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Background document

THE ORGANIZATION OF INDUSTRIAL RESEARCH IN DEVELOPING COUNTRIES 1/

by

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* A summary of this document has been distributed as ID/CONF.1/28.

1/ The views and opinions expressed in this paper are those of t.e consultant and do not necessarily reflect the views of the secretariat of UNIDO.

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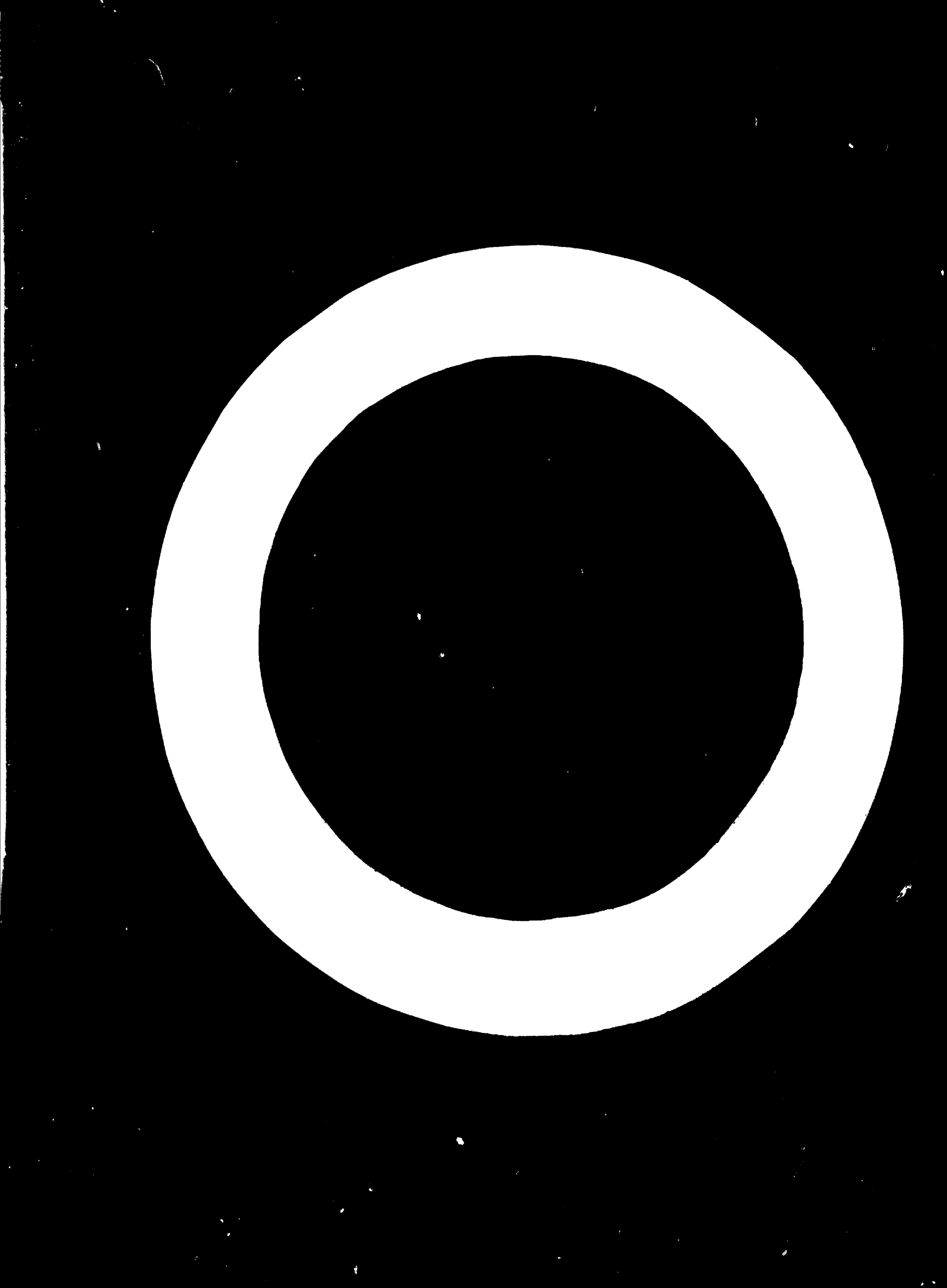

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ANNEXES

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United Nations Industrial Development Organization

INTERNATIONAL SYMPOSIUM ON INDUSTRIAL DEVELOPMENT
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Background document

THE ORGANIZATION OF INDUSTRIAL RESEARCH IN DEVELOPING COUNTRIES

Corrigendum

Page 1:

A footnote should appear on the first page to the effect that Mr. Hiscocks was assisted in the preparation of this document by Mr. G.S. Sanders, for Chapter XIV, and by Mr. V. Gallafent, for part of Chapter XI.

Page 11, paragraph 37, 1st line:

Insert "be prepared to" between "should" and "carry".

Page 49, paragraph 184, last line:

Insert "to be" between "strongly" and "discouraged".

Page 53, paragraph 201, 2nd line:

Insert "more" before "junior".

Page 56, paragraph 212, last line:

Insert "area" at the end of the sentence.

Page 75, paragraph 296, 5th line:

Insert "the exchange rate on research has been" before "calculated".

Page 91, paragraph 358, 3rd line:

After "laboratory buildings" insert "before the builders have left the other end. This has led to a demand for flexibility in laboratory buildings".

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Preface

The scope of this report

1. This report deals with the general policies governing the organization and financing of research and development work. It deals with the personnel policies which should be followed, with the management of research and development and with the dissemination of the results of research in industry.

2. In research, by which is meant the production of new ideas and techniques, new materials and processes and finding the means of exploiting these, the first requirement for high productivity is to ensure that manpower of the highest quality is selected to carry it out and direct its use. For this reason three chapters in this report concern the selection and use of personnel.

3. The policies advocated are based on those that have met with considerable success in advanced countries, modified so as to meet the circumstances and conditions of the developing countries. These conditions normally include shortages in technical and managerial skills, and shortage of capital, but no shortage of unskilled labour.

Introduction

The value of research

4. The progression of physical science is much more connected with your prosperity than is usually imagined. You owe to experimental philosophy some of the most important and peculiar of your advantages. It is not by the foreign conquests chiefly that you are become great but by a conquest of nature in your own country.

The above words were spoken by the eminent scientist, Humphrey Davy, approximately 160 years ago, and their message is generally accepted by statesmen, politicians and industrialists as being even more applicable today than it was then.

5. Research and development are now regarded as two of the most potent factors in economic development, and in the advanced countries this is well illustrated by the fact that the amount of money spent on these activities and the number of men engaged on them have doubled about every twelve years. This exponential increase over the 300 years since the introduction of scientific papers has reached such an extent, in some of the most highly developed countries, that it appears that it will now need to level off. However, the developing countries are, in the main, at the starting point of the curve and growth of research, and development in these countries can be expected to follow the same pattern, though probably with a steeper rise than was the case elsewhere.

The over-all cost of research and development (R and D)

6. The advanced countries spend very large sums of money on R and D. In some of them more than 50 per cent of this money comes from the Government, even though much of the work may be carried out by industry. Very large sums are spent on defence work and also, in some countries, on space projects. These types of expenditures are unlikely to affect significantly most of the developing countries.

7. Given below are some figures that illustrate the situation in those advanced countries; they are for 1962, the last year for which comparable figures are available. All money has been converted to United States dollars for comparison.

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	Over-all expenditure in millions of $	Expenditure per capita $	Percentage of gross national product at market price	Percentage spent on business enterprise	R and D personnel per 1,000 of working population
USA	17,531	93.7	3.1	35	10.4
Belgium	133	14.8	1.0	63	3.5
France	1,108	23.6	1.5	30	3.8
Germany	1,105	20.1	1.3	60	3.9
Netherlands	239	20.3	1.8	65	4.5
United Kingdom	1,775	33.5	2.2	36	6.1
USSR			3.0		8.8

8. It is not, of course, feasible for a developing country in the early stages of its existence to spend this amount of money on these activities, even if it wanted to, because of the lack of trained scientists, technologists and engineers, but as the educational systems of these countries develop, so will dependence on and, therefore, expenditure on R and D increase.

The purpose of industrial research

9. A few years ago the Confederation of British Industries made a survey of research being carried out by industry and the purposes of this research. The results were:

	Per cent
Basic objective research	10
Development of existing processes	35
New products	35
General services	20

the report went on to say that five out of six projects undertaken found commercial application or were likely to do so.

Government support of R and D

10. A feature of R and D, even in advanced countries, is the part played by the Government and, in a number of these countries, the Government is the biggest single

source of R and D funds and the largest single employer of scientific and technical labour. Government policy, therefore, has a very decisive effect, not only for the reasons just given, but because the fiscal system can be organized so as to encourage and even canalize expenditure on R and D in those directions which will have the greatest beneficial effect on the economy.

11. Technology has been defined as the science of the useful arts and the technologist is, therefore, one who applies scientific principles to the invention, realization and production of products and services required by the community jointly and individually.

12. The nature and complexity of the problems vary very considerable from area to area. Weather and atmospheric conditions, water and fuel supplies, rich deposits of mineral resources or dependence on agriculture may all vary from one country to another, depending on geographic location and set of particular conditions. In some countries tradition, religion, social structure or other factors are more conducive to technological change than in others.

13. For these reasons no generally applicable pattern can be set forth which can be used everywhere to bring about the benefits of R and D, but general principles can be derived from experience elsewhere, and systems which have worked successfully can be described, so that the experience of others can be used, appropriately modified where necessary, to initiate in new countries those practices that have contributed so successfully to the industrial growth of the advanced countries.

General requirements

14. The translation of scientific or technical ideas into productive and profitable industrial operations depends, of course, not only on good R and D but on the availability of raw materials, transport facilities and other segments of the national infra-structure, and the availability of a wide range of people with the necessary technical and administrative skills. Above all, what is required are people who can realize the potential of some natural resource and who can bring R and D and, later, productive skills to its economic exploitation. The problems of R and D are basically twofold: the selection of the right problems and the selection of the right people to solve those problems. The old saying, "Necessity is the mother of invention", is very true. The recognition and evaluation of necessities can, therefore, be a primary step in the direction of good and rewarding research.

I. INSTITUTIONAL RESEARCH

15. The traditional picture of scientific research is that of the gifted and dedicated philosopher assisted by a number of devoted followers delving into the secrets of nature or into the supposed secrets of nature, as was the case in the search for the "philosophers' stone".

16. The present-day picture is necessarily different, if only because of the tremendous volume and high cost of research. The application of its results in the advanced countries has, however, had a dramatic effect on the standard of living and the health of their peoples.

17. Research and development require the employment of highly trained persons working in specially designed buildings and using equipment that is often complex and expensive. The day of the lone researcher has ended, and we have entered, especially during the last half century, the era of the research organization or research institute. In research institutes many skills must be blended together to achieve the desired goals, and the institutionalization of R and D is a matter to which much study is being devoted at the present time Many elderly scientists hanker for the patriarchal system, but even they recognize that institutionalization is inevitable.

Categories of research

18. Research may be divided broadly into categories. First is the fundamental work whose object is purely that of extending the boundaries of knowledge without reference to any practical application. Second, there is basic work, sometimes called "basic applied", "oriented basic" or "objective basic": research aimed at providing the foundations on which applied research can be built. Third, applied research, using the results of fundamental and basic work, is aimed directly at the solution of practical problems. It may include, for example, the utilization of the natural resources of a country or the production of substitutes for imported materials.

19. Development is the application of the results of applied research to the direct needs of industry, either by the introduction of new processes leading to the production of new products, or by the improvement of existing processes or

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products; or by other forms of application. Since the results of this work are directly applicable to industry, this type of work is often carried out by industry.

20. Research can be either an individual effort or the work of a team, but development work is almost invariably team work. Developing countries in a very early stage of industrialization will mainly need development work that adapts known technology to local materials and conditions.

Importance of basic applied research

21. Over the last forty years much has been done to put traditional industries on a scientific foundation, and this has involved the carrying out of a large amount of basic applied work, in order to establish the scientific principles of traditional practices. This has, sometimes, led industrialists to say that much research is unproductive, but they have failed to realize that it is not possible, in general, to evolve a new process or improve an old process until scientific understanding of existing practices emerges.

22. The leather industry is a case in point. In the last four decades great improvements have been made in the production of leather, but only as a result of the basic work carried out in various countries to determine actually what happens when skin or hide is tanned into leather. In the same way, fifty years ago many processes in the iron and steel industry were carried out by rule of thumb, and the successful production of steel, for instance, depended on the personal skill of one man, who judged temperatures by eye and who made other decisions by equally imprecise methods. Industry demands steel in large quantities with predictable properties, and these properties can be obtained and maintained only by strict scientific control of the steel-making process.

Inter-disciplinary work

23. To achieve these ends study and research by scientists of many disciplines are necessary, since many advances in industrial practices lie along lines which do not fall within any one of the traditional scientific disciplines, but fall across them. The value of a research institute is, therefore, that it brings together engineers, technologists and scientists of various disciplines who can pool their knowledge and skills in the solution of such problems.

Types of research required

24. In developing countries it is seldom that completely new technologies are required. The requirements are usually for the adaptation of known technology to local products and conditions.

25. Basic applied research may be needed in addition to development work but it is most unlikely that any fundamental work will be required. Even in actual production and manufacturing processes, developing countries can frequently obtain considerable technical help from advanced countries, either freely or under licence, and this aspect will be dealt with in a later chapter.

26. In general, therefore:

(a) Work should be done on the development of new processes and the improvement of existing processes;

(b) Work should be done on the development of new products and new uses for existing products;

(c) There should be a survey of local raw materials and their possible development;

(d) Attention should be paid to the improvement of industrial productivity so as to reduce, if possible, the price of the products;

(e) Regard should be paid to the economic and sociological aspects of the processes being developed. Obviously, little of value will accrue from the development of processes which cannot make a financial profit and from those processes which, for one reason or another, prove unsuccessful, either because the type of labour required is not available or because the product, when produced, is not acceptable to the local population and finds no ready export market.

Importance of home market

27. It is highly desirable in the development of products that there should be a home market as well as a potential export market. The home market is then able to buffer the fluctuations of export market prices. Too often, the produce of developing countries has been used purely for export, and when the price falls the economy of the producing country is in danger. These effects would not be nearly so serious if there were a home market for some of the produce.

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28. A case in point here is cocoa production in Ghana. Ghana produces a significant proportion of the world's cocoa, yet consumption of cocoa in Ghana is very small. Cocoa originated in South America where it was one of the important foods of the Aztecs, and it would obviously, therefore, be an advantage in the feeding of the people of Ghana if cocoa, surplus to export requirements, could be processed locally so as to provide an acceptable and economic food-stuff. The fact that in the developed countries it is used mainly for the production of chocolate and confectionery does not mean that it must be used in that way in the producing country.

Standardization

29. The organization should have regard for standardization. It should study standards in force in other countries and should be able to advise local manufacturers on how their products rate in regard to the requirements of the export market. It should also develop standards for use in the home country.

Equipment services

30. It should be able to advise on processes and on the instruments and equipment necessary to carry out and control those processes. It should know where such equipment and instruments can be obtained and should be in a position quickly to determine the current cost.

Feasibility studies

31. It should provide a technical-economic consulting service on scale of operation. This is very important. In many developing countries there are factories operating uneconomically and some that are not operating at all, simply because the scale of operation was wrong. Instances are known where good advice was given to the countries concerned, but they decided to build for larger production, and for various reasons were never able to attain the larger scale.

Infra-structure

32. For a factory to work economically it must be assured of supplies of suitable raw materials, electric power, water, and such facilities as are adequate to keep it running for most of the year. If this cannot be done, the operation becomes

uneconomical. There must therefore be means of determining the adequacy of these supplies and services.

33. Coupled with these should be studies of siting and location. These again are important: an industry must be sited near its source of raw material, or the infra-structure must be such that the raw materials can be brought to the factory with reasonable ease and the finished products conveniently transported from the factory to the points of use or export.

Market research

34. If possible, the institute should be able to carry out market research. This should cover not only potential demands but questions of quality, mode of packing, and public presentation.

Extra-mural work

35. If funds are available, the institute should make grants-in-aid for the establishment of studentships and fellowships and for scientific research carried out, perhaps, in local colleges.

Sponsored research

36. It should be prepared to carry out sponsored research for industry, government departments, and other interested bodies, and in connexion with this work it should also be prepared to carry out analyses and tests.

Development work

37. When possible, it should carry its work through to the pilot plant stage or to initiate pilot plant runs for industry on a repayment basis.

38. It might also act as a focal point for the setting up of industrial research associations, and such associations could, in the early years, be centred on the campus of the institute.

Extension services

39. It should provide extension services for clients, that is, it should provide advice on such matters as the progress of processes or quality control, and it should visit factories and plants so as to determine whether improvements, either in processing or organisation, are called for.

40. It should, if possible, be in a position to advise on matters such as factory lay-out, selection of machinery, production costing, and the general principles of factory management.

Library service

41. It should maintain an up-to-date technical reference library which can be consulted by local industrialists, and government departments; and it should provide, for a fee when appropriate, technical literature, summaries and bibliographies, when requested by local industry.

Activities of new institutes

42. It is not, of course, suggested that a new institute can carry out all the functions mentioned in the preceding paragraphs, but these are the functions and there are others, which should be the ultimate goal.

43. However, in new institutes the immediate goals will be to start a technical library; to provide a general advisory service; to work on adaptation of materials or processes and to study local conditions. It can also, at a very early stage, advise on standards of performance and quality and can provide a simple testing service for industry.

II. TYPES AND FUNCTIONS OF INDUSTRIAL RESEARCH INSTITUTES

44. Types of industrial research institutes are many and varied. Some institutes carry out research in any scientific field as long as the work falls within the competence of its staff: these are sometimes called "divergent" or "multi-purpose". Then there are two types of specialist institutes: those which practise a particular scientific discipline, such as physics or chemistry, and those where the work of the whole institute is aimed at a particular product or process and where a number of disciplines are used in achieving this end.

45. For instance, a rubber research institute might have sections dealing with the growth and selection of rubber trees, the tapping and collection of rubber latex, the treatment of the latex and possibly the compounding and moulding of rubber into usable products. Such institutes are sometimes called "unipurpose" or "convergent", because all the activities of the institute converge to one point, although the spread of interests may be very wide. These are also sometimes called "commodity" institutes.

