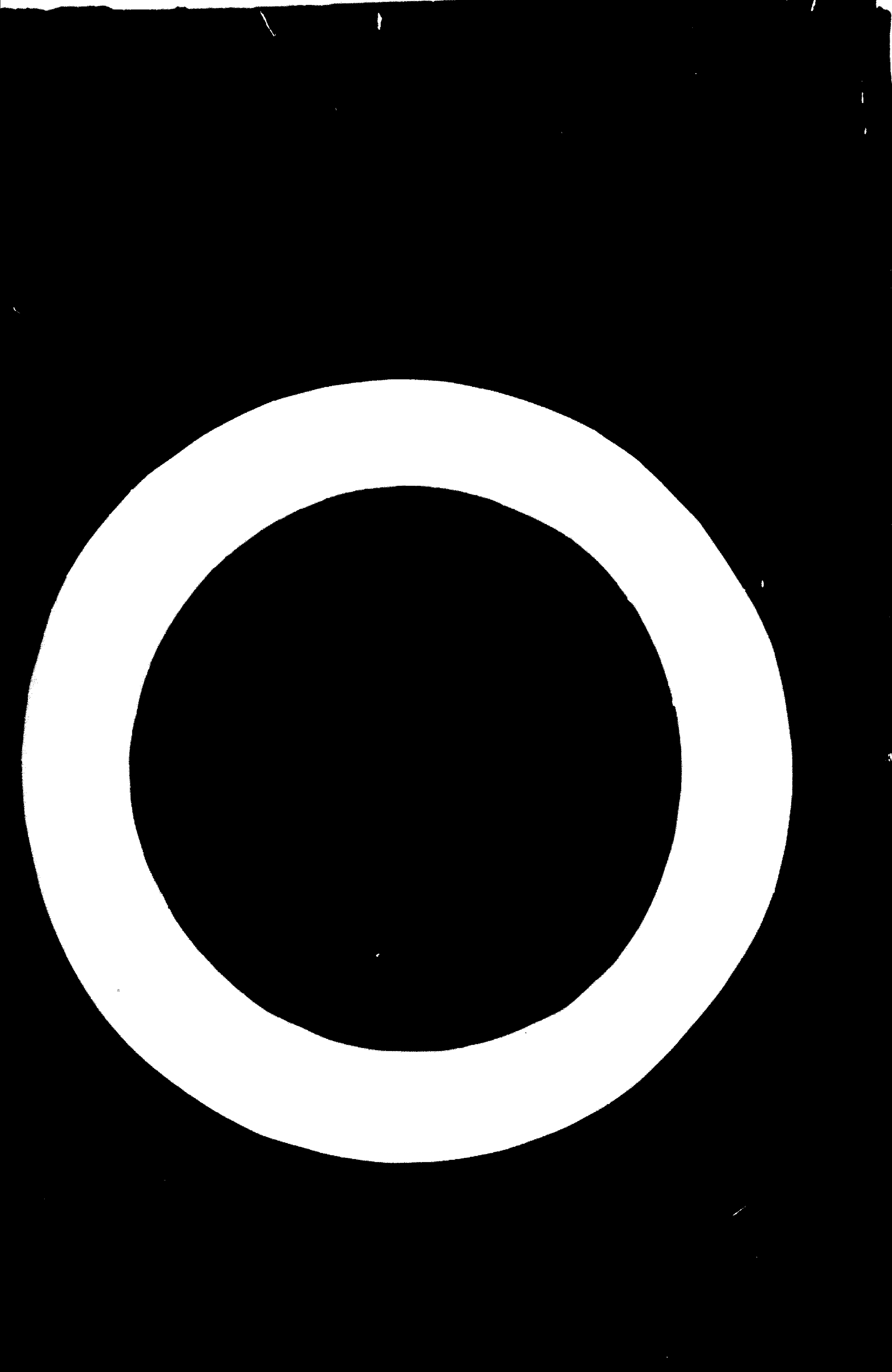


FIG. 6



While the production manager's field is essentially a combination of applied technology and management methodology designed for and concerned with a given set of outputs, the research manager has to take into account simultaneously a complex set of parameters. He has to work with thinkers and inventors whose brain power is more moment than brawn or endurance and whose work patterns are not predictable, let alone controllable or measurable; they are quite often snail-moving, even static ! He has not only to be familiar with techniques of management required for the proper running of his technical organization specially in relation to the supporting level of staff but he should know the special techniques for the management of intellectuals. To be able to produce results worthy of adoption in practice, the research manager should acquaint himself with the knowledge of the market as well as of the production methodology, and he has to be conscious of the machine and material costs. Above all these, he must know that within the organization he is protagonist of change and that every change brings with it a series of reactions having great impact on human relations. In order to get the best results, the horizon of a research manager has to be wider and his approach and strategy rather worked out closer than those of a production manager.