46. There are also industrial research institutes which cover not only the scientific disciplines but also the human sciences, such as economics and sociology and which also advise on non-research subjects such as management and marketing. These could, perhaps, be designated "comprehensive".

Choice of type of research institute

47. It is very difficult to say, without a study of all the circumstances, which type of institute is required in any particular instance. It is perfectly clear that every country or group of neighbouring countries needs at least one multi-purpose institute. It is usually in these institutes that new industries or activities are born, because these are frequently inter-disciplinary.

48. It may well be that when a particular activity of a multi-purpose institute becomes of such a size and complexity that it creates imbalance in the institute, this particular activity should then become a specialist institute.

49. An example of this in the United Kingdom is the National Physical Laboratory (NPL) which was founded sixty-six years ago. There are now in the United Kingdom a National Engineering Laboratory, a Road Research Laboratory, a Building Research Station and a Hydraulics Research Laboratory; but the scientific

work on all these subjects started in the NPL which then branched off into separate institutes as circumstances demanded, thus leaving room and facilities at the parent laboratory for new developments.

50. This does not mean that these developments would never have taken place in the United Kingdom unless the NPL had existed, but it is quite clear that they would have been much delayed but for the existence of a large multi-purpose laboratory. For this reason, such institutes are regarded as the seed beds of new technologies.

Specialist research institutes

51. With regard to specialist institutes, probably only large and wealthy countries can afford to have institutes devoted entirely to single scientific disciplines, but in a country or group of countries where the economy is largely dependent on a particular crop or mineral resource, it may well be desirable to establish institutes to deal with this product alone. Thus we have the Rubber Research Institute in Malaysia, the International Rice Research Institute in the Philippines, the Commonwealth Cotton Corporation serving the British Commonwealth nations, and similar bodies. There are also numerous national specialist institutes such as the Coconut Research Institute and the Rubber Research Institute of Ceylon; and multi-purpose but specialist institutes, such as the various organizations devoted to R and D on agricultural machinery. It will be seen, therefore, that the pros and cons for specialist institutes can be determined only in the light of the activities and requirements of a particular country or area of the world or in the light of the requirements for the development of a particular crop or other natural product.

Comprehensive research institutes

52. Institutes of comprehensive type have grown up in the United States and are now spreading to other countries. They differ from the normal natural science research institutes in that they provide a comprehensive service to industry or Government. While basically concerned with research in divers fields, such as chemistry, engineering, physics and mineralogy, they also advise on economics sociology and other human sciences and act as consultants on management, organization and related problems.

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53. These institutes have the ability to reduce their technical findings to practical matters of cost, finance and market requirements and they can thus assist industry in its usual problems involving technical and economic considerations simultaneously. These types of combined services are usually known as "techno-economic".

54. It may, of course, take a long time to build up a sufficient range of staff to cover all these aspects of a project but the availability of these types of services is of very great importance in new countries. In due course, they can advise on marketing, packaging and branding of products, for which, indeed, they can often help to foster a market.

55. Techno-economic analyses by an industrial research institute can provide industrial managements and Governments with information on which to base plans for expansion; so can surveys of raw materials. The latter can cover all the natural resources of the country, or they may be confined to one or two resources which appear to offer commercial possibilities.

56. It is clear that a broadly based institute with the necessary range of professional staff can assist industrial development in many ways and each country must determine the nature and extent of the assistance it needs and the extent to which it can allocate funds for the purpose.

57. Industrial Research News[1/] has published an interesting table setting forth the services offered by a range of seventeen industrial research institutes in fourteen countries, both advanced and developing. The table is produced in annex I, and it is interesting to note how many of these institutes offer services such as feasibility and productivity studies and other services normally associated with industrial management, as well as the traditional services on raw material utilization and process development.

Subjects for study

58. Having considered in outline the main general types of industrial research institutes, consideration should be given in somewhat more detail to the functions of institutes as applied to problems in developing countries.

1/ Centre for Industrial Development, Industrial Research News, (United Nations publication, Sales No.: 66.II.B.6).

59. In the first place, the research organization should initiate and carry out research for the promotion of industry in general - both primary and secondary industries. In this connexion it will pay special attention to the utilization and processing of indigenous products, either for use and sale at home or especially for export. It will also be concerned with the production at home of products which would otherwise need to be imported.

60. One point which is sometimes overlooked in developing countries, in the preparation of products for export, is that export trade can be built up only if the products exported are of the highest possible quality and of consistent quality. Importers in the advanced countries will not repeat orders unless they are sure that they are going to get products which will be at least as good as any similar products obtainable elsewhere.

III. THE CONTROL OF RESEARCH ORGANIZATIONS

61. The setting up of an R and D organization is an expensive matter; therefore, the first problem to be considered after the need has been established, is how the institute is to be financed. In a later chapter the various ways of financing R and D institutes will be discussed fully, but a basic consideration is whether there is any organization, or group of organizations, in the area concerned willing and able to invest the necessary capital. In many developing countries the only organization that could contemplate the setting up of an R and D all-purpose institute, as a long-term development, is the Government. For many types of activity this applies also in the advanced countries.

62. There has been much argument about whether industrial research institutes should be publicly or privately controlled. Public control ensures that the work of the institute will be relevant to the economy of the country, and it also assures greater continuity in the work. But countries are controlled by politicians, and political requirements are sometimes subject to rapid changes; such changes can be inimical to scientific and technological requirements. Public control, therefore, should not be of the direct and detailed kind which interferes with the day-to-day work of an institute.

63. Private control achieves significant independence from rapid changes due to the vagaries of politics but does not ensure that the organization will be more concerned with the economic well-being of the country than with the earning of private profits. However, the choice as between private and public control is not normally determined on this consideration but on the much more mundane problem of who can supply the necessary finance.

64. If an institute is publicly controlled, this does not necessarily mean that it must work wholly on problems set or approved by the Government, since the institute can carry out repayment work for private industry. An organization which can work for the Government and for industry really has the best of both worlds, provided that Government does not interfere with the technical work carried out and trusts the director and staff to use their resources gainfully and not in any way that might militate against the over-all policies and requirements of Government.

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65. It may well be, of course, that as the industrial economy of the country develops, local business and industrial organizations will be prepared to finance some or most of the work of the institute, but in countries in the very early stages of development, there are few, if any, such entrepreneurs.

Government sponsorship

66. The position is arrived at, therefore, that the first steps in R and D in many developing countries must be sponsored by the Government, or by a group of Governments and, even then, it is often necessary for a significant proportion of the capital requirements and early running costs to be provided by a world-wide organization, such as a member of the United Nations family, or by wealthy foundations in the advanced countries. However, these external organizations cannot usually undertake the complete and continued financial responsibilities; and this almost inevitably means that the local Government or Governments must be financial partners in the project and that they will, in due course, become the major source of its funds.

67. Government participation in the financial arrangements means, of course, that the Government will have a say in what the institute does and how it does it. However, as has been said earlier, long experience has shown that politics and science do not mix well. It becomes necessary, therefore, to devise means whereby the Government can be assured that it is getting value for public money invested, without the research institute becoming a pawn in local politics so that its growth and possibly even its existence depend entirely on the whim of the Government of the time. Pressures should not be brought to bear upon the institute with regard to its work or organization in order to achieve particular political ends of an ephemeral nature. The means whereby reasonable government control may be exercised without government interference will be outlined later.

Non-government R and D

68. Many industrial research organizations are not government establishments. The commonest type of these is the research and development division of a large commercial company, but this confines its interests to the products and processes used by the company. There are some such organizations in developing countries, but they normally serve large foreign comapnies or local subsidiaries of such

companies. These organizations are usually concerned mainly with control problems, most of the real research being done in the main laboratories of the company, usually in an advanced country.

69. Occasionally, laboratories are set up by local chambers of trade to provide services on a repayment basis to members of the chamber. These laboratories frequently are concerned mainly with testing to specification. Their work is mainly analytical in character and the laboratory also serves as a technical information centre.

Sponsored research institutes

70. In some advanced countries there are sponsored research establishments, although this type of establishment is more common in the United States of America than elsewhere. Some of these have opened branches or subsidiary establishments in other countries and sometimes in developing countries. These establishments are staffed, in part, by people from the parent laboratory and they have the great advantage of being able to call upon the knowledge and experience of the parent organization, but because their work is sponsored, the results may be available only to the sponsors.

Industrial research associations

71. Another type of industrial research establishment is the industrial research association, a type of organization pioneered in the United Kingdom almost fifty years ago and of which there are now fifty-four in that country. Most of these are state-aided financially, but some are not. In this type of organization the member firms of a trade or industry subscribe money to set up and maintain industrial research laboratories to study the problems of their industry, to provide technical information centres and to provide advisory services to members.

72. When this movement began the Government gave significant financial support, with the intention that this should gradually diminish until the associations would be self-supporting. However, while the proportion of government support varies widely from industry to industry, the current intention is that some measure of government support will be maintained indefinitely.

73. It was originally thought that associations of this type would be mainly useful to smaller firms which might be unable to maintain their own research

divisions. In fact, this has not been so. Big companies which spend large sums on R and D are often the main supporters of the Research Associations, and this is due mainly to two reasons: first that big companies are probably big because they support R and D and second, that the research-oriented firms employ trained staff who can appreciate and adapt the results of the work of the Research Associations, whereas the small firms, often having no such staff, are unable to absorb and benefit from the research results.

Government controlled institutes

74. It has been said earlier that even in advanced countries much of the cost of R and D is met from government funds and that in many developing countries the Government is the only organization able to undertake the financial responsibility of setting up and maintaining industrial research organizations. Even in a moderately important project, the R and D element may well occupy several years, and it can be carried out efficiently only against a background of financial stability and continuing policies.

75. Some means, therefore, must be found of canalizing government funds into the R and D organization and of seeing that government requirements are given adequate attention in the organization, while at the same time the efforts of the staff remain planned and systematic and do not degenerate into mere trouble-chasing for political ends.

R and D. board

76. The best means of achieving government participation and stability of policy is for the Government to set up a body, a "research and development board" on which it will be adequately represented but which also includes representatives of various aspects of the national life, such as learned societies, chambers of trade, development bankers, investment corporations and educationalists. This can be quite an extensive grouping of all elements of the community having an interest in R and D and in the betterment of the country's economy.

77. This board will serve not only the purpose of giving over-all support and direction to the organization but should serve the purpose of ensuring the support of all aspects of the country's life represented on it.

Membership of R and D board

78. The board should have as its chairman a person prominent in the business or academic life of the country and its terms of reference should normally call for an annual report on the operations of the organization to be addressed to the Prime Minister or to an appropriate minister. Even in the early days of the organization's life, this board should meet perhaps twice a year. Later, when the organization is established and on an even keel, once a year will probably be adequate, although the director of the organization should of course be enabled to appeal to any member of the board on any particular subject that may arise for help and advice.

Executive committee

79. From this board there should be elected a very much smaller executive committee which should meet more frequently and be the main source of support for the director and staff. It will be the authority in whose name the day-to-day activities of the organization are carried out. In the very early days of the organization this executive committee may need to meet monthly and later it should, perhaps have three or four meetings *per annum*.

Membership of executive committee

80. On the executive committee should be concentrated those members of the board with scientific, technical or economic interests, if possible with experience in research and development, for whom it is often useful to become associated with those aspects of the operations of the organization in which they are expert. They can do this by occasional visits to the laboratories and by discussion with the project groups working there.

81. The executive committee will, of course, devolve upon the director all the necessary managerial functions, but the director will report to the executive committee on all major activities of the organization and will look to the executive committee to support him, especially in the matter of raising funds. This committee will report to the research and development board annually, and in its constitution there should be some provision for rotation of membership. A useful provision is that members serve on the executive committee for a period of

three years and then be ineligible for re-election for a period of one year. With a new organization, this would mean that the original members of the executive committee would have to be appointed for 1, 2 or 3 years so as to get the system running smoothly. This rotation of membership provides against the possibility of the building up of vested interests.

82. Experience has shown that sometimes when an executive committee has remained unchanged for a number of years, the members tend to favour certain projects and react against proposals for change. The three-year rotation of membership provides for continuity of control, and also for the introduction of new blood, leading to a changing outlook, so as to meet the changing requirements of the country.

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IV. ORGANIZATION OF INDUSTRIAL RESEARCH INSTITUTES

83. Within the present century, scientific research has changed from a craft to a large-scale industry, and it has had to learn such lessons as it can from industry and adapt them to its purpose. Since this is mainly intellectual, they may indeed have as much to learn from considering the principles underlying the administration of such institutions as universities, schools and hospitals, as from industry.

The small institute

84. In the new and small industrial research institute the director will guide and supervise all the work and the few staff will report directly to him; but as the institute grows in size the director will have many duties and interests connected with, though outside, the institute itself. An organizational pattern will then emerge.

85. The "emergence" of an organizational pattern is referred to because it is quite wrong to adopt an organizational chart and then try to fit people and problems to this chart. The pattern of organization must be based on the nature of the work and the abilities and personalities of the staff. Also, in the early days, labels and titles should not be attached to members of the staff in any permanent sort of way. As the operations of the institute develop, those members of the staff possessing the necessary attributes of leadership will demonstrate their ability, and these are the people who will be the division heads or group leaders of the future.

The larger institute

86. When the institute becomes of such size that the director cannot, himself, control the whole organization, an organizational pattern will develop, and this will probably follow the lines, at first, of a division between the technical work and the non-technical administrative work. Thus, we have a pattern as shown in chart 1, annex II.

87. The object in forming divisions and groups is to facilitate the work, but it must be impressed upon all members of the staff that their loyalties are to the

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institute as a whole and not merely to one section or group. This means that their skills and abilities must be available in solving problems brought to the institute and not merely the problems assigned to their own group.

88. The setting up of divisions can be either along the lines of scientific disciplines or along the lines of the purpose to be served. Thus, in an institute there might be a division of chemistry and a division of engineering; or there might be a process development division involving both chemistry and engineering. The types of divisions should be determined on the basis of convenience of work, and most successful research institutes have in their make-up a measure of each type. In addition to the formal divisions, there will need to be project groups, having attached to them members of various divisions, either whole or part time, during the period the project is active.

Project groups

89. The creative individual is the key to most of the really important scientific discoveries. Increasingly, however, the small groups or teams of research workers have assumed added importance in the production of technical change. These groups have made possible prompt, frequent and easy exchanges of ideas and questions.

90. Groups are a powerful means of introducing the inter-disciplinary approach to research. It is not necessarily the case that research has become more complicated because at each stage it has to be as sophisticated as current knowledge and ability will permit. It is, however, true that the more extensive foundation on which present-day research is based not only permits but requires that several disciplines combine in order to solve problems more quickly. While among the many means of producing technological change team research has become so important, the freedom of the individual researcher within the team must not be restricted, and his creative opportunities must be encouraged in every way.

91. It has sometimes been argued that there should be no formal divisions in an institute and that all staff should be regarded as a pool from which members of project groups may be drawn as required. In practice, this has not proved very successful. It has been found that staff are happier if they feel that they have a particular and permanent niche in an organization. They do not mind being seconded from their permanent place, provided that they feel they are going to return to it when their part of the special job is completed.

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92. An argument against divisions organized purely on the lines of disciplines is that cross-fertilization is diminished. On the other hand, an argument against the retention of permanent project groups is that once the members of the group have reacted on each other further reaction becomes slow. This means that the best results are obtained by a constant but gradual change in the personnel of such groups. Numerous changes are, of course, difficult in a small institute, because the number of people available to change around is small, but even here the value of change should always be borne in mind by the management.

93. In the small institute with just one organizational division, and that between technical work and non-technical administrative work, it will probably be necessary, as shown in chart 1, for an assistant director to be appointed to co-ordinate the technical work. He will report to the director, as will also the administrative group leaders.

94. The director will spend much of his time on public relations and in negotiations with users of the work, but the assistant director will also have contacts with the users, though at a much more detailed level than does the director.

95. As the institute grows, the pattern will become something as shown in chart 2, annex II. Both chart 1 and chart 2 are taken from the Manual on the Management of Research Institutes in Developing Countries.[1]

The comprehensive institute

96. In chart 2, which is the organization plan of a comprehensive industrial research institute, there are now several assistant directors, each in charge of group activities such as technology, engineering and economic studies; there is also an assistant director for administration, including the library and personnel administration.

97. Whilst these charts show possible organizational schemes for a small and a large institute, it should be repeated that the schemes must be based on the nature of the work and the abilities and personalities of the staff. An industrial research institute is a living organism and the same biological law applies to it as to any other: the organism must adapt itself to its environment or perish.

98. As an institute grows, the scope of its work will increase. It will start purely as a technical institute probably dealing with problems mainly in engineering,

1/ United Nations publication, Sales No.: 66.II.B.3.

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chemistry and economics, but, as it expands, it will cover other scientific disciplines such as biology, physics and geology and technologies such as metallurgy and mineral processing.

99. It will necessarily be concerned with economics but may also extend into the field of sociology. The larger the institute the broader will be the coverage that can be given to projects and the more necessary it will become to use the "project team" or "task force" approach. When this principle is employed it is not essential that all members of the task forces should be members of the staff of the institute. Some special aspect of a problem could be dealt with by a consultant or temporary research fellow especially recruited to contribute to its solution. The operation of these teams, crossing the usual formal organizational lines, requires adjustment on the part of the professional staff and puts new demands on managerial skills. This is because the varied professional skills and experience required to reach an optimum solution are brought to bear simultaneously on the problem.

Project group staffing

100. The system makes use of the total pool of technical talents in all parts of the organization and, therefore, avoids the tendency in specialized sections to build up large staffs in order to handle all facets of the problem internally. It also tends to inculcate a very much stronger sense of responsibility in the men of the different disciplines, because instead of working with others of the same discipline, they may well be the only representative in the team; this puts on them individually the onus of providing the contribution of their discipline, while enlarging their knowledge and experience of the contributions made by other disciplines. This has a valuable effect in the development of staff, although, as has been said earlier, working exclusively in project teams is probably not to be encouraged. It is good for every specialist to work with others of his own discipline from time to time, since they can, when necessary, criticize his ideas and, if necessary, counter any tendency towards inflated opinions of his own ability.

101. Whatever the general scheme of organization, it is important that all members of the staff should have horizontal contacts with staff in other divisions or teams, so that they will have a fair knowledge of other problems and projects being investigated in the institute and can, if required, contribute to those also.

General management

102. Management of research is different from management of most other human activities. In research, management involves no rigid controls, no disciplinary restrictions. It should always be regarded as an enabling process, that is, it provides the money, facilities, and all else that enable the research to proceed, smoothing the way and creating the right climate; and ultimately furthering the implementation of results.

103. The understanding of research management has progressed rapidly in the last twenty years but still has far to go. It can greatly assist the productivity of research. Good management stimulates creativity and retains faith in the ultimate return on wise investment, even though the return may not be immediate.

104. Individual creativity is an important contributor to research productivity, but a combination of the creativity of many people is what makes the successful research organization.

105. Some ten years ago there was something of a divergence of opinion between leading research directors in the United States and the United Kingdom. It was then thought by many in the United States that the most desirable characteristic of a scientist was that he should be a good member of a team, whereas the United Kingdom maintained faith in the creative individual. It was felt in the United States that in some instances the really creative scientist tended to be an individualist and was sometimes an "oddball" who did not fit well into a team. Since that time American directors have found that creativeness is essential for many types of work and that creative people will, on the whole, co-operate adequately in a team. In the same period, more directors in the United Kingdom have learned the value of the team approach. There still seems to be rather more emphasis on the individual in the United Kingdom, but the differences in organization of research between the two countries are not now significant.

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V. THE DIRECTOR

106. Cervantes has wisely said: "When the head aches all the body is out of tune." The most important appointment in a research organization is that of the director. On his knowledge, experience, foresight and energy the success of the organization will largely depend. This is especially so when the organization is new and small, because then he will be laying the foundations of future scope and methods of working, of future personnel policy and of the image which the organization will have in the minds of government, business interests, the local population and scientific organizations elsewhere. He should, of course, preferably have no direct affiliations or private relations of any kind with any type of industrial, commercial, financial or political organization.

107. As with all those employed in the organization, the director must know to whom he is responsible - whether to a board of management, government department, or minister. The duration of his appointment, length of notice to quit it (on either side), salary, allowances, length of leave periods and any special terms of appointment must be clearly set out in his contract, as must also his powers in regard to appointment and dismissal of other staff, the extent to which he can commit the organization financially or contractually and when and in what manner he must report to the board of management, executive committee, minister or other superior authority.

108. These matters can be set out in a job description, but the controlling authority should always be prepared to negotiate on them with a suitable person. No effort or time should be spared in finding a suitable man; it may, of course, not be possible to find one having all the desired qualities, but only then should someone else be appointed.

The scope of the director's activities

109. In the early days of a research institute the director will be the director of research, the director of the institute, the administrative officer, the money-getter and the money-spender. He is the reservoir of much technical knowledge and experience and the chief staff selector. He is the main contact with the outside world of science and technology, and often he has to be, in large measure, his own architect.

110. As the institute grows the director will not be able to concern himself with all details of the work and, thus, the direction of research will pass to his assistant directors. He himself will find his time very full dealing with those who provide the finance, clients and those who can use the results of the institute's work. While his contacts with junior staff will become less (though not, of course, ceasing altogether) he will be in close touch with the assistant directors, the personnel manager and the head of the finance section. Technically, his most important function will now be as arbiter when differences of opinion arise, as they are bound to from time to time, between his assistant directors. He will also be chief assessor of priorities in regard to projects, staff, money and facilities.

111. In the small institute the director should preferably be something of an expert in the matters being investigated but in the large institute this is not necessarily the case: what is needed is a person well trained in science and of the right experience, temperament and breadth of outlook. There is, in fact, a school of thought that holds that the director of a large organization should not be an expert in any of the subjects studied in his institute, for fear that he will have an emotional attachment to one branch of the work, which may cloud his judgement and cause him to allocate more money and facilities to that branch than are justified. There is much to be said for this point of view.

The director as staff selector

112. Among the many qualities of the director is that of being a good selector of staff. There have been several organisations which were quite unusually successful though directed by men of no great technical eminence: but these men had the inestimable quality of being able to attract good men to their institutes, even though they were already of greater technical eminence than the director himself, and of being able to choose those whose subsequent performance fulfilled their earlier promise and the institute's requirements.

The director's relations with staff

113. The director will be not only the person who will advise on or initiate the general personnel policy of the organization; he will assume the duty of implementation of the policy for the rest of the staff. In this he must be

sympathetic yet firm: ready to give decisions when required but not officious, ready to delegate responsibility and ready to hold people accountable for the delegated responsibilities. He must pay due regard to criticisms of his staff but should always be ready to defend his staff against unjust criticism. At times he must not flinch from making unpleasant decisions and, above all, where his staff are concerned, he must ever be ready to give credit for good work well done.

Expatriate directors

114. Almost inevitably at first, in many new, developing countries, the director will need to be an expatriate, because very few developing countries have men of sufficient experience to set up an institute, although indigenous people can be trained to take over from the expatriate in due course. This process should not, however, be hurried. In several developing countries, for understandable reasons, expatriate directors have been replaced by nationals of the country at too early a stage, and highly productive institutes have, as a result, fallen into mediocrity.

115. The desire to have a country's research organization under the control of a national must be very great and is commendable, but good directors cannt be produced in a year or even two years and it is, therefore, a wise country that decides not to try to replace the expatriate before it is quite certain that an equally good replacement has been found for him.

Scientist or administrator?

116. The director of a research establishment must be a scientist, and there has been much argument as to whether his skills should be primarily in science or administration. In the small establishment, as has been said, he will be the director of research, and here his scientific skill will be paramount. In the large establishment his administrative abilities will be very much more important, and scientific ability will be supplied mainly by members of his staff. It is, however, felt by many that the director should be of such scientific stature that his staff will respect and follow him for this reason. The scientific stature of the director, no doubt, has an effect upon the morale of the scientific staff, but it is not so certain that in the large institute, administrative ability does not have an even greater effect upon the success of the institute and, therefore, upon staff morale.

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The director as administrator

117. In the larger establishment the director has necessarily to spend much of his time dealing with matters of personnel and finance and he cannot possibly be familiar with the details of all the scientific work that is going on there. This is particularly the case in a multi-purpose or comprehensive establishment because the director will be scientifically eminent only in one discipline and his staff will cover many disciplines.

118. As the research establishment becomes institutionalized the number of people reporting directly to the director must be kept to a minimum. Many experienced laboratory administrators feel that this number should not exceed five, but a great deal depends upon the length of time that the director has been in the organization and it depends even more especially, on whether it has grown up under him.

119. Where an organization has grown up under a director, experience has shown that he can control much more of the detail of the work of the establishment than can a director who comes into the organization when it is fairly mature. In fact, in some advanced countries, some of the tragedies of research establishments may be seen in directors who have done tremendous work in building up establishments which have then reached such size that the director can no longer direct in detail; but by that time, he has reached an age when he finds it difficult to alter his ways of working. At that stage the original director can become a hindrance to progress.

Administrative help for the director

120. Directors are frequently chosen for their scientific abilities rather than their administrative abilities, and it is unfortunately the case that the qualities required for eminence in science are not those required in administration. Eminence in science has usually been achieved not only by the exercise of a creative and inventive brain but by meticulous attention to detail. The administrator of a sizable organization who concentrates on detail becomes an encumbrance.

121. He must be able to devolve detail upon others or he will never get a real grip on the broad problems of the establishment. It is desirable, therefore, that the eminent scientist should have at his right hand someone who can assist him with administrative problems and who can act as a sort of general manager of the

organization. This arrangement has worked excellently provided that the director is willing to be guided by his administrative colleague on matters of administration. The administrator can be a non-scientist but it is preferable that he should have been trained as a scientist even though he may later have turned his abilities to administration.

122. The larger the institute the further the director is from the details of the scientific work being carried out, but this does not mean to say that he does not have a powerful influence on this work. Lees and Leermaker have said "The research director does not direct research, he protects the scientists from those who wish to direct them". By this they meant that it is the director's job to approve objectives, allocate priorities, and to see that the scientists are not subjected to undue interference. The scientist himself is the only person who can determine the pattern and course of his experiments.

123. A novel point of view about the main functions of a director was put forward by Bronowski who said that the director's principal function was to be a provider of foresight. He believed that the other major activities of directors were really those that assisted him to assess the way requirements were likely to develop, and he derived hence the power to direct them rightly. Certainly, the ability to see ahead is extremely valuable. Major research projects take some years to mature, and the director must endeavour to determine what the requirements will be several years ahead rather than what they are at the immediate moment.

124. If the organization of the laboratory is well founded, the personality of the director, while very important, will be rather less important in the large institute. Broadly, all that he can do is see that conditions are created in which good research can be done; but in the large institute it is the group leaders who set the pace of discovery rather than the director himself.

Devolution by the director

125. Directors of all establishments will spend considerable time on work outside their own walls, attending boards and committees or lecturing; they may travel extensively. A director will be the principal ambassador of his organization. Other members of the staff will also have considerable dealings with outside bodies, and it is most important that they should be able to rely on the director's support of their actions. The more he is engaged away from his laboratory, the more must

he be prepared to leave its internal administration to others. No institution can function efficiently if all decisions must await the personal approval of someone who is frequently not available. Some decisions must, of course, be made by the director in person, but he should be prepared in other cases to support any reasonable action taken by his deputies in his absence.

126. Despite the difficulties, several directors of large laboratories still continue to engage in research. This is undoubtedly a good thing in the sense that to suffer themselves the frustration and delays inherent to experimental work helps to allay in them any undue impatience they may feel about the progress of the work of their staff. On the other hand, there is always the tendency for such activities by a director to grow and to distort the balance of work within the organization. There is a danger that the work in which the director is himself expert will seem to him of greater value than the other researches. If this view is allowed to effect his decisions on priorities he will fail in his futy as director of the laboratory, however good his leadership in research.

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VI. STAFF ADMINISTRATION

127. The productivity of an industrial research organization will depend on its ability to recruit able staff and to employ them on projects which are, and which the staff themselves feel to be, rewarding, both technically and economically.
128. Industrial research organizations employ a wide variety of staff and the over-all terms and conditions of employment will no doubt be agreed by the employing authority whether government, industry, or private foundation, in the light of national and local requirements and standards. In the personnel field the most important function of this authority will be the appointment of the director - the man upon whose judgement, initiative, and ability to select and keep able staff and maintain high morale by means of sound personnel policies, the productivity and success of the organization will largely depend.
129. Industrial research organizations employ many types and grades of staff, many with their particular ways of working. Some are skilled and some are not so skilled, but all must contribute to the productivity of the organization. A well-founded personnel policy must be moulded to this end.

<u>Professional staff (scientists, engineers, technologists, economists)</u>

130. The most important group of staff is the professionals, the scientists, technologists, engineers, economists and others. They are the people with the knowledge and ideas and to them falls the duty of supervising the work of the assistants, technicians, and secretaries. They will also maintain contacts at the working level with others of their own discipline, with other research and commercial organizations, with government departments and with potential users of the results of their work.
131. The professional staff will be university trained and should have a bias towards applied rather than basic research. They must have high standards of ethical behaviour and an ability to get along with other people, because they will have dealings not only with their staff but with those from whom funds are received and with those who will use the results of the work. They should have an interest in the economic and sociological consequences of their work and should be prepared to tackle any problems within their professional competence.

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132. A mistake sometimes made is for industrial research organizations to spend a lot of money and trouble trying to find creative recruits. Quite apart from the fact that most really creative scientists are happier when engaged on basic research, many industrial problems call for an analytical approach rather than creativity. When choosing staff it is necessary for a clear idea to be formulated about the types of work to be done and, therefore, about the types of scientists needed to fulfil the requirements. "Analytical" in this context does not mean chemical analysis, but the study of materials, properties, processes, and products so as to enable a reformulation of products or processes, thus overcoming product deficiencies or production difficulties. Much trouble-chasing in industry is of this type.

133. The professional staff, especially the physical scientists, will usually be profession-oriented rather than organization-oriented and will tend to be individualists needing reasonable freedom from detailed supervision in carrying out their work. Particularly, they should have freedom, when the nature of the work allows, to consult experts within and outside their own organizations. Normally they will plan the details of the work themselves. They tend to be impatient of delays occasioned by "administrative" requirements, the reasons for which may not be entirely clear to them. They are, however, dedicated workers and should be allowed to publish the results of non-confidential work in the scientific press. This not only enhances their own reputations but also that of the organization in which they work. They should also be encouraged to become members of professional societies, and it is sometimes the case that the organization will help with the payment of the necessary fees.

134. Such people are in short supply in most countries and particularly in the developing countries which will often need to recruit them from advanced countries, at least during the earlier years of the organization's life. In these cases the objective will be that expatriates will, in due course, be succeeded by nationals. In some instances local "counterparts" are assigned to be trained for the job but it is doubtful whether this is wise in the very early days of an organization. It is often better to wait and see if a leader emerges from the local staff and to give him every opportunity to develop his abilities to the take-over point. To attach an inexperienced and possibly unsuitable "counterpart" to a director cannot but be frustrating for both of them and is bad for the organization.

135. Also, during the formative years, it will be necessary to cover as wide a range as possible with a small staff and it is often preferable, therefore, to recruit staff with subsidiary knowledge and skills in addition to their main disciplines. Thus engineers or chemical engineers may have studied industrial management and/or statistics or economics. Chemists may have studied geology, botany, pharmacology, economics or statistics, as well as the more usual physics and mathematics. All scientific staff will need to have a working knowledge of electronics. The scientists will not only have basic university degrees but, often, higher degrees. Generally, the possessors of higher degrees are more desirable as recruits, but this is by no means always the case.

136. Most directors of research establishments adopt the "open-door" principle in personnel matters, that is, any member of the staff who has a serious matter to raise with the director can do so. The director must see that this privilege is not abused and his own time wasted by trivial or "try on" matters, and he must also see that the concession is not used as a means of by-passing group leaders or section heads with whom the matter should properly have been raised. He will always, however, remember that matters which to him do not seem very serious may appear to be of the greatest importance to an inexperienced junior.

137. It is quite a good plan in larger establishments for some rather older member of the staff to be "big brother" to specified junior recruits. He can "show them the ropes", and a recruit can be encouraged to discuss with him his doubts or difficulties. Again, experience has shown that young people making the change from university studies to industrial research tend to worry over matters and thereby impair their efficiency, when a short discussion with a colleague of greater experience could resolve the difficulty or doubt in a very short time. This applies particularly to young people starting work in a new country.

<u>Research fellows</u>

138. There is a growing practice in research laboratories to appoint research fellows. These are usually young Ph.D's, who are appointed for a period of two or three years to work on a specific research problem. They are not permanent members of the staff and are not, therefore, expected to take part in the more routine work of the establishment, nor are they diverted onto short-term tasks and trouble-chasing.

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The personnel manager

139. The types of staff normally employed in a research organization have been described briefly above. In the very small organization the director will be his own personnel officer. He will know each member of his staff personally and will soon learn their capabilities and limitations and will allocate the work accordingly.

140. The director has, however, many other matters to attend to, and he will necessarily spend much of his time dealing with those who provide finance and with potential users of the results of his work. As the organization grows he will need to devolve more and more and it is very important that he should be able to devolve - a process that does not come easily to some technically trained people, who are much more inclined to deal wholly with a matter or to divest themselves completely of responsibility for it.

141. Another important personnel matter that falls to the director is to see that his scientific staff keep in close touch with each other and use to the full their joint expertise in solving problems. This does not happen automatically, because many scientists have a natural tendency to want to solve all their own problems. Experience in a large laboratory with a total staff of about 1,500 demonstrated constantly the necessity of devising means of bringing the scientists together so that they would keep each other informed about their problems because it often happens that a development in one discipline can lead to a solution of problems in an apparently unrelated field in another discipline.

142. As the staff grows the director will need to devolve much of the detailed work regarding personnel upon someone specially chosen for this work. In some countries it is the practice to appoint people trained only in personnel work, whereas in other countries it is more usual for an older scientist, who is interested in people, to take over this type of work - often on a part-time basis. The latter course is preferable for dealing with problems relating to professional staff, although a professional personnel officer is often better in his dealings with junior assistance and technicians. However, it is only in a large organization that one officer can be allowed to spend full time on such matters.

143. In large organizations the personnel officer will need to be assisted by a welfare officer to help staff - usually juniors - in their various problems. When staff are drawn from a large area the welfare officer will spend much time arranging accommodation for new members, and she (for welfare officers are usually women) will have a general supervisory function regarding canteen, wash rooms,

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women's rest rooms, and so on. She will also be able to assist in solving minor problems of incompatibility of temperament which may arise.

Personnel records

144. In a large organization the personnel officer will be supported by the usual office staff, and although his section will constitute part of the administrative division, it should have a separate room or rooms and its correspondence and files should be handled and stored separately from those relating to the general business of the organization. This ensures that personnel matters are dealt with confidentially and that private matters concerning members of the staff do not become public knowledge. There should also be provision for confidential interviews with members of the staff.

Staff salaries

145. Salaries and wages paid to all staff must be based on an adequate system of payment and awards and should be related to general levels of salaries in other professions and trades in the area. Only in this way can a stable staff be recruited and retained. Salaries which are too low will either not attract staff at all or will attract only those who have failed to find employment elsewhere. When possible, salaries should be flexible so as to reflect the value of the individual to the organization. The term "when possible" is used because many research organizations are government establishments and, in these, normal civil service payment rules apply and often do not allow for flexibility.

146. In some organizations annual salary increments are granted at a fixed rate, subject to satisfactory service, but in others no automatic advances are made, but all additional payments are based on evaluation of the work of the individual. Even in some government organizations a measure of flexibility is achieved by the director having power to grant double or even treble increments in recognition of outstanding work. Alternatively, the director may have power to grant increments at less than yearly intervals for specially valuable service. In some organizations, salaries are confidential between the employer and employee, but in others, especially government-controlled establishments, they are known publicly or at least to the rest of the staff.

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Overtime

147. In the matter of overtime work, any payment should be in accordance with local custom. If overtime is paid to junior staff it should be a strict rule that all such work should receive prior sanction. It is seldom that overtime is paid to professional staff but it is useful for the director to have power to make ad hoc payments in the unusual event of a job requiring many extra hours of work over periods of weeks or even months, but, even in these circumstances, the case is often met by the granting of extra leave on the "time in lieu" principle.