7.9.3 Cost Consciousness: Bringing home the cost-consciousness of an operation in a research organisation is a complicated job. Nevertheless, a good manager has got to have data of cost analysis, to be able to take appropriate decisions and ensure that the research output is obtained at the minimum possible cost.

7.9.4 Leader of Team Work: Inter-disciplinary approach immediately brings in the question of team work and the team work brings in problems relating to management of human beings, specially of those who are specialists. A Research Manager has to choose and develop a proper team of specialists and get them set to a common goal. A Research Manager has to have outstanding and original attainments, creative abilities to be able to handle the several problems and qualities to win true respect to his leadership from the very intelligent people he works with as well as from the supporting staff who might not be intellectuals in the sense applied to R&D personnel.

contd.8

8 THE PROCESS OF TACKLING RESEARCH PROJECTS

8.1 Systomatic Procedure

Having identified specific Research Projects and having assigned relative priorities and having secured an establishment with the necessary organization and management, attention is now called for to the exact process of tackling those projects. R&D today is no more a matter of 'hit and miss'. Whilst 'hit and miss' methods might occasionally give substantical results because the projects have been accidently hit rightly, attempts are often made to continue with the hit and miss method for the simple reason that following a systematic procedure would involve some self-discipline and possibly some hard planning and work. There are many instances where R&D has been embarked upon without a proper review of the present state of knowledge and consequently resources and efforts have gone in directions from which they could have been easily saved. Costly experimental work has been carried out without properly designing it and without having an eye on how the results of such experiments would be analysed to arrive at tangible conclusions. A systematic drill is therefore necessary for achieving maximum results in Institutional R&D work. The following steps are suggested as a general guideline. Though these steps are simple and well-known, it is by short-circuiting them that one often gets into difficulties and wastage of resources and efforts. Hence a re-emphasis and a restatement of these steps are necessary.

Step 1 Statement of the Research Project and Its Purpose and a Brief Review of the Basic Principles of the Science and Technology of the Subject

Step 2 Formulation of a Comprehensive Bibliography on the Subject relating to the Project

Step 3 A Critical Review and Survey of the Existing Knowledge - in Both Theory and Practice

Step 4 Determination of the Areas where Lacuna Exists or Knowledge is Insufficient

Step 5 Identification and Selection of Specific Problems which should be looked into

Step 6 Analysis of the Problem and Design of Experiment

Step 7 Experimentation

Step 8 Analysis of Results

Step 9 Discussion of Results and Conclusions

Step 10 Recommendations

Step 11 Appropriate Communication of the Recommendations; and

Step 12 Guidance and Assistance in the Translation of Recommendations into Practice

Though the steps have been indicated separately, in practice some of the steps could, on the time scale, be overlapping but conceptually one should keep in view clearly the purpose and differences in the steps.

8.2 Quality Control on Methods of Testing and the Testing Equipment

The adoption of standard methods of testing and the use of properly calibrated equipment are essential prerequisites for dependability and reproduceability of the results, which is the essence of quality control in the experimental programme. Many instances are available where test reports on identical specimens in the same laboratory as well as test reports on the same material from two laboratories have differred considerably leading to erroneous conclusions. Differences in results of tests carried out by different persons in the same laboratory with the same equipment or differences in results of tests carried out in different laboratories may be attributed to one or more of the following factors:

(a) Differences in the accuracy of the testing apparatus or equipment,

(b) Differences in the quality of materials used as standard references,

(c) Differences in the skills of the operators engaged in testing, and

(d) Differences in the environmental conditions specially in temperature and humidity.