Patent payments

148. Although patents granted in regard to discoveries and inventions made by an employee during the period of his employment and related to matters which are the subject of his duties will normally be the property of the employer, as laid down in the terms of employment, some organizations do pay, as an act of grace, a proportion of royalties received to the employee who made the discovery.

Pensions and superannuation

149. Most organizations of any standing have arrangements for staff pensions or superannuation. These are usually contributory, that is, the employee pays perhaps 5 per cent of salary and the employer, perhaps 10 per cent, and the proceeds go to the purchase of an annuity, the size of which is usually, in current practice, related to the employee's salary on retirement or to his average salary over his last three or five working years.

150. If the employee resigns he is normally entitled to receive at least his own contribution with interest, and sometimes - but not often - he also receives the employer's contribution as well. In some cases there is only one set of benefits, and in others the contributions are paid to an insurance company and the employee has some choice in the form of superannuation. In another scheme a wide choice of insurance companies and benefits is given to the employee. However, the usual provision is for the contributions to buy an endowment assurance for men and a deferred annuity for women.

151. Some industrial research organizations are government owned and operate as part of the civil service. In some such cases pensions are non-contributory and the

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employee may get nothing if he resigns before reaching retirement age. This is understandable and even reasonable for some types of civil servants, for example tax inspectors, whose value and experience are gained as a result of their work; but for scientists it is inappropriate in view of the great need for scientists to be mobile between universities, research establishments (whether government or not) and industry. One concession to this need is made by at least one Government. If a civil servant wants to change his job he may submit a request, and if the proposed change is judged to be in the national interest, his accrued (non-contributory) pension rights are put into "cold-storage": that is, when he reaches retirement age he can then draw the pension appropriate to the period he spent in the civil service.

152. This matter of transfer is very important in industrial research establishments, because it may well be desirable that a scientist who has developed a process should transfer with his process to the organization which is going to develop it commercially. He may then, when the process is well established, return to the research organization and will be all the more valuable for his period of industrial experience.

Leave of absence

153. The number of days' holiday per annum is laid down in the contract of service, and in most industrial research organizations employees are allowed to take leave within an agreed limit at any time convenient to the organization. In some organizations the amount of annual leave increases with years of service up to, in the case of some countries, six weeks per annum - thirty working days.

154. It is invariably the case, however, that leave entitlement is subject to the exigencies of the organization, and in some there is no provision for the carrying-over of leave from one year to another. In other organizations, accumulation of leave is allowed, and this is of great convenience especially to expatriates who can thus accumulate sufficient leave to take a holiday in their home country or to tour laboratories in other countries. However, there is usually a limit to the period during which leave can be taken, and any leave not taken by the end of that period is lost. In one country, leave not taken because of the requirements of the organization is accumulated throughout a scientist's working life and when he retires he is paid for those periods.

155. The granting of sabbatical leave will be dealt with below, in discussing older scientists. It is a powerful means of stimulating somewhat jaded workers. There is usually a provision in regard to sabbatical leave, that at the end of the period an employee shall return to his home base for a minimum period of one, or sometimes two years.

156. Usually, provision is made for the granting of special leave, with or without pay. Special leave with pay is usually granted in the case of the death of an employee's wife or husband or other close relative, and special leave without pay is granted for domestic or social reasons which justify the employee being absent but which do not justify payment of salary. Special leave with pay is sometimes granted to employees who are, for private reasons, visiting another country and who can, while in that country, visit scientific institutions doing work of value to that of the home institute.

Older scientists

157. One of the biggest problems in research organizations in most countries is the problem of the older man. This is much more of a problem in basic research than in applied research. In a symposium on the Direction of Research Establishments held at the National Physical Laboratory near London ten years ago,[1/] representatives from research establishments in seventeen countries felt this to be the major personnel problem.

158. As scientists get older they increase their knowledge and experience but their power of invention usually decreases. The optimum age varies with different professions, but for fundamental work in the physical sciences the peak age is thought to be about thirty to thirty-five years. In industry the problem is not so great because many researchers transfer to such fields as process control or technical sales. In universities the emphasis is on new knowledge and the constant stream of young, inquiring minds maintains progress. Research establishments, which are not an intrinsic part of an industrial firm, are usually more static in their numbers and movement of personnel.

1/ 26-28 September, 1966.

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Technical obsolescence

159. With the present-day exponential growth of science and the rapid development of new ideas and new techniques, scientists can quite quickly become somewhat out of date. This is known as "technical obsolescence". It is now felt by some employers that scientists and engineers should return to university at intervals of not longer than ten years to bring themselves up to date.

Sabbatical leave

160. Another means whereby professional staff can bring themselves up to date is by taking special courses in new technology at universities, by carrying out research in another institute where they can meet and discuss new ideas and techniques with a wide range of other scientists or by taking part in a study tour which will enable them to see what is being done and hear what is being talked about in other institutes. In order to enable them to undertake such activities, sabbatical leave of up to one year should be granted on the recommendation of the director, who will assure himself of the value to the organization of the proposed activities.

Maintenance of productivity

161. The reasons why many scientists become less productive in their researches as they grow older are not easy to elucidate fully. Young people are naturally more venturesome mentally and physically. Also, not having a reputation to maintain, they are not so afraid of suggesting or trying something which other people will ridicule. Then, perhaps above all, they do not generally have many of the domestic preoccupations of older men. Sir Lawrence Bragg, a Nobel Prizewinner at twenty-six years of age, and son of a Nobel Prizewinner, has said "The greatest enemy of research is preoccupation."

162. Whatever the reasons, this situation has to be faced by directors of research establishments, who must ever be watchful that members of their staff do not get into a rut and that they take every opportunity of keeping themselves up to date technically by reading, attending scientific meetings when possible and by taking part in symposia and seminars. "In house" seminars must be arranged where staff members can expound to their colleagues important new developments in their disciplines or submit accounts of their work for comment and criticism.

163. When possible, scientific specialists visiting the area should be persuaded to address the staff. The director and senior members of the staff should also be very careful not to dampen the enthusiasm or in any way ridicule ideas of their young colleagues. The practice of "brain storming" no doubt grew out of this very need.

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VII. RECRUITMENT, APPOINTMENT AND EVALUATION OF PROFESSIONAL STAFF

164. Candidates for appointment are normally obtained by invitation, advertisement or recommendation, and where the number of candidates is sufficient, choice is made after a study of the candidate's university and employment record, followed by an interview when geographical considerations allow.

Invitation

165. Staff obtained by invitation are usually senior people such as directors or deputy directors. It is not uncommon for the appointing authority to survey the field, and if this indicates some particularly suitable individual, a confidential approach is made to determine whether he would be interested in the post. This type of approach may then involve negotiations with his present employers concerning his release. There are now consultant firms which specialize in this type of activity.

166. Recommendation is employed both for senior and junior posts. The director will write to other directors and especially to professors known to him, explaining his requirements and asking them if they have any member of staff wanting or needing a change or any likely students about to finish courses who will then be wanting posts. This method is particularly applicable when the organization is contemplating expanding into a new field of endeavour, because the directors or professors approached will be those who have had experience of the new field.

Advertisement

167. The commonest method of obtaining staff is by public advertisement. The journals and newspapers to be used must be chosen carefully as being those likely to be seen by potential applicants, and present competition is such that in some countries the better class of newspapers carry several pages of display advertisements for technical staff, many of them inserted by personnel and management consultant firms on behalf of clients. Gone are the days of two-line advertisements in small print, which appeared mainly to be of value in testing the power of the reader's eyesight but which gave little, if any, information about the job.

168. Applications are usually made on a form to be obtained from the organization. Applications should be dealt with as expeditiously as possible and all applicants

should be informed when the appointments are filled. It is bad public relations to leave applicants in doubt for long periods.

Interview

169. The interview must not be regarded as a test of the candidate's technical knowledge, since this should have been established beforehand from the particulars given in the written application, but rather as a means of assessing such qualities as his personality, general intelligence, alertness, and adaptability. Many organizations have obtained better results from alert, intelligent, co-operative scientists who had no previous knowledge of the subject on which they were required to work than from men already expert in the field but lacking those characteristics.

170. In some countries it is now the practice for a psychologist to be a member of an interviewing body but experience has shown that there is good correlation between the assessments of experienced scientific interviewers and subsequent performance. The presence of a psychologist can, at times, be useful but in many countries is not considered at all necessary.

171. Interviews may be organized in various ways. The usual arrangement is for the candidate to meet a panel or board which should consist of at least three and preferably not more than five people including the chairman. The director and, in the larger institutions, the head of the division or team in which the vacancy occurs, should be members of the panel. The other members might be the chairman or a member of the executive committee, the senior administrative officer to deal with the questions of salary, and an expert in the candidate's discipline, for example a professor from a local university.

172. The members of the panel should be fully briefed beforehand on the requirements of the post, and the candidates should also be supplied beforehand, in writing, with all normal information so that time is not wasted at the interviews by repeating numerous details to each candidate.

173. Members of the panel should endeavour to elicit all relevant information about the candidate and should frame their questions so that the candidate can express knowledge, views or opinions in his replies. Questions which require just Yes or No for an answer should, in general, be avoided. Panel members should not use the interview as a means of expounding their own views: the candidate should do nearly all the talking.

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174. It is not uncommon to find after a series of interviews that there may be some confusion in the minds of the interviewers between various candidates, and to avoid this it is a good plan for each member of the panel to be provided with a form to be completed about each candidate during the interview or immediately after the candidate has left the room and before the next candidate is admitted. This applies whether one candidate is to be chosen from a batch or whether all those worthy of appointment are to be offered posts. A possible form is given below and is basdd on one suggested by Anstey and Mercer:

Name. Age. Sex.

Present job and pay.

Date of interview Please tick the appropriate boxes

X	X Applies	Tendency to X	Average	Tendency to Y.	Y. Applies	Y.
1. Good bearing and address						Unimpressive in bearing and address
2. Expresses himself clearly and concisely						Has difficulty in expressing his thoughts
3. Quick on the uptake						Slow to grasp the point
4. Sound technical knowledge						Gave wrong answers to some questions
5. Good range and depth of interest						Narrow interests and little culture
6. Has initiative and grasps his opportunities						Disposition to drift along
7. Has taken pains to find out about the job						Has made no attempt to find out about the job
	Outstanding	Good	Average	Poor	Useless	

Over-all assessment

Interviewer's initials

Even without the use of such forms the unanimity of experienced panel members is usually striking.

175. A variant on merely putting ticks on the above form is to award marks: four marks for X down to zero for Y, in each of the seven criteria. The highest possible mark is therefore twenty-eight for a candidate outstanding in all respects, and the lowest is zero for someone utterly unsuitable. Only those candidates with fourteen marks or more should be considered.

176. The other fairly common method of interview is the series interview. In this method the candidate visits in turn three to five assessors whose opinions are collected and collated afterwards. This takes up more of the candidate's time, but is said to eliminate the effects of the interaction of the panel members on each other.

177. The basic function of the interview is:

(a) To determine that the candidate has all necessary information about the job;

(b) To check the basic facts about him;

(c) To observe the candidate's outward appearance and manner;

(d) To test the candidate's ability;

(e) To test his personality;

(f) To persuade the candidate, if necessary;

(g) To give the candidate a chance to clear up any doubts and uncertainties in his own mind.

<u>Teaching and students</u>

178. It is very useful for the professional staff of industrial research institutes to give some time to teaching at local universities or technical colleges. In the first instance this brings an air of practicality to the teaching, and in the second it brings members of the staff into contact with students and enables them to see whether any of these are likely to make desirable recruits for the research organisation.

179. In somewhat larger research organisations it is a very good plan for the organisation to receive vacation students. These are university and technical college students who may wish to work on subjects allied to their studies during the long vacation. Receiving such students can be somewhat time-consuming but experience

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shows that many of them can make a real contribution to the work of the organization. Unless the students live near the institute it will be necessary to pay them an allowance to cover their extra out-of-pocket expenses, and if a small salary can be paid on top of this so much the better.

180. This has been found an excellent means of recruitment of junior members of staff, since the group leaders get a chance to see and work with a student over a period of four to eight weeks, possibly for two or three years in succession, and can choose from these vacation students those with the right outlook and abilities to enable them to work productively in the institute.

Contract of service

181. Good personnel relations depend to a significant extent on the employer and employee knowing just where they stand in relation to each other. The principal matters in this connexion are best dealt with in a contract of service which should cover the following points:

(a) The parties to the contract should be stated clearly. For instance, it should be clear whether the employee is a servant of the institute, the government or any other body, and whether he is engaged to work only at the institute or wherever else his duties may require;

(b) There should be a broad description of duties, and this should make it clear that the employee is expected to assist the work of the institute in every way possible and not only in his particular discipline;

(c) The period of the contract should be stated, that is, whether the appointment is for a fixed number of years or for an indefinite term, and this clause should also state the length of notice required either for the institute to terminate the employee's contract or for the employee to terminate his appointment. It should also state whether there is a probationary period;

(d) The initial salary payable should be stated and also the frequency of payment, that is, whether weekly, fortnightly, monthly and so on;

(e) It should be stated whether the employee is expected to give his whole time to the post or whether he may undertake private work with the permission of the institute;

(f) The employee should be required to observe any reasonable working instructions given to him by his supervisor;

(g) The employee should undertake to observe trade or other secrets of the institute or its clients;

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(h) He should undertake, on leaving the employment of the institute, to return to it any property of the institute, including records of his work;

(i) The terms of engagement should provide that rights in inventions and discoveries made by the employee during the period of his employment and relating to matters which are the subject of his duties should belong to the employer. For this purpose he may be required to sign documents implementing this requirement;

(j) Some statement should be made about payment of salaries during illness;

(k) The length of holidays should be stated;

(l) If the employee is required to work away from the institute for any significant length of time, some statement should be made as to whether the institute will pay the expenses involved, such as, for instance, the expense of the employee being accompanied by his wife and family and the possibility of needing to move his home;

(m) Some statement should be made about sickness, accident and fringe benefits and about superannuation provisions in which the employee can share.

182. In addition, contracts or service sometimes contain a restrictive clause which provides that the employee may not enter other employment in the area on any of the subjects on which he has worked at the institute without the approval of the management of the institute. The attempted enforcement of such a clause can, however, lead to legal difficulties in some countries.

183. It is quite useful to incorporate the conditions of service together with general staff rules in a booklet, a copy of which is given to each recruit when he joins the staff. This booklet should be brought up to date periodically.

184. Item (e) above is very important in some countries where, because of poor pay, it has become the practice for many professional people to have two jobs. In some instances it has been found that even when adequate salaries are paid, the employee takes another job as if from force of habit. This is strongly discouraged.

185. Another matter of some importance in some countries is the survival of the old belief that a man of learning does not work with his hands. A physical scientist or engineer who does not use his hands as well as his head often cannot pull his weight in the organisation. This belief will, no doubt, die out but its survival in some areas has been a minor embarrassment.

186. Another unfortunate matter met with in a few countries is that staff have been appointed as a result of political influence rather than technical ability. Although the director, if backed by his governing body, can do much to mitigate this evil the real cure rests in the hands of the politicians or those who exert the influence.

Probation

187. In many research organizations it is usual to have a probationary period on appointment. For professional staff this is sometimes two years and for more junior staff one year. If there is such a period this should be stated in the contract or terms of employment. In the case of a two-year probationary period for professional staff, it has been found convenient and helpful to review the recruit's progress after nine months and then after eighteen or twenty months. If, at the end of nine months, the recruit is making insufficient progress he should, if possible, be moved to other work under a different division head or group leader in case his unsatisfactory progress is due to some incompatibility of termperament. The final review should be after eighteen to twenty months' service, so that the recruit can have reasonable time to find another job if the decision is that he should not be kept. This system is very good when operated properly but in periods of staff shortage its operation tends to be lax with unfortunate results for the organization.
188. In some countries the period of probation is, in effect, laid down by labour law, since after the period laid down an indemnity entitlement is incurred. For assistants one year on probation is adequate and for junior clerks the period could be as short as three months.

Periodic evaluation

189. Questions about staff recommended for increments or promotion cannot, in larger institutes, be settled just from the personal knowledge of one man. A system has to be devised so that all staff can be considered fairly and, just as important, feel that they are being considered fairly and that advancement is not due to chance or nepotism. Most sizable organizations have an evaluation or assessment system which is brought into full operation usually once a year, although in some organizations assistant staff are evaluated every six months, junior professional staff once a year and more senior professional staff every two years.

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190. Some systems are simple, and some are more complex, but all should aim at recording the general scope of each employee's work, the manner in which he has tackled this work and with what success or otherwise and should indicate his future potentiality. In short, the system should discover which men are most responsive to the particular environment provided and are, therefore, capable of wider responsibilities and further advancement. It is necessary to list all the qualities needed in someone able to do first-class work and then to determine which of these qualities and to what extent staff members already possess these and which staff members require improvement either by counselling or training. The advantages of a systematic approach to this matter lies first in the fact that the assessment is comprehensive: it is very easy to overlook some virtue or fault which may not be very relevant at the time but which may prove important later; second, it is carried out at regular intervals and therefore provides a valuable record of all employees' progress; third, it is as revealing about the reporters as about those reported on; and above all it assures the employee that his progress and achievements are considered fully and that advancement is based on total performance, not on some chance happening which may have come to the notice of the director.

191. The characteristics of staff on which information is required fall under the following general headings:

(a) Scientific or technological ability;

(b) Judgement and common sense;

(c) Initiative and drive;

(d) Speed, accuracy and method;

(e) Power of expression both orally and in writing;

(f) Leadership and personal relations.

192. The order of importance of these qualities will, of course, vary with the nature of the duties of the employee and in certain posts special requirements may arise. These should be provided for in the report form used.

193. An important aspect of any reporting procedure should be that the person reported on should himself provide information about new qualifications and experience gained since the last report, and in some organizations he is informed which people will be reporting on him.

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194. In many systems only adverse reports are communicated to the employee, but the practice is growing of discussing the report with the employee in a friendly and constructive fashion in what is called a "counselling interview". This is a most desirable development because quite often a young man may exhibit minor deficiencies which become of greater importance as he grows older and assumes greater responsibility for the work of others. Friendly advice can often correct such tendencies before they become set habits, because the people concerned are often not aware of them or are perhaps not aware that they might have a detrimental effect on their careers.