Each of the above factors require careful attention with a view to eliminating the causes responsible for the differences and such a process of elimination will be successful if a suitable quality control system is available in the R&D establishment. To achieve this, the following activities must be a part of the Quality Control Service in the establishment:

(a) Calibration of apparatus and equipment used in testing;

(b) Training of personnel engaged in testing so that they adopt standard methods of test at all stages;

(c) Use of standard reference materials for testing; and

(d) Research in the methods of testing either to improve the existing methods or to evolve better and more suitable methods.

Whilst conceptually the quality control activity has to be visualized as an independent activity of an R&D establishment, whether it could be incorporated into the divisions intended for the normal working in the establishment or as a separate division, will depend upon the nature and size of the R&D establishment.

8.3 Time and Cost Targets

On the programme of many R&D establishments stand today projects which have not seen the light of the day for over a decade; there are projects on which the expenditure incurred appears to have become nobody's business. Whilst undoubtedly there should be sufficient flexibility in both time and cost, every research project has to progress with a certain defined cost target. Both the cost and time targets have to be worked out as best as the analysis of the initial data would permit. Endeavours should be made by all concerned to keep to these targets; but in view of the very nature of certain R&D projects it may not always be possible to stick to them. On each occasion when it is feared that these targets are not likely to be adhered to, a thorough scrutiny should be made and revised targets established. This is the surest way in which the entire team could be made conscious of these controlling factors. A delay in the fulfilment of a Research Project could result in their becoming irrelevant in the context of the rapid advancements the world might have achieved or the industry could have advanced by then beyond the point at which these results could be useful to it.

Moreover, a point which should be appreciated here is that one who invests in research, naturally will and should ask for returns which have accrued to one as a result of research. It is not infrequently that this question is answered away by a jumble of words; "we are in pursuit of truth", "intellectual work cannot be equated to returns", and so on. If returns were nobody's business, research activity would have come to a standstill long long ago except for those who can afford this intellectual pleasure.

8.4 Monitoring the Progress

Every R&D management would have to monitor the progress of each research project. The monitoring is necessary not only to keep track and chase the progress but also to determine the specific problems faced during the course, bottlenecks experienced with a view to getting over them. Periodic discussions within the group on the basis of definitive reports are therefore necessary for enabling a systematic review to be made. Standard proformae have to be designed; a form which is being used in a large industrial research institute in India is reproduced in Appendix IV (Page 70) as an example. The periodicity of the review will naturally depend on several parameters but by way of example again, it might be mentioned that in the organization whose proforma is illustrated in Appendix IV, the review is done every month. Experience has shown that such a review enables securing not only a fair progress but also clarifies the directions and ideas in relation to a given problem.

APPENDIX IV

PROGRESS REPORT
(Re: Item 3.4)

GENERAL INFORMATION

Project No

Project Schedule

Commencement	Target	Original	Revised

Estimated Expenditure

So far	Original	Revised

Reporting Date

Last Report	Present Report

S. No.	Aspect of Work	Likely Proportion in total work	Completed so far as %
1	Literature Survey		
2	Compilation of Bibliography		
3	Review of Present State of Knowledge		
4	Analysis of the Problem in Details		
5	Design of Experiment		
6	Procurement of Material/Equipment		
7	Fabrication of Experimental Set up		
8	Collection of Data		
9	Computational Work		
10	Experimental Work		
11	Analysis of Results/Data		
12	Conclusions and Recommendations		
13	Formulation of Technical Report		
14	Development of by-products such as technical papers, [illegible] and Patents		