195. Many other types of evaluation have been used over the years. Other systems have been based on reports by three people each in day-to-day touch with the reportee, but this system can be employed only where very large staffs are concerned and when they are engaged on comparable and fairly routine types of work, as with drawing assistants in a large engineering drawing office. In this system, formerly used in a very large firm in the chemical industry, the markings can be reduced to a numerical value.

196. Another system asks the supervisor to report on the reportee's reaction to a number of situations and if these situations have not arisen in fact, to predict reactions. This system may be satisfactory in the hands of trained psychologists but is not necessarily successful when operated by physical scientists.

197. In most reporting systems there is provision for appeal by the reportee if he does not get the advancement he thinks he deserves, and in his appeal the reportee can set out, in a memorandum to the director, his case which he may think was not adequately dealt with in the report. It must be remembered, however, that the first law of promotion is that there is always someone on the other side of the boundary - if Number 1 of six people is promoted Number 2 will feel aggrieved and if Numbers 1 and 2 are promoted Number 3 will feel aggrieved and so on. The director must be on the alert to see that promotions and pay increments go to those whose performance has earned them and to see that there is no injustice owing to favouritism or personality clashes.

Promotion

198. An aspect of promotion which is very often overlooked by candidates and is sometimes overlooked by those making the choice is that the candidate must be judged

on his suitability for the more senior job and must not be judged solely on how he does his present job. Past performance is, of course, often a good guide but most promotions involve a widening of responsibility, especially for the work of others and it is sometimes the person who is not really good at his present work who has the temperament and ability to lead others. This must be borne in mind despite the general probability that a good man will be good at anything he sets his hand to.

199. It is because so many scientists do not take kindly to managerial work, or are too interested in their technical work to be bothered with such matters, that many research establishments now have two ladders of advancement - the organizational and the scientific or "special". The organizational is the normal, and as the scientist rises in the hierarchy he increases his responsibility for the work of others and necessarily becomes more and more involved in administrative and managerial functions. He is, therefore, less involved in actual scientific and technical work.

200. In the case of the man who climbs the "scientific" ladder, he is promoted purely for his scientific excellence and, except perhaps for one or two assistants, he has no supervisory functions. In the United States such people are sometimes called "consultants" and in the British Scientific Civil Service they have the same titles and rank as others but with the word "special" added.

201. Under this system it is possible to have a scientist attached for administrative purposes to a group led by a junior person and this has not yet led to any difficulties. It also answers the criticism formerly made against the larger research establishments that they merely turned good scientists into second-class administrators.

Dismissal

202. Directors should not hesitate to dismiss unsuitable members of staff although this course is seldom necessary in view of the careful screening of staff members before appointment.

203. However, it sometimes happens that a staff member suffers a serious moral lapse, when dismissal is justified. Dismissal for professional incompetence should be resorted to only after the employee has been tried in two positions under two group leaders, since it is often found that apparent incompetence is due to incompatibility of temperament in the first assignment.

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VIII. ADMINISTRATIVE AND SUPPORTING STAFF

Administrative staff

204. The work and conditions of employment of secretarial, clerical and accounting staff are essentially similar to those in business or government departments in the area.

205. In the very small organization, one man with accounting experience and one typist can probably cope, but as the organization grows the administrative work will be subdivided so as to provide sections for general administration, accounts, procurement of equipment and supplies, personnel matters and care and maintenance of buildings. The library will also be associated with this group.

206. In a new and small organization the library may well be tended by a clerk or even a typist, but as it grows a librarian will need to be appointed who may either be a professional librarian or a scientist who has taken a course in librarianship and who can also, therefore, answer minor technical inquiries. The decisions as to which books and journals are to be purchased for the library is one for the professional staff to make. In large institutions there is often a library committee under the chairmanship of a senior member of the staff and having on it representatives of the various disciplines employed in the institute.

207. It must be understood by all non-technical people that their function is to help the technical staff. Some administrators get the idea that their function is to control events, and this is quite wrong in a research organization. Scientists are often impatient of administrative requirements, and any managerial attitude adopted by non-scientific staff can soon lead to trouble. This does not mean that most scientists object to reasonable guidance and even control but being profession-oriented they expect this to come from people whom they regard as their professional superiors.

208. In some research organizations there is a "we and they" attitude; that is, the professional scientific staff resent any measure of control assumed by non-scientists, and the administrative staff regard the scientists as rather feckless people who must be guided appropriately. This sometimes shows up in the matter of ordering equipment and stores. To the non-scientist a spectrometer is a spectrometer, but to a scientist one spectrometer can be used for certain purposes

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and another spectrometer may serve a very different range of requirements. Specifications of equipment and stores must always, therefore, be by scientists although the processes of ordering and payment are purely non-scientific functions. If the non-scientists regard their function as being to assist the scientists to do their job, the result can be a harmonious relationship in which each person contributes to the productivity of the organization.

Technicians and assistants; supporting staff

209. In addition to the professional staff many other supporting staff are employed in an industrial research organization. Some of these will have minor professional qualifications and some will be studying in their spare time to attain full professional status. Often, the organization will help such people by giving them time off, sometimes one day a week with pay, to attend classes and by lending them certain necessary textbooks.

210. These assistants, as they are usually called, carry out experimental and observational work within guidelines delineated by the professional staff. Where most of the observational work is rather repetitive and routine, girls often make better assistants than boys, with the added advantage that after some years they will marry and resign; new girls can then be appointed in their place and trained for new types of jobs, this frequently being easier than re-training older assistants. Assistants will frequently have their homes in the vicinity of the organization, and they are frequently recruited direct from high school. Many research organisations maintain a close liaison with high schools in their area so as to be in a better position to recruit suitable assistants from them.

211. Many research organizations in developing countries are working on the utilisation of natural plant and animal resources, and this often requires facilities for biological testing and the employment of trained biological assistants.

Workshop staff

212. In addition to assistants, industrial research organisations employ a variety of technicians - mechanics, carpenters, glass-blowers, electrical and electronic wiremen, and welders, according to the type of work carried out. These people are usually employed on the terms and conditions appropriate to their trades in the

213. Every research organization needs a workshop and the number and types of people employed in it will depend on the types of research carried out. In a purely chemical laboratory there will need to be facilities for glass-blowing, simple woodworking and metal-working, electric and electronic wiring; but in organizations carrying out engineering investigations a wider range of constructional and engineering work is called for, together with some skill in precision work. As the organization grows, wider ranges of technical skills are required and a possible splitting up of the workshop into woodworking, metal-working, glass-blowing, and such activities may be called for, together with the setting up of an engineering drawing office and design office.

214. At first, however, the requirement is for one or two technicians able and willing to turn their hands to any job that comes along. These people must be intelligent and with some technical school training. An important part of their work will be to assist with the maintenance of buildings and equipment and the carrying out of minor modifications to the plumbing and other small repairs. At a somewhat later stage a valuable addition to the workshop is a trained instrument maker who can service many of the instruments used in the institute.

215. Workshop all-rounders are becoming increasingly scarce in many countries, because industry, the main source of technicians, is increasingly training and employing specialist turners, grinders, welders, and others, so that the all-round mechanic who, after taking a short training course in glass-blowing, would then meet most requirements of a small laboratory is becoming rare. In some large research organizations, training and apprenticeship courses have been instituted to train young men to meet laboratory requirements.

216. In the small organization such supervision as is required in the workshop will be given by the scientific staff, but in a larger shop employing six or more technicians a foreman will be required. It has been found very productive to regard technicians as part of the research team. The men then feel personally involved in the success of the project, and if allowed to take part in the proving of equipment they have made often make valuable suggestions for its use and improvement.

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Support ratio

217. The ratio of the number of professional staff to those who assist them is known as the "support ratio". This varies with the type of work and the main disciplines pursued and also varies from country to country. In advanced countries it varies in general between one and three and is often an indicator of shortage of professional staff, because when such staff are hard to obtain it becomes imperative that their skills be used to the utmost by providing them with as many assistants as they can gainfully employ.

218. The following current analysis of a large British research laboratory, established about sixty-five years ago, may be of interest:

273 scientific officers; 24 research fellows; 426 experimental officers, 50 per cent with professional qualifications; 240 scientific assistants; 294 clerical staff; 405 industrial staff, porters and gardeners, etc.

IX. THE SOURCE OF PROBLEMS AND FACTORS AFFECTING THEIR ECONOMIC SOLUTION

219. It is not possible, of course, to list specific projects that an industrial research organization should work on. These will depend upon the general economic and sociological conditions of the country or area concerned, on the nature of the agricultural and mineral products available or potentially available, on the existence or otherwise of entrepreneurs, on the number and skills of the population, on the numbers and skills of the staff of the research organization and on many other factors.

220. In view of the fact that industrial research is intended solely to be applied in industry, this objective must always be kept in mind, and the work must be carried out against the background of industrial conditions and the economics of the industries concerned. Therefore, among the many factors to be taken into consideration will be:

(a) The importance of the objective in relation to consumer preference and sales;

(b) The importance of the objective in the reduction of manufacturing costs;

(c) The timing of future developments within the industry and the manner in which the desired new knowledge would fit into them.

221. The scientists must decide whether it is practicable to carry out research on the selected objectives and must also decide on the lines of research to be followed. This estimate of practicability, or chance of success, coupled with an estimate of the cost of the research effort, will be set against the forecast of financial reward before the decision to proceed is taken and priorities allocated.

Types of research

222. Research organizations can work in any part of the R and D spectrum - composed of fundamental research, basic applied research, applied research and development. In developing countries it is highly unlikely that there will be money or time available for fundamental work. Fundamental work is normally published fully in

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the scientific Press and in the advanced countries some 10 to 15 per cent of the total R and D effort is on fundamental work, usually in the universities and research institutes. The results of this fundamental work are, therefore, available to the developing countries, which will be more interested in adapting these results to the technological requirements of the local economies.

223. Sometimes application can be direct, but often basic applied research has to be done so as to convert the more fundamental ideas into commercially practicable processes and so as to make these processes relevant to the raw materials available and the requirements of the country.

224. In a number of industries, especially science-based industries, such as electronics, chemicals and instruments, competition takes place not only through the price of existing products but also through the speed with which new or technically better products can be brought onto the market.

225. Typically, a science-based firm spends some 5 to 10 per cent of its turnover on R and D, and, as has been stated elsewhere, there is a "threshold" which must be crossed or exceeded before R and D becomes viable. Therefore, this 5 to 10 per cent of turnover must be taken together with the value of the R and D "threshold" which determines the minimum necessary production to assure economic viability.

226. This is generally true of industry, but must not be taken to mean that no small firm will ever make a profit. There are numerous instances of small firms employing just two or three scientists doing successful business making specialized scientific products.

227. An important factor in all industrial scientific research is what has become known as the "lead time", that is the time required to take a new idea from the initial decision through research, development and design to first commercial production. A short "lead time" is highly desirable, because this more quickly produces profits on the investment in research and also enables those working on the subject to get onto the market ahead of possible competitors.

228. Much of the success of R and D in the United States seems to be due to the short "lead times" achieved there. They are often 20 to 30 per cent shorter than in the United Kingdom. This ability to translate research results to commercial production with little delay has been a most potent factor in industrial development in the United States. All other countries, therefore, investing in R and D must endeavour to keep the "lead time" as short as possible.

Transference of advanced technology

229. One of the many difficulties met in transferring Western technology to developing countries is that of scale. In the advanced countries with their need to economize in employment of labour, industry has been operating in ever-larger units. Smaller units mean increased cost, and this can be a serious drawback to their operation, yet in developing countries there is no market for the products of large units, while the higher-priced product of a small unit stands but little chance of success in the export market.

230. It has been said earlier that the fundamental problem of industrial research is the making of two choices: choosing the right problem and the right people. Choosing the right problem may fall to the institute itself or the problem may be posed by a local industrial organization. The institute should be prepared to work on the latter type of problem for an appropriate fee.

Criteria for choice

231. The abilities required in the research organization so that subjects may be selected which will actually pay off and the estimate of the amount to be spent on, or invested in, such work is not reducible to an exact science. Until it is, "hunch" is bound to play a significant part in making the choice of subject for investigation. However, factors involved in the successful management of research and development are:

(a) Broad technical knowledge;

(b) Commercial sense;

(c) Imagination to foresee needs;

(d) Imagination to foresee applications;

(e) Ability to size up actual or potential staff, both for technical adequacy and for qualities such as tenacity of purpose and intellectual honesty;

(f) Strength of character to undertake calculated risks and abide by the consequences, to know when to admit defeat and terminate an unsuccessful or unprofitable line of work;

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(g) Ability to convince laymen (who usually control the finance) of the desirability of a given proposal and of the probable utility of the results;

(h) Ability to secure teamwork and co-operation between specialists of different disciplines.

The institute's choice of problems

232. Every institute should have provision for carrying out research of its own choice but often this research will be of the type which no single commercial organization would be prepared to finance. For instance, a country might have special problems concerning the corrosion of iron and steel and although a local manufacturer may be prepared to sponsor work directly affecting his operations, the over-all problem is of such wide effect that the Government would need to support it.

Sponsored work

233. The question of the payment of fees by sponsors must now be considered. If work to be carried out is to be wholly confidential then the sponsor should pay the full economic cost of the work. If the work, whilst of concern to the sponsor, is also of concern to other sections of the economy, then a somewhat reduced fee may be charged. Where, as has happened sometimes, Government had been intending to carry out research on a problem raised by industry, there could be a sharing of costs, provided that the results can be published.

234. These points must be stated clearly in a contract, which in all cases should set forth, inter alia:

(a) The parties to the contract;

(b) The nature and description of the problem;

(c) Whether the work is confidential to the sponsor;

(d) If not confidential, whether the institute may publish the results;

(e) The ownership of any patents arising from the work.

(f) The extent and mode of payment for the work.

235. In some cases it may also be necessary to deal with the ownership of any special materials or instruments purchased by the institute purely for the pursuance of the investigation.

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236. The signing of a form of application for tests or investigations by the client constitutes the contract.

237. On receipt of an application for an investigation to be carried out there should always be a full and frank discussion between scientists of the research organization and representatives of the sponsors, so that the scientists will know exactly what the sponsors want. It is sometimes found during such discussions that what the sponsors originally asked for is not what they really want to know. The objective must be clarified and mutually agreed upon before a contract is entered into.

238. The method of payment for work done must be adapted to circumstances. In the cases of tests or standard chemical analyses, predetermined fixed fees can be charged. Where investigations are involved, it may be possible to charge a definite fee or to charge on the basis of cost incurred plus a fixed fee.

239. If the agreed objective is such that the institute cannot give any firm estimate of the cost of the work, a sum of money should be agreed upon as a first limit. When the expenditure of this sum is being approached, the institute should inform the sponsors, providing at the same time a statement of progress so that the sponsors can decide whether the work is to continue and the new limit within which they are prepared to continue their sponsorship.

240. It is sometimes mutually convenient for an industrial concern to pay a retainer to the research institute. Such arrangements help to stabilize the finances of the institute. The client then has a call on the services of the institute up to the value of the retaining fee and also pays any extra which may arise. The client often receives somewhat advantageous terms under such an arrangement, as do clients who submit large numbers of samples all requiring the same type of test or examination. In this latter case, the fixed test fee is abated somewhat, because the test equipment can be left assembled and the staff (usually assistants) who do the tests become really proficient and therefore quicker at the work.

241. In the case of sponsored work it is sometimes advantageous for members of the staff of the sponsor to supplement the staff of the research institute, and it is sometimes necessary for members of the staff of the institute to work at

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the sponsor's premises. In fact, this collaboration between institute and industrial staff is greatly to be encouraged because it leads to a quicker commercial application of the results of the research.

242. Any money earned by the institute should go to the organization to enable it to purchase more equipment or engage more staff. This may seem self-evident, but it is mentioned because in some countries money earned by a basically governmental establishment must go to the State in order to reduce the amount of financing required by the institution. This is undesirable, because the director and staff of the institute find that by taking paid work they are merely working on clients' problems rather than on their own, with no compensating advantages.

Specialist or product research

243. It is rather unlikely that in a developing country sufficient funds will be available immediately from industry for the setting up of a specialist industrial research institute unless that country happens to possess an industry of world-wide significance, such as the rubber industry in Malaysia; even so, the work of such an institute would normally be confined to the problems of that industry.

244. There are, however, in a number of the advanced countries, institutes operated by private foundation, and in some instances these organizations have established laboratories in developing countries. These are operated purely as sponsored research establishments, as in the United States, and frequently the local government is the main customer. There is, however, at least one instance of an international product research institute supported financially by a private foundation.

Work paid for by Government

245. The board of management and director of an industrial research institute can often see problems, the solution of which is important to the economy of the country, when these problems are not realized by, or of major concern to, individual units in industry. Also, in order to maintain the scientific creativity of the institute's staff there must be, as stated earlier, some provision for them to work on problems of their own choosing, provided that such problems are approved by the director as being within the objectives of the institute.

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246. Not all technology is directly derived from science, although in most modern industries it is. It may well be necessary, therefore, to study the scientific aspects of traditional processes so as to devise means of improving them, by way of products or of productivity. Since traditional processes are frequently operated by individuals or families with little, if any, capital, work on these will probably need to be done at government expense.

Economic and sociological studies

247. In a developing country economic studies must parallel those in the natural sciences. In the economic field it will be necessary to study the economics of proposed investigations and of the industries concerned, so as to determine whether the investigations will, if successful, improve the economic state of the industry either by enabling it to improve its present products or to make new, salable products.

248. A full technological-economic investigation can often show that productivity of an industry is reduced in certain sections of the process employed. An economic study, therefore, of the cost of an industry, followed by the technological study of those sections of the process that are unduly costly, can often improve the economic viability of the whole industry.

249. Coupled with the economic examination should, if possible, be a sociological examination, because here again it is sometimes found that psychological or sociological inhibitions or difficulties tend to make an industry uneconomic, and a proper study of these can possibly overcome them.

250. Many industries, especially the traditional ones, use methods the reasons for which are now lost in the mists of antiquity. A sociological study, as well as a technological study, is extremely valuable in such cases because experience has shown that nothing is more difficult than to change the habits of people, and these habits cannot be changed successfully except on the basis of a full understanding of the sociological factors.