EXPLANATORY INFORMATION

Project Title

Scientific Team

Work Completed so far

Main Project

Auxiliary Work

Conclusion at the present Stage and Direction for the Future

[illegible] GROUP COORDINATOR DIRECTOR

9 TRANSLATION OF R&D INTO INDUSTRIAL PRACTICE

9.1 The Principles

If all that has been said above is strictly followed, implementation should not normally offer any difficulty; the outcome of the work should be by itself implementable. Since the processes of technological forecasting, the processes of identification and planning of the Research Projects, the processes relating to organization and management would all have had the closest involvement of the industry, the solution of any research problem should automatically mean fulfilling a need of the industry; thus there should be no difficulty in implementing the research findings provided a proper system for transfer of technology exists. The results of the investigations having been ensured as being not purely academic by inter-disciplinary approach and by having taken into consideration all the parameters that an industrial undertaking would be interested in, the findings become implementable quantitatively also. If engineering in its correct sense has to be an effective tool for the conversion of available resources into meaningful and concrete wealth for the benefit of the society, engineering has to find an optimum solution to convert the abstract into the concrete, giving due weightage to all the parameters involved. Likewise, the system for transfer of technology has to take into account the various relevant parameters in order to convert the abstract knowledge in science and technology to meaningful and concrete results. The efficiency of the system for the transfer of technology thus assumes special significance. Since the system is assumed to have been fully taken into account in planning the Research Projects as discussed in Section 2, all that need now be considered are those aspects in the system which are directly linked to translation of R&D results into industrial practice.

9.2 <u>Pilot Plants and Commercial Plants</u>

Where the laboratory scale studies have indicated the success of a process, innovation or method and where all available knowledge and experience indicates that these are likely to be successful in commercial usage, the next natural step would be to verify the validity of workability of these in practical situations. It is extremely difficult to generalise how this verification can be achieved. There would be issues where one could try the findings and implement them straight-a-way into the manufacturing process without involving a high degree of risk. There might be others where it would be desirable to make pilot plant trials. The pilot plant trials may be with a view to determining the applicability of the laboratory findings in field or to refine or review or revise certain of the laboratory findings before it is put into commercial practice. In general, pilot plant trials are expensive both from the point of view of the capital investment as well as the running costs. Therefore, the needs and the advantages of pilot plant studies have to be considered and gone into very carefully. Sometimes when the pilot plants are of a relatively smaller size than the commercial units - though several times larger than the laboratory scale models - one could still have the drawbacks associated with scale effects and thus the pilot plants may not sometimes serve any better purpose than the laboratory models. On the question whether the pilot plant should be the responsibility of the R&D organization or of the concerned industry, a generalization is impossible as it again depends upon a given situation; it would be possible to consider and arrive at a most appropriate solution when specific cases are taken.

9.3 Project Engineering

A proper interfacing means an active process of conversion and a chain system for the flow of R&D. One of the difficulties faced by the developing countries however is that facilities and resources are not easily available for carrying out large scale, semi proto-type or pilot plant studies on promising laboratory processes and innovations. Entrepreneurs are generally not willing to invest capital and resources on projects or innovations, which have not been proved to be economically viable. Thus, serious bottlenecks in the conversion of the laboratory R&D work to industrial utility are faced. In such a case, a new interface has necessarily to be estabilished between the laboratory and the industry, for example a project engineering firm, an organization like the National Research and Development Council in India, which might provide a risk finance and so on. In any such intermediary facing only the laboratory concerned with the R&D, the entrepreneur concerned with the industrial utility of a given process and those project engineering firms who can assist in the conversion of the laboratory know-how to industrial application, have to be actively involved.

contd. 10

10 CONCLUSION

The Industrial goals with the national setting, the concept of technology transfer system available, and the status and nature of the industrial base will determine the Planning base. The process of planning itself starts with technological forecasting which has to take into account not only the technological possibilities but also the socio-economic aims, aspirations and feasibilities . The forecasts have then to be converted into plans of research objectives covering an appropriate period. Specific Research Projects should then be identified, on the basis of mission-oriented approach, from within the framework of such plans and priorities assigned to them.

The finances, manpower and equipment necessary to support the R&D activities on the basis of specifically identified Research Projects would have to be provided resulting in an Institutional R&D establishment. In order to make the establishment a powerful tool, its organization and management would have to be carefully worked out; the concept of management of R&D, being substantially different from the conventional management of administrative services or production units, should receive the closest attention. Selection of the right type of leaders for R&D management should be insisted and Matrix System of R&D management should be adopted as far as possible. The processes required during the actual working of Research Projects should be clearly spelt out even when some of them are very obvious and a systematic drill of the procedure should be insisted upon in the overall interest of progress.

Translation of R&D findings into industrial practice should not present any problem if the industry has been actively involved - not merely by membership on Committees etc - but at all stages and in all matters. The industry should be made to feel the ownership of R&D Establishment and thus made to identify itself with the inputs, the processes and the outputs. Interfacing of Transfer, Pilot Plant and Project Engineering need consideration but the extent to which resources and efforts should be spent on them to translate the R&D results have to be judged with wisdom in each given case.

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