251. What is required, therefore, is a combined examination of economic, sociological and technological factors. But a research institute in its early days may not have staff to undertake all these examinations. Nevertheless, physical scientists employed in the institute should be aware of these factors, and they can often make valuable suggestions.

Follow-up work

252. In this connexion, when improvements are introduced in an industrial process it is often important that the scientists follow these up and see that they are used, and if they are not being used, to find out why. Even in advanced countries it can happen that a few months after an improvement has been introduced into a manufacturing process, investigation reveals that new equipment is lying idle and that the workers have reverted to their old ways. Although this is essentially a problem of industrial management, the scientist can often greatly facilitate the adoption of new ideas, and serves a most valuable purpose by helping to train staff destined to work with new ideas and new equipment.

253. The introduction of improvements often involves the retraining of staff, and it is important above all that modifications should be explained carefully to the workers in terms they can understand, so that they can see the value of the modifications.

Feasibility studies

254. One of the most important functions of a multi-purpose industrial research institute is that of making feasibility studies. Feasibility study confirms not only that there is adequate technological knowledge to operate a project but also that other factors essential to economic production are available.

255. First, there is the question of the adequacy of the infra-structure, including the availability of roads, transport, electrical power, water and of suitable types of plant.

256. Then there is the question of the possible costing of the processes and, above all, of the potential market for the product.

257. Other financial aspects of a project are the investment requirements and finance and pay-back arrangements. Too often in developing countries small industries have been started and have then had to be discontinued because of lack of sufficient quantities of raw materials, water and other shortages, or lack of facilities for getting the raw materials to the factory or the finished products away from the factory to the points of use.

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258. A feasibility study, therefore, is essential before a new industry or a new factory is established. Part of the feasibility study will probably need to include advice on the types of machinery required, their cost and where this machinery can be obtained. Here again, it is very important to secure the right machinery and to make certain that people and facilities are available for maintaining and repairing it. This is very important because equipment in developing countries sometimes lies idle simply because some part of it has broken down and there are no local facilities for repairing it and no foreign currency for importing spare parts.

259. There is, of course, a series of further steps that can be greatly facilitated by the institute, such as drawing up specifications and issuing a book of tender for equipment; building and civil engineering works; the supervision of equipment; and the manufacture, erection and supervision of plant construction, start-up and commissioning.

Information service

260. Another function of an institute from the first stages of its existence is to provide general technological information. For this it will need to establish a technical library; but sometimes it will not have the information itself and one of its important functions is knowing where to obtain the necessary information, which it will do by means of its contacts with other research institutes, with scientists in other countries and with specialized libraries.

Testing and standardizing services

261. The institute should also be able to provide testing and standardisation services. For this purpose it will need to be equipped with simple physical testing machines and with the facilities for carrying out chemical analyses. It should also have in its library sets of standards specifications, particularly those of the countries to which it may be hoping to export local manufactures. The institute should be prepared to carry out tests to ensure conformity of the product with these specifications. Nothing is more important for a country that is attempting to build up an export trade than to inspire confidence in foreign purchasers that the materials or products they will buy will, in fact, be usable and will conform to the generally accepted standards.

Equipment advice

262. Another service which the institute can perhaps provide is that of valuation of a plant and its equipment. It should, therefore, collect in its library catalogues and other information from plant manufacturers which will enable it to advise on the purchase of plant, and this will also be essential in the study of the economic feasibility of the processes.

Relative economics

263. Of course, in many developing countries the economic factors differ from those in advanced countries. In advanced countries there is a constant move towards mechanization and automation so as to lower labour costs, whereas in many of the developing countries capital is scarce, but labour is cheap and plentiful. Such countries tend, therefore, to adopt labour-intensive processes, while the advanced countries tend to adopt capital-intensive processes.

264. However, the availability of relatively cheap labour in developing countries can be misleading. It is sometimes the case that labour is used to such an extent that although each individual receives only a small salary, the total cost is greater than would have been the case in an advanced country where much less labour would have been employed. However cheap the cost of labour, a labour-intensive industry cannot always compete economically with a highly automated capital-intensive industry.

265. For instance, a short while ago in a sugar-producing country, in order to make work available, the Government banned the importation of harvesting machines. The sugar-growers stated that in two or three years they would be out of business, because, even on the low wages prevailing in their country, they could not possibly compete with the mechanized industries of other countries.

266. There is another factor: in some factories, so many people are employed that they get in each other's way, and this leads to over-all inefficiency.

Sociological factors

267. To achieve economic viability, sociological factors must be studied. In some developing countries there are deep-seated traditions concerning the types of work various members of the population can undertake without losing face. Sometimes, these factors are based in the earlier colonial life of the country, and they manifest themselves in unusual ways.

268. For instance, in a factory erected for the processing of a root crop the output was only 30 per cent of capacity - partly because sufficient supplies of fresh water were not available, but mainly because the factory could not get an adequate supply of roots. Apparently the old men of the area were prepared to dig the roots, but the young men were not. They said that this was peasant work, and that now they were a free country they were no longer peasants and were therefore no longer going to dig roots. Factors of this sort must be studied and, where possible, education of the population must remove such inhibitions.

Techno-economic surveys

269. Techno-economic analyses provide industrial management with information on which to base plans for expansion, optimum use of resources and the improvement of economic returns. The function is primarily that of analysing growth opportunities for the project, taking into account the socio-economic conditions and thus giving management a guide to new or developing factors that may affect its long-term programmes. This sort of information is required not only by individual industries but also by national economic planning bodies, ministries of development and the like.

270. The provision of these services does presume, however, that the necessary range of skills is available in the research institute. A broadly staffed institute can approach the problems in their entirety, looking not only at technical efficiency but at all the other factors affecting the over-all productivity of the enterprise.

Choice criteria

271. The industry to be developed must be carefully chosen and in the early stages of a country's development special attention will no doubt be given to timber, textiles and such semi-handicraft industries that appeal to the traditional, social and economic characteristics of the local workers and which do not necessarily follow the pattern of imported foreign products. This is important if indigenous and appropriate lines of development are not to be inhibited, since the products of local industry must enter into mutual competition with imported articles which may have, in the early days, such additional advantages

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as brand names, appearance, price. Industrial design and the various aspects of marketing must also be considered so that the home product will not be thought to be inferior by the local population and may prove suitable for export as well.

272. When a laboratory or research group is newly established, quick results will be more desirable than in the case of an organization or group with positive results to its credit. This would indicate that short-range problems should be attacked first, so that results show quickly. In order to publicize results of the institute's work, it is a good plan, other factors being equal, to work on the development of products that can be sold at a low price.

273. Creating a moderate profit on a product that sells in large quantities can confer a rich reward for the research effort. Within classes of goods, metals, plastics, textile fibres, and others, there appears to be a direct correlation between the selling price of the products and the volume of their sales. This merely means that every major product is in competition in a free market with several other products; but it means also, for the research director, that work on low-priced products can more easily engender industrial growth and in the long run large profits. It is said of a large chemical manufacturer in the United States that for years they operated on the philosophy that they would develop a low cost material and that others would then find uses for it.

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X. FINANCING RESEARCH ORGANIZATIONS

274. Consideration will now be given to the financing of research. As has been said above, in most developing countries, only the Government has sufficient resources to undertake the establishment of the organization even if help has been received from advanced countries, from established research organizations elsewhere or from some member of the United Nations family.

275. If some business group or foreign research foundation is prepared to set up and finance an industrial research organization, this will no doubt be very helpful; but a time will inevitably come when the Government of the country considers that there should be a publicly operated industrial research institute. In order that the institute can begin to become effective in a reasonable time, the Government may well consider the advantage of having a financial stake in the institute right from the beginning. It now remains for consideration to be given to the various means whereby the necessary finance can be provided or raised.

Direct government financial support

276. Most countries work on an annual budget, and unfortunately 365 days is too short a period for the initiation and completion of most R and D projects. The difficulty arises, therefore, that since funds are voted for a fiscal year, the research organization is never quite sure if it is going to continue to get funds in the succeeding years, so as to complete the projects. In many instances the financial arrangements of the Government do not provide for the earmarking of funds for subsequent years. To get over this difficulty, in some countries the research organisation budgets for three or four years ahead under an agreement with the Government that, while funds can be voted only for one year, the future funds will be forthcoming, subject, of course, to any national crisis. This is sometimes known as a "rolling-estimate" because it is always reaching forward beyond the strict period of budgeting.

277. A rolling estimate means that the budget is drawn up annually against a forecast for a further two to four years, thus indicating that expansion may be undertaken during those years. The amount of expansion will no doubt be related to the estimated economic growth of the country and will also bear relation to expected availability of staff.

Carry-over of annually allocated funds

278. In many countries any surplus of allocation of funds over expenditure is automatically absorbed by the national exchequer.

279. This is unfortunate because it sometimes leads to directors spending funds, perhaps rather rashly, towards the end of the fiscal year when much wiser expenditure could be made later. The surplus of funds might have such causes as the non-availability of staff or late deliveries of equipment; if provision can be made for the carry-over of funds, such provision often leads to true economy.

Budget sub-heads

280. Public funds allocated to the research organization may well be divided under the usual sub-headings such as equipment, staff, consumable materials and so on. The sub-divisions under which funds are allocated should be kept as few and as flexible as possible, again so as to achieve true economy. The director, in consultation with his executive committee, should be left to decide whether the objectives of the organization will better be achieved by spending more on equipment, perhaps, rather than staff. He should also have wide discretion in the grades of staff employed; for instance, in some cases two qualified scientists and four assistants may not only be cheaper but more productive than three qualified scientists and two assistants. This may involve the director being authorized to reallocate funds under the general heads or sub-heads of his allocated funds.

Balanced expenditure

281. Generally, experience appears to show that laboratories in developing countries tend to be under-equipped, but, on the other hand, there are some which have been so lavishly equipped that there has been insufficient finance for the employment of adequate staff to use the equipment. Instances are known of elaborate buildings with neither staff nor equipment in them. This applies particularly to elaborate library buildings which, on inspection, are found to contain very few books. All of this is, of course, absurd. Beautiful buildings can be functional also, but books and equipment are the tools of the trade of the research workers, and good research is often done in quite simple buildings.

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Income from sponsored work

282. In many countries, both advanced and developing, government research establishments are enabled to carry out sponsored work for payment. In some countries, money so earned is used by the research institute for its various purposes. In other countries, money so earned goes to the central treasury and is offset against the research budget.

283. As has been stated earlier, the latter system, which is quite common, is to be deplored because it gives very little incentive to the research institute to seek and carry out sponsored work. This system could mean that the institute might be engaged in relatively unimportant work which is paid for, when it might better be doing some important work at government expense. This system has little to recommend it, except for the consideration that the staff of the research institute might have government security of tenure. Extra staff employed to cope with sponsored work might, after a while, find themselves with no sponsored work to do, which would leave the Government with a staff responsibility. However, methods can be devised for overcoming this difficulty.

284. Another reason devised by some Governments for adopting this method is their concern for the over-all employment of scientists. They contend that if the research institute has a government grant and can also use all the money it earns from industry, it might attract to itself an undue proportion of the country's scientific talent which might be required in some other field.

Special taxes

285. Some countries have used considerable ingenuity in raising money for research. For instance, one European country paid for its research for many years by a tax on football pool betting. Then, at least two South American countries have put a tax of one fourth of 1 per cent on commercial investment to finance their research programmes. This has the advantage that as commercial activity increases so do the funds for research, but it has the great disadvantage that when commercial activity decreases, which is just the time when more research is required, money for research decreases.

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286. Many of the commodity research institutes of the world are supported by taxes on the product they investigate; for instance, the Coffee Research Station of India. The Jute Research Station of India is financed by a voluntary levy on the out-turn or production of jute manufactures, and the Tea Research Association is financed by a voluntary levy based on the acreage of the contributors' tea gardens - half of the necessary money being raised by the industry and half contributed by the Government. A research cess of 0.875 per cent is levied on every pound of rubber exported from Malaysia. The cess is collected by the Customs Department and is paid over to the Malaya Rubber Fund Board which makes the necessary disbursements to the research and development units under its control, including the Rubber Research Institute of Malaya.

287. This matter of tax on producers is quite common for commodity research institutes, but in some countries certain imported products are processed on a large scale, and in a number of instances research on the processing is paid for by a levy on the imported product. In some countries the levy is statutory and in others it is a voluntary levy based on the volume or weight of the product imported.

288. Some developing countries are now considering a special 5 per cent tax on industrial profits to finance industrial research.

Effect of planned economies

289. The fact that most research in developing countries is government financed does not prevent the founding in those countries of sponsored research institutes, which obtain all their finance from clients. However, most developing countries have planned economies, and these are held by proponents of national planning to favour research and development, which are regarded as important elements in the national economic development. Many of the larger industries are state owned or state controlled and their research budgets will, therefore, be part of the national budget and will be treated as normal government expenditure.

290. On the other hand, the opponents of planned ecomomies say that industry in a planned economy is sheltered from competition, and this removes the incentive to do research with, for instance, the objective of reducing prices.

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Development plans and research

291. Most countries have development plans and in some of these the need for and provision for research is made specifically, but in many development plans, while the need for research is often stressed, no provision as such is made for it. However, some development plans operated by development corporations make provision for the carrying out of feasibility studies and comment upon the shortage of technical staff as being the major problem. In these countries the need for the employment of expatriates is stressed and provision is usually made for nationals to receive technical and scientific scholarships.

292. In some developing countries in Africa the development plans, in so far as scientific research is concerned, are centred in the universities or in institutes operated in close collaboration with the universities. In Kenya the sum of approximately $75,000 is to be used each year in the first three-year plan for the carrying out of small industries research and the training of managers and entrepreneurs. In this case it is hoped that after three years the institute will be self-supporting.

293. In many developing countries the principal industry is agriculture, and traditionally, development of agriculture has been regarded as a government responsibility. Industrial development in these countries has, in many instances, tended to centre on food processing or the processing of agricultural products.

294. A survey, therefore, of the financing of industrial research tends to show that in the advanced countries about 50 per cent of industrial research is carried out and financed by industry. The balance is financed by Government, though it is not always carried out in government controlled organizations but may well be carried out by industry at government expense.

295. Of course, in the advanced countries, quite a significant proportion of the total fundamental and industrial research is carried out for defence purposes, but such research often has an important "fall-out" for industry. Some years ago, a survey in a large laboratory, engaged not only in industrial research but in defence research, showed that 60 per cent of the defence research would need to have been done for purely industrial purposes had it not been required for defence purposes. A proportion of the defence research expenditure in advanced countries can, therefore, quite reasonably be regarded as normal industrial research.

Staff costs

296. Needs and costs vary so considerably over the world that it would be impossible to give any general estimate of the cost of operating an industrial research institute in any particular country. The cost of the same research varies considerably from country to country. Thus, at the moment of writing, the exchange rate between the pound sterling and the United States dollar is 2.8 - calculated as being about 6.5; thus research in America costs two and one third times as much as the same research in Great Britain. The cost per qualified scientist or engineer in two countries may differ by a factor of ten. It will be seen, therefore, that it would be idle to try to forecast, on general grounds, the cost of research in any particular country since this can be determined only by experience.

297. Another factor in which discrepancies occur is in the career prospects of scientists. Thus, in the United Kingdom, a scientist, if good, may expect to be earning 2.5 times as much money after twenty years as when he started work after university, but in the United States this factor is probably about 1.5.

298. There is, however, an important factor in research and that is that 60 to 86 per cent of the running costs of research establishments, omitting the original capital cost of buildings and amortization, but including the cost of equipment, is spent on salaries and wages. Salary and wage rates are, therefore, very important factors in determining the cost. This is quite important also in organizing research because staff time is the most expensive item in the institute's budget. Organization must, therefore, aim at saving time, even at the expense of somewhat enhanced costs of other items, provided these items save time, especially of the more expensive professional staff. The British Commonwealth of Nations includes some twenty developing countries, and the pattern of research in the Commonwealth can, therefore, be regarded as somewhat symptomatic of the general case.

299. In these countries, research in primary industries was, originally, conducted by ministries or universities and was supported entirely by public funds, then mainly supplied by the United Kingdom. This continues to be the pattern so far as production for local use is concerned, but where export staples are concerned, particularly those cultivated on a plantation basis under expatriate control, many of these countries have commodity research organizations which are, in part, supported by a levy on the product, usually on exports, but sometimes on production

plus a levy on exports. The emphasis on export levies is largely because such levies are much easier to collect than are production levies. The rest of the cost of the research institute comes from public funds, and in many instances the support from these two sources is 50 per cent each.

300. Often the institutes are concerned with both the production and the processing of the crop, and by some standards, therefore, may not be regarded as purely industrial research institutes, but as agricultural research institutes in part. However, agriculture is a productive industry as far as the economy of the country is concerned. Thus there are commodity institutes in various countries for such products as rubber, tea, coconut, tobacco, sugar, bananas and coffee.

301. As far as secondary industry is concerned, the research association system has not flourished greatly in the developing Commonwealth countries, although it has been developed in the advanced members of the Commonwealth and in India.

302. Most of the purely local firms in the developing countries do no research at all. They normally employ well-known techniques and do not seem to need any involved research. What is really important for these industries is the availability of efficient information services.

303. Again, in the United Kingdom the present Ministry of Technology, formerly the Department of Scientific and Industrial Research, control some twelve laboratories engaged on both basic and industrial research. This pattern has been followed in the more advanced countries of the Commonwealth and has been attempted in India, but here it has run into difficulties because the general circumstances of the industries do not enable the results of co-operative work to be absorbed readily. Also, there has been difficulty in industry making its research needs known to the institutes, and it has been found that work carried out in some of the research institutes is too advanced for assimilation by local industry.

304. One of the problems encountered in a number of countries really turns on the availability of finance. In research, as is well known, there is a threshold in magnitude of effort, and until this threshold is passed research is usually non-productive. It is considered by some experts that the threshold for an institute is ten professional scientists plus their supporting staff and that an institute smaller than this will be unable to maintain sufficient activity to ensure progress.

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305. The effect of reasonable size is shown in some of the very successful institutes, such as the International Rice Research Institute in the Philippines which receives support from the Ford Foundation; the Rubber Research Institute of Malaysia and the Tobacco Research Institute in Rhodesia. These institutes are financed on such a scale that they have been able to make real and valuable contributions to their industries.

306. In the colonial era, a number of research institutes were set up in various parts of the world (for example, East Africa) which served several colonies in an area; but unfortunately, as these colonies became free, the federations broke up and each colony insisted on having its own share of the research organisations. The result was that potentially valuable research organisations have ceased to exist in their original form and are now serving only one country to the cost of their former partners. Scientific research is not bounded by political boundaries, and it is greatly to be regretted that political considerations have affected the research situation in this way.

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XI. INVENTIONS, THEIR PROTECTION AND LICENSING

307. It will be clear that inventions may arise from various sources. The institute may itself engage in work leading to invention, or it may be empowered to acquire from third parties within the territory or in a foreign country the right to make use of inventions in the industry of the territory. Of course, individuals or companies in the territory may make their own arrangements to acquire such rights, but since this will, where the patent-owner is outside the territory, normally involve the transference of funds by way of royalties, there may be fiscal barriers to such private transactions.

308. The procedure to be followed will largely depend on whether the territory has a patent law and an effective system of granting patents. If it has, then the institute should itself protect any invention it may make, both in the territory and in such foreign countries as may in the particular circumstances seem appropriate. The decision to protect an invention in foreign countries will depend on a number of factors, including the value of the invention as a means of protecting the export materials of the territory in the patented article, or as a means of obtaining funds by way of royalty licences granted under the foreign patents obtained. A deterrent to such patenting abroad, at least on a large scale, will usually be the cost of it.

309. It should be remembered that a patent law is a two-edged weapon in that if there is a patent law in force in the territory, individuals and companies within the territory, and in foreign countries, may obtain patents in the territory which in the absence of any overriding considerations such as those mentioned below will be as enfo ceable against the institute as against a third party.

310. The law, however, may provide overriding considerations of which the following are quite customary and are recommended:

(a) It may be provided that in relation to inventions concerning food or medicines the patentee must grant a licence to any party in the territory who seeks to work the invention in the territory and can show that he is able to do so. Such a compulsory licence will normally require payment of a royalty which, if it cannot be agreed by direct negotiation, will be settled by a legal tribunal;

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(b) It may be provided that if an invention which is the subject of a patent in the territory is not being actually worked in the territory by actual manufacture, the patentee must grant a licence to a party seeking the same in the territory subject to the royalty premise referred to under (a).

311. Item (a) obviously protects the territory against undue monopolizing of basic requirements for health. Item (b) in various modifications is included in the law of many countries and serves to prevent the demand for a patented product from being met solely by importation from abroad to the detriment of the economy of the territory.

Licensing

312. In the event that a particular invention is required for industrial use in the territory and is not available by way of compulsory licence, as under (a) or (b) above, it will be necessary for the institute or some other body to negotiate for a licence. In doing so, attention must be paid not only to the amount of the royalty to be paid and the basis of its computation, but to the method of payment to be adopted, for instance in what currency.

313. Where the institute has a patented invention in the territory, or abroad, this may be licensed to third parties on any acceptable terms. It may, in some cases, be possible to effect cross-licences with parties owning patents of interest to the institute, whereby the actual payment of royalties may be offset or entirely avoided.

314. It is to be observed that inventions made by employees of the institute will generally be the property of the institute. If the employee is paid a salary which takes into account the prospect that he may make inventions, no special recompense to the inventor in respect of any invention will normally be necessary. However, it is usually desirable to afford the director of the institute a limited discretion to make some payment to inventors, especially if the invention is made by someone not normally engaged in research.

315. In granting licences to third parties it is generally preferable that the licence should be non-exclusive, so that a number of different third parties may be licensed. If the prospective licencee asks for an exclusive licence and it is decided to grant it, the terms of the licence agreement should contain some guarantee of a minimum royalty, payable to the institute, thereby to ensure that the invention is actually worked.

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316. In some cases the institute may decide to adopt the policy of freely licensing the nationals of the territory to operate the invention. This does not, however, eliminate the desirability of patenting the invention, since the patent will remain effective against extra-territorial companies and thus serve to protect the domestic industry.

Proceeding in absence of patent law

317. If the territory has no patent law, there is no practical way of protecting the results of the institute. But analogously, no third party can obtain a patent effective in the territory against the institute. Inventions patented in other countries would be freely available for use in the territory; but it should be appreciated that the descriptions of inventions contained in patent specifications are rarely sufficiently detailed to enable a manufacturing use of the invention. There is almost always a body of knowledge, generally referred to as "know-how", which must be acquired and this may be as valuable, or even more valuable, than the patent right itself.

318. Even when negotiating patent licences the would-be licencee should see to it, if possible, that the licensor undertakes to convey not only the patent right but also his know-how on the invention. And when there is no patent protection involved, the licencee may still need to acquire know-how.

Research development corporation

319. There are many problems in the industrial exploitation of inventions that are not the sort of problems scientists are normally able to tackle. The exploitation of an invention can need commercial expertise and an expert knowledge of international patent law. To meet this situation, a number of countries have now set up special organizations. The first of these, as far as is known, was the National Research Development Corporation, set up in the United Kingdom in 1948, and about the same time a somewhat similar organization was set up in Canada; and another in India.

320. Although the functions of such a corporation will necessarily need to be devised to meet local conditions, it is perhaps of interest to note that those of the British corporation are as follows:

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(a) Securing, where the public interest so requires, the development or exploitation of inventions resulting from public research, and of any other invention as to which it appears to the corporation that it is not being developed or exploited or sufficiently developed or exploited;

(b) Acquiring, holding, disposing of and granting rights (whether gratuitously or for consideration) in connexion with inventions resulting from public research and, where the public interest so requires, in connexion with inventions resulting from other sources;

(c) Promoting and assisting, where the public interest so requires, research for satisfying specific practical requirements brought to the knowledge of the corporation where they are of the opinion that the research is likely to lead to an invention;

(d) Assisting, where the public interest so requires, the continuation of research where it appears to the corporation that the research has resulted in any discovery such that the continuation of the research may lead to inventions of practical importance.

321. The 1966 Annual Report (18th) of Canadian Patents and Development Limited has just been published and quotations from this should be of interest to any country concerned with the problem of applying industrial research to the benefit of the national economy:

(a) Canadian Patents and Development Limited acts both as a clearing-house and as a sponsor for inventions. It obtains patent protection on ideas that appear valuable and licenses them to industry on a royalty basis. The bridge across the gap between the invention of a scientist and its use by others is often blocked at both ends: the scientist might not wish to digress from his research to develop the idea, while industry might be unwilling to consider it without more evidence of its value. When this situation arises the Company spends its royalties on contracts for the development of inventions;

(b) Canadian Patents and Development Limited is a Federal Government Agency set up to encourage the use of ideas from the National Research Council and from the laboratories of other government departments. Under contract, its services have been extended to provincial research organizations and to some universities. It even imports ideas from the United Kingdom, Australia, India and South Africa under exchange agreements. It does not, however, handle the ideas of private citizens.

Canadian Patents and Development Limited collects ideas, evaluates them, and files patent applications on cases considered valuable. A few cases have been licensed on a "know-how" basis because they are unpatentable, or because the potential market was too small either to attract competition or to repay patent costs. But generally patents are the key to the Company's operation: they provide the protection that encourages industry to spend time and money developing a new product or process;

(c) In licensing, Canadian Patents and Development Limited acts as liaison between inventors and businessmen. This is not just a matter of carrying and translating messages, but of imagining uses for new ideas, and publicizing them and bringing them to the attention of prospective users. Since industry is being asked to risk its own money, it is important not to oversell.

322. Some research workers are quick to see commercial possibilities in their inventions but many are not, and it should be the duty of the management of all industrial research institutes to be alive to the possibilities of exploitation, whether by patent or not.

323. In a large institute it is worthwhile for one member of the administrative staff to become skilled in patent matters and for him to assume the duty of keeping in touch with developments in the institute, with a view to obtaining patent cover on any likely discoveries. If a research development board exists in the country he can liaise with them, but if there is not such a board he can advise the director on patenting requirements and can also advise members of the research staff on aspects of their results which may affect the possibility of patenting.

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XII. EXTERNAL TECHNICAL ASSISTANCE

324. In most developing countries it will not be possible for the industrial research organization or for other sections of the community to supply all the technical and managerial expertise necessary to solve all problems, and special assistance will be required. This will, in general, be obtained from advanced countries. A note on the various channels whereby technical assistance flows to developing countries may, therefore, be not inappropriate.

325. Most advanced countries have accepted the principle of aid to developing countries. Some channel their aid wholly or mainly through the medium of the United Nations Organization which in turn administers aid mainly through its various agencies. Some countries, however, also have extensive systems of bilateral aid. The United States apart, this applies mainly to the former colonial Powers which have, for various reasons, continued to give special help to their former colonies. This help can be financial, technical and/or managerial.

The United Nations and its agencies

326. Much technical information is passed to or gathered by the United Nations agencies and is made available in various ways to the countries needing it. Much is carried by consultants undertaking advisory or other visits to the developing countries on behalf of the United Nations, and much is carried back by nationals of the developing countries who make paid educational or training visits to the advanced countries, such visits being arranged by United Nations agencies.

327. Again, very valuable means of communication are the various seminars arranged by United Nations agencies on regional and international bases.

328. Certainly, even more will be done in this connexion now that the Centre for Industrial Development is to expand into the United Nations Industrial Development Organization in the near future. The transfer of technical information and knowledge will, no doubt, be a major concern of UNIDO.

Direct technical aid

329. Much information and advice is exchanged at the working level between scientists in the advanced and developing countries, and technological "know-how" travels from the R and D departments of international firms to their branches in the developing countries. The trade and scientific journals and books of the various countries also help in the flow of information.

330. Some advanced nations have set up special government-controlled organizations for assisting developing countries both technically and in other ways. Two examples of these are the United States' Agency for International Development (AID) and the British Ministry of Overseas Development, but similar organizations also operate in France, West Germany, Sweden and Holland.

331. A number of countries have experimental organizations devoted to the solution of scientific and technical problems arising in the tropics and semi-tropics, where most of the developing countries are. This is especially so in France, the Netherlands and the United Kingdom.

Twinning

332. Many scientists, technologists, economists, and other trained personnel are recruited in the advanced countries for service in the developing countries, either directly or through the United Nations, and there are close ties between many universities in the advanced countries and those in the developing countries. There are also close ties between specialist research institutes in the various countries; and a development which shows much promise is the "pairing" or "twinning" between an established industrial research institute in an advanced country and one in a developing country. This is also sometimes known as interinstitute co-operation.

333. The established institute can assist in the early days with the direction or management of the new institute and also with such matters as the choice of problems to be worked on, loans of staff and equipment and especially with collaboration on projects. It often happens that in the course of an investigation advanced or specialized techniques and equipment are needed, unavailable in the developing country, but available to the institute in the advanced country. Also, the advanced institute may have been established many years and possess a backlog of knowledge, experience and literature that can be invaluable to the new organization.

International experts

334. Development of industries in the developing countries can be greatly assisted by international experts. These experts often go to the developing countries on behalf of United Nations agencies or of their own Governments as part of bilateral aid or by direct recruitment. They usually serve for a limited number of years,

varying from one to three, with possibilities of extension of contract, if this is necessary. A development of this, particularly in one country, is that recently retired experts are recruited to serve in developing countries for a small number of years, and this has proved very successful because it has brought to the developing countries the accumulated experience of people who have been involved in the growth of similar industries in their own countries.

Secondment of experts

335. One of the difficulties arising with regard to experts going to the new countries is that they have often, in the past, been uncertain of their futures when their contract in the new country expires. It has been found necessary in many instances, therefore, to base these experts in organizations in their own countries, so that they can return to these organizations in due course.

336. Thus the British Ministry of Overseas Development employs experts who serve abroad but who are regarded as members of a British institute on secondment. It is this uncertainty about the future that has, in the past, militated against many experts going abroad.

337. The other difficulties are, of course, personal ones, such as the education of their children, since many of the developing countries are unable to offer educational facilities of the type required. Unless some special financial provision is made to cover this matter, it means that experts sent abroad must be relatively young or of such an age that their families are past school requirements.

Universities and international firms

338. Of course, many experts go to developing countries from international firms as part of their normal duties in the firms. Many go on secondment from universities in the advanced countries. A number of these universities now have complementary posts to cover service abroad of a specified number of the members of their faculties.

Training and fellowships

339. Many students from developing countries attend universities in the advanced countries and there take degrees in various scientific and technical subjects or in

the human sciences. It is perhaps regrettable that the training they receive is the same as that given to nationals of the advanced countries, because they often find that jobs of the type for which they have been trained do not exist in their own countries. It is stated that about 80 per cent of the students from developing countries, trained in the United States, do not, in fact, return to their own countries.

340. Often, what is required is a form of training specially geared to the requirements of their home countries, and this usually is not available. For instance, when the United States of America was a developing country, land grant colleges were established, the so-called "cow colleges", and most of these have now evolved into sophisticated universities. Despite these difficulties, university training in advanced countries can be a considerable help; still, what is of even greater help is specific training in the problems of the developing country concerned, and this type of training is usually provided in specially arranged seminars or in specialized institutes. Here again, difficulties arise, because nationals of developing countries who have successfully undertaken a training course in an advanced country and then have returned home are often quickly promoted, with the frequent result that a few months after their return they are not doing the work that utilizes the results of their training. This situation is fairly widespread and will, presumably, continue until the supply of trained people in the developing countries approximates to the demand.

341. Another quite popular form of training is the granting of fellowships to nationals of developing countries so that they can study special subjects in one or more advanced country. This is, perhaps, one of the most productive types of training, because the choice of subject studied during the fellowship will normally be made to fit the requirements of the home country.

Some difficulties

342. In general, the relationship between industrialists in advanced and developing countries in the matter of technical development is good, even though the industrial advances of the developing country may have an adverse effect upon established trade in the advanced country. A case in point is the oil-seed industry. Most oil-seeds are grown in tropical and sub-tropical countries, and past practise was for the seed to be exported to certain advanced countries which then processed them for the

production of vegetable oils and cattle-feed. Now, many of the developing countries naturally wish to process their own products, both for home consumption and for export of the processed products. Export will in the main be to countries that formerly processed the seeds themselves, and in those countries certain firms will have a large capital investment in the processing plant. This readjustment of a world trade is bound to create difficulties on the export side, even though it leads to expanded trade in consumer products in the developing countries.

343. In some instances, this type of difficulty has been met by firms in advanced countries establishing processing plants in the producing countries; this means the transfer of expertise and "know-how" to the new country. The real requirement is to determine what needs of the advanced countries are not at present being filled and then to establish industries in the developing countries to supply those needs. Even then, in order to make the industrialization process economic, care must be taken to develop industries, utilizing those products that can best be produced in that particular country.

344. For instance, in recent years numerous developing countries have tried to establish industries for the processing of citrus products. The world market for citrus products is large, but finite, and some of the developing countries do not grow the right type of fruits to meet the demands of the western countries. In such countries, therefore, the development of a citrus product industry is doomed to failure unless the product is for home consumption only. These types of difficulties can be avoided by consulting the international organizations and market experts.

XIII. BUILDING FOR RESEARCH

345. Most scientific research needs housing specially adapted or built for the purpose. As a matter of fact, the erection of specially designed buildings for scientific work, commonly called laboratories, dates back less than fifty years, but during that period there has been a vast advance in design and techniques. It would be impossible in a report such as this to deal at all effectively with building for research from the architectural and engineering standpoints, but there are certain aspects of research buildings which affect the organization and management of research carried on in them, and it is proposed here to deal only with these.

Site

346. The first problem in building for research is to choose a suitable site. This should not be near the centre of a city because many laboratories produce noxious or annoying fumes; yet it should not be too far from a city, or there may be difficulties in housing staff members and particularly in recruiting junior members. Also, if an industrial research institute is too far from a main centre of population, business people, visiting scientists and other interested persons will then find it difficult to visit the institute, and the mutual exchange of information and ideas will thereby be reduced.

347. In the case of specialized laboratories, it may well be necessary for them to be sited near the source of the product with which they deal or, alternatively, near the point of consumption of the product. For instance, much research on wool is done in the wool farming areas of Australia and also in the great wool manufacturing centre of Yorkshire in England. However, a multi-purpose laboratory should preferably be within reasonably easy reach of the main academic and cultural centre of the country, because this will enable members of the staff to meet other professional people and visitors and thereby maintain touch with new ideas and developments elsewhere.

348. The site should be much larger than the immediate requirements, because laboratories have a strong tendency to expand and there is often a need for open space in which special experiments or pilot runs can be carried out. Water and electricity should be available and also gas: the latter can, if necessary, be supplied to the laboratory in cylinders if there is no town gas system. The site should be pleasant and, if it is not, should be made so by landscaping and gardening where this is possible.

The first building

349. The type and size of building to be erected first will necessarily depend to some extent on the nature of the work to be carried out, but mainly on the amount of money available. In any case, the building should be capable of expansion both in floor area and in height.

350. The first building to be erected will probably contain chemical and engineering laboratories, workshops and offices for the director and administrative staff. It should also, if possible, contain a large room capable of being used as a lecture room, and canteen facilities, which should prefereably consist of a cafeteria for the junior workshop staff and a small dining-room for the senior professional staff when they wish to entertain visitors. At other times, it is a good plan to encourage all levels of staff to lunch together because their talk will largely be "shop", and communal lunching is a powerful means of keeping members of the staff of a research institute aware of each other's problems; also it is a powerful forum for cross-fertilization. In addition, there should be a small private dining-room in which the director may entertain important visitors when he wishes to discuss confidential business with them. At other times the director should use the general facilities.

Library and service location

351. Another "must" is the library, and this should preferably be somewhere near the eating arrangements, as should also the general stores. As a research institute grows and some of the laboratories and workshops are necessarily some distance from the centre, a significant amount of time of staff is taken up in walking to and from the canteen and to and from the library. If these two facilities are adjacent, staff will often combine the two and will get into the habit of making visits to the library just before or after lunch and will also, especially if the weather is bad, visit the library after lunch to see the latest journals, and this helps to keep them up to date in their subjects.

352. A new feature of modern laboratory construction is the light and airy library. Book bindings are usually dark in colour, and rows of them, combined with dark-coloured shelves and furniture can give an impression of dark caverns. There is no reason at all why lightness and airiness should not be combined with scientific literary searches.

353. Another matter affecting general organization is the question of whether divisions should have their own libraries. It is now generally agreed that in a large institute, although there should be a central library where all books and papers in the institute should be catalogued, it is an advantage also to have divisional libraries, or else much time is wasted by staff in going to the central library to look up references. In fact, certain types of books are accommodated in the actual working laboratory - these being among the "tools of the trade". Similar arguments apply to the siting of other common services such as stores and central workshops.

Large buildings or small?

354. At a later stage in the growth of an institute it will be necessary to decide whether each division or section shall have separate buildings or whether large buildings will be erected which will house a number of divisions. There is much to be said for either arrangement. Sometimes, work of one division is inimical to the type of work carried out in another division; for instance, work in an engineering testing laboratory, causing vibrations or percussion, will affect delicate physical apparatus in a metrological laboratory. Fumes from a chemical laboratory can cause annoyance, and so on. On the other hand, having separate buildings for the different divisions tends to create divisional loyalties rather than institute loyalties and it is more difficult to effect the desirable intermingling of staff which the single building facilitates.

Heating and cooling

355. Many developing countries are in the tropics or semi-tropics and this poses special problems for laboratory buildings, because not only may they have to be heated at some seasons, as in the more temperate parts of the world, but provision has to be made for cooling the buildings in the hot season. For some types of work, air-conditioning becomes essential.

356. Until recently, few major studies had been carried out on the design and erection of laboratory buildings, although such work had been done in regard to hospitals and schools, where the difficulties are similar in principle. However, in the last six years several surveys have been made, particularly in the Division of Architectural Studies of the Nuffield Foundation in the United Kingdom; the Division

of Chemistry and Chemical Technology of the National Academy of Sciences - the National Research Council in the United States. Both have published excellent reports on their work.

Offices

357. Another problem to be decided when laboratories are being built is whether professional staff shall have separate offices or whether they shall be housed at desks in the laboratories in which their assistants are working. There is a strong tendency currently for staff to want separate rooms, and this should generally be discouraged; a separate room removes the professional member from direct supervision of his assistants and also encourages a tendency to become "chair-borne", which is very undesirable. However, in some types of laboratories fumes or noise make a separate office essential. Admittedly, in the case of very senior officers, a separate room is desirable, because they will often need to discuss business matters with sponsors, or carry out various types of private interviews.

358. For the junior members of the staff who may, from time to time, wish to have quiet conditions, as for writing reports, it is a good plan to have a series of rooms attached to the library which a staff member may reserve for a period of days, if necessary. For this period the room should be his, so that he can leave his books and papers about without fear of their being disturbed.

Flexibility in buildings

359. The requirements of science are unpredictable, and it is a common experience among those who have been concerned with large-scale laboratory construction to find that they have to start modifying one end of the laboratory buildings: that is to say, the shell of the building may be of ferro-concrete but the internal walls are often of light and movable construction, on a module, and it is a matter of much discussion as to what the module should be. Many organisations have found that a module of about ten feet is adequate. This means that one can either have one large laboratory thirty feet by ten feet; or one twenty feet by ten feet, plus one ten feet by ten feet; or three laboratories each ten feet by ten feet. Some laboratories have been built on a smaller module. For instance, a famous plastics research laboratory has been built on a four-foot module in such way that everything within the shell is movable in units of four feet. In this particular building,

the windows and the cladding of the building are on a four-foot module, with the result that even windows and fume cupboards can be moved, if desired.

360. In some parts of the United States, there was a fashion a few years ago for building laboratories without windows, on the grounds that this facilitated air-conditioning; but it is believed that this might have had an undesirable psychological effect upon the staff. Windows are now provided, except in those rooms where they are undesirable, such as in dark rooms, or where it is necessary to keep equipment at a particular temperature and/or humidity. In some rooms it has been found useful to have removable sections of floors and ceilings. It is a common thing in a laboratory of fixed construction to find that it becomes necessary to build, for example, a fractional distillation column taller than a room. Facilities, therefore, for building tall apparatus should be available.

Should services be centralized or not?

361. Another matter that has received a lot of attention is whether laboratory services should be centralized. Of course, services like mains water or electricity must be centralized, but services like vacuum, standard frequency, distilled water or special gases create difficulties when centralized. There is the difficulty, also, that a breakdown in one part of the institute will affect the whole of the institute. When services are arranged separately, this cannot happen and if there is a breakdown in one room, equipment can often be borrowed from a nearby room to meet immediate requirements. Thus, the use of a central vacuum service in one room may affect the use of this in another room, and it is now generally considered better to provide such services individually to the rooms.

Flexibility in furnishings

362. It is very desirable in rooms requiring a lot of bench space, such as in chemical laboratories, to have the plumbing arrangements adaptable and the benches movable so that they can be organised to meet the requirements of the moment.

Provision for amenities

363. The lecture theatre should have provision for the showing of films. Some institutes also provide for simultaneous translation because international seminars are organized in them periodically, but this can possibly be regarded as a luxury.

364. In either the cafeteria or the lecture hall there should be facilities for holding social functions, and if space permits, sports facilities should be provided on the site. Social events and sports help considerably in enabling staff to mix and in improving general morale. This is very important in some developing countries where the research institute may house the only group of professional people in the area, and the building up of a reasonably active social life, whose centre is the institute, can be a big factor in assisting staff recruitment.

365. When money is short, it is often thought by the authorities that every available cent should be spent on scientific requirements. This view is short-sighted. A reasonable sum spent on staff amenities usually earns bigger dividends than an extra piece of equipment or a few more feet of laboratory space. Not only do such amenities assist in recruitment but they can be a significant factor in the building of staff morale, and they also serve the very valuable purpose of bringing various grades of staff together on an equal footing, with the consequent cross-fertilisation and exchange of information and views so necessary in scientific work.

366. It is hoped that the comments above demonstrate that the type and layout of buildings can have a marked effect upon the organization of the institute.

XIV. ENGINEERING DESIGN

Introduction

367. R and D is sometimes aimed directly at the design and production of equipment and machinery, but more often the industrial realisation of the results of R and D demands the design and construction of these engineering products.

368. A large research institute, especially one concerned with the physical sciences, will contain a design office, and this chapter describes, therefore, the general principles of engineering design.

General considerations

369. Engineering design is rather like an assembly process. The designer has to assemble in his mind and then on paper certain factors in order to describe clearly a machine, article or process which meets a particular specified need.

370. Mechanical engineering design was defined in 1963 by a committee of the United Kingdom Department of Scientific and Industrial Research (known as the Fielden Committee):

> ... the use of scientific principles, technical information and imagination in the definition of a mechanical structure, machine or system to perform pre-specified functions with a maximum economy and efficiency.

This definition, although limited to mechanical engineering design, does provide a valuable guide to the needs of all designers.

371. The process is described in chart 3, annex II. Here design engineering is seen as a process fed by four inputs:

(a) From research comes an ever-developing science. The mechanical designer is fed with new insight into problems of static and dynamic structure design, new means of improving system efficiencies, and so on, while the electronic designer is fed with new insight into circuit behaviour and complete new media in which to operate. The chemical engineer and the civil engineer are equally dependent on their research backing;

(b) From research also comes a steady flow of new materials, components, and devices. Again by way of examples, one should quote the mechanical designer's need for new structural materials such as reinforced plastics and cements and the electrical designer's need for new components that might have sprung from research into, for example, solid state physics;

/...

(c) From the user who may be the designer's customer or client, or even another department within the same undertaking, should come a clearly specified need. This is probably the most neglected step in engineering design. Too often do designers start straight into design hardware with no precise specification of the desired performance. Time spent clarifying performance, cost and appearance specifications <u>before</u> any design work is begun is time well spent;

(d) Again from the user, directly or indirectly, must come constraints in the shape of limitations placed upon the designer's freedom of choice of means to achieve his objectives. These constraints can take the form of standards or preferred components. For example, the purchaser of a chemical plant may specify directly that all pumps are to be of a given type or make. Publications of standards or data sheets by national bodies are, in effect, constraints on behalf of the public at large.

372. From the four inputs listed above the designer has to conceive and specify the required product. In the course of his work, he may have to prepare various models (physical or mathematical) on which to test the effect of the specified working environment on the whole or on parts of the product concerned. This may be followed by redesign and fresh prototype testing, and the whole cycle may be repeated many times before a satisfactory solution is reached.

373. To illustrate this, we can develop chart 3 into a more elaborate representation of the total process, as shown in chart 4, annex II.

374. With this pattern of the process in our minds, we can now begin to clarify and list those factors which can most contribute to improving the designer's effectiveness.

<u>Contact with research</u>

375. It is important that the designer maintains close contact with the research workers who provide him with his basic science and design concepts. If these concepts come from other organisations or other countries, it may not be practical to arrange close personal contact, but the designer must at least have every possible access to the publications containing the data he requires. A wise company will go further than merely provide access: it will give the designer instruction in a suitable form to ensure that he is constantly up to date. A positive incentive can be even more effective in encouraging this, as can be seen in an article in the <u>Conference Board Record</u> of March 1966, entitled "A Results-Oriented Development Plan", wherein is described the practice of one company which gives time rather than money as a bonus for good work. The employee can save up this time in a "bank" until he

has accumulated enough to be able to satisfy a need that he sees in himself. He can then claim the "banked" time to go away from his firm to study the particular aspect or science in which he needs more knowledge.

Knowledge of new materials and components

376. A designer who continues to specify traditional materials and components will quickly be overtaken by his more enterprising competitors. The good designer must be encouraged to study the advancing material technologies relevant to his discipline. To this end, visits to exhibitions, other industries and suppliers of materials are essential. Opportunities to experiment with new materials and get used to their peculiarities, properties and workability should be provided.

User constraints

377. All designers should be aware of the great advantages that accrue to the user of equipment that conforms to as many standards as possible. Even should a user not actually specify standard components, a designer must continually strive to make the most of them. Some of the advantages are:

(a) Ease of manufacture (few would nowadays dream of specifying non-standard screw threads without very good reason);

(b) Ease of access to spares;

(c) Less need for special maintenance tools;

(d) Interchangeability of parts;

(e) Reduction in manufacturing and spares stocks;

(f) Readily available design data for standard parts.

For all these reasons, the design office must be well supplied with standard data of all relevant materials and parts used.

378. One of the problems, admittedly, is that of choosing appropriate standards for use in products that are to be exported as well as used on the home market. The variations in world standards makes this a problem but a little forethought and ingenuity (for example, conversion kits) can often overcome difficulties.

379. Under the general heading of "user constraints" must be mentioned the vital matter of cost. The ideal solution to the design problem is that which performs

effectively at the lowest possible manufacturing and operating cost. Cost consciousness should be as much a part of a designer's make-up as the ability to calculate stresses and speeds. Furthermore, a designer must be brought to realize that it is rare to achieve the optimum design the first time; continual redesign with hindsight and assistance from others should always be encouraged. This is sometimes known as "value analysis", a technique wherein each part of every product is scrutinized carefully to ensure that its cost of manufacture is kept below its value, the latter being defined as the value the part contributes to the whole.

The user specification

380. It may be necessary to carry out many tests and experiments to establish the exact performance required of the device being designed. Average values alone are useless. Precise definition of the whole population of possible values is necessary. To illustrate this, imagine the design of a highly stressed component part of a motor car suspension. Past experiments should provide data on the frequency of occurrence of various values of load to be withstood; such data can be shown in the form of the familiar distribution diagram as shown in figure 1, annex III.

381. The need for information in this form will become clear when it is realized that material properties also have a given distribution of values that can be depicted in a similar way. Superimposition of the two diagrams will indicate the frequency of occurrence of failures in service as shown in figure 2, annex III.

382. The shaded area indicates frequency of failure. Should this frequency appear unacceptably high, improvement can be gained by redesigning the component to make it stronger; also, by specifying higher quality material with less variance in its properties and thus a narrower distribution diagram. This example should indicate the need for clear specification of the required product performance, including limits of extreme performance required.

The design process

383. Design is an iterative process. Trial-and-error is its most common component. At the present time, a number of aids are appearing on the scene which should help to reduce the tedium and the time taken in the process.

384. Computers can now be used to carry out some of the more lengthy "batch" calculations. Examples of this are:

(a) Cut and fill calculations for the civil engineer;

(b) Reliability calculations for the communications engineer;

(c) Heat exchange calculation for the boiler designer;

(d) Design calculation for the aero-space industries;

(e) Pipe work design for the chemical engineer.

385. Where aesthetics are involved and the designer must see a three-dimensional model or at least a perspective drawing of the object he is creating, computers linked to cathode ray displays are now being developed which can show perspective pictures created from relatively scanty information. Going a step further, it is possible to make the perspective image rotate, come nearer or recede; or move parts as, for example, when a car is shown opening and closing its doors.

386. However, such specialist aids will be slow of adoption anywhere except in the most advanced countries. Before they become widely available, we are more likely to see computers being used in the "good housekeeping" aspects of design, described below.

The mechanics of designing

387. Once the designer has sketched out a part or a whole of the product he is working on, it is essential that he has the facilities to make it or have it made and then to test it or examine it for suitability. If the part is simple, there is much to be said for providing the designer with facilities for making it with his own hands, assuming that he has the skill. Many manufacturing problems will here come to light, because the designer will automatically simplify to save himself trouble. On the other hand, if the designer's skill is not up to the task, his hand-made prototype can lead to wrong conclusions and test results. Each case must be examined on merit.

388. Whatever the method for making prototypes, the overriding need is speed, for two reasons:

(a) Each day saved in bringing a new product or process into manufacture will usually provide an extra day's profit far in excess of the cost of urgency;

(b) A designer who has to turn his attention to other projects while he waits for prototypes may lose his train of thought and exhibit a noticeable lowering in effectiveness.

389. This argument speaks also in favour of test facilities and equipment being made available. Of course, very expensive test equipment cannot be provided on such a lavish scale that nobody has to queue for it, and such cases require careful examination to reach the best compromise. In this examination, however, some estimate of the cost of lost time for the reasons given at (a) and (b) above should be included.

Good housekeeping

390. The expression "good housekeeping" is intended to cover those aspects of the design process concerned with keeping orderly tidy records of the product or process as it is evolved. The whole problem of keeping parts lists "consisting of" schedules, drawings, specifications and other such records in a manner that is consistent and clear is a vast subject in itself. The methods used to number and identify parts and materials require much thought so as to gain the greatest possible advantage of standardisation and ease of use.

Summary

391. This chapter has not intended to deal at length with problems of design: indeed, all the services available to the designer such as the drawing office, test department, inspection, process planning, cost accounting and purchasing would all have to be explored in detail in order to clarify the interaction between them and the domain of the designer. Rather has it been attempted to present some of the concepts of design process from which design facilities might stem.

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XV. THE DISSEMINATION OF RESULTS

General

392. Problems involving the application of research results arise mainly with regard to work done on the institute's own account or non-secret work done on behalf of Government for the general betterment of industry or public welfare. The application of work done for sponsors will, of course, be the responsibility of those who pay for it.

Publication of results

393. In developing countries, research and development will be aimed at the economic development of the country, and the results of the work are, therefore, of value only inasmuch as they are known, and used in industry.

394. Results of scientific research should, as far as circumstances allow, be published in the scientific Press. This not only makes the knowledge available to those who wish to use it but is a valuable means of establishing the reputation of individual workers and of the research institute. It is the only way by which scientists and technologists can establish professional reputations, and it should therefore be the policy of the research organisation to encourage its staff members to publish the results of their work whenever possible.

Dissemination of results in writing

395. Many industries, especially in developing countries, do not themselves have trained staff, able to utilise the results of the work of the research institute, and the institute must, therefore, have a publication policy suitable to the potential users of its work. This will call for some skill in the writing of reports and brochures that the recipients can understand.

396. Some industrial research institutes publish periodical "newsletters" in which they outline the various investigations they have in progress. These are addressed to potential users of the results of the work. Some send specially written letters to firms and entrepreneurs, and some produce printed leaflets, preferably illustrated. Then, in addition to these activities, articles in trade journals are often quite productive, as are also short, popularly written items

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in the daily newspapers. If it is desired to bring the work to the notice of people in other countries, abstracts of scientific papers in the various international abstract journals achieve this fairly efficiently, though after some delay in time.

397. Abstracts are a possible means for the research institute to assist local industry. Not only abstracts of the institute's own papers but abstracts of other papers likely to be of interest can be copied and circulated.

<u>Dissemination of results in pictures</u>

398. The eye can transmit either words or pictures to the brain. Psychologists tell us that some words change instantaneously and involuntarily into pictures but that it is uncommon for pictures to change involuntarily into words. To present the eye with a picture would, therefore, seem to be a more effective method of communication than to offer it words. This is so if immediate communication is the sole object, but the brain often seems to work on the "easy come, easy go" principle, and what is remembered is frequently that which costs some effort. Thus a completely pictorial communication will have an immediate impact if the pictures are well chosen, but to produce any lasting effect they will probably need written additions. The pictorial method seems to have even more impact with unsophisticated people, and where the subject can be presented in this fashion, it may be especially suitable for use in certain countries.

<u>Use of films</u>

399. The sound and motion picture presents a very valuable medium for getting information over, especially when the viewers can be given a statement, preferably illustrated with "stills" from the film, which they can take away with them to study afterwards. It has been found that the sound-track film is a valuable means of communication, especially where efforts are being made to introduce new techniques.

400. Care must be taken, of course, to have sound-tracks available in the language or languages best understood by the potential audience. It is also a valuable means of presenting accounts of some of the work of the institute to visitors or at symposia and conferences held away from the institute. Also, films can be sent for showing in places and at times when it would not be

convenient to send a member of the institute's staff. However, it is always preferable for a member of the staff to be present at a film showing so that questions from the audience can be dealt with.

Oral communication

401. Experience in advanced countries (and very little information about developing countries is available on this point) is that most technical information is conveyed by word of mouth. This may seem surprising in view of the vast amount of technical literature, but several inquiries have established this. People meet in offices and laboratories and outside; they meet at conventions and symposia, and most of their conversation is a sort of "shop".

402. This principle points to the need for "salesmen" of technical information, and many research organisations employ such people specifically for this purpose. Much of the communication is done, of course, by the working scientists in the normal course of events, but specially chosen liaison officers have been found to be particularly effective. Often, the director of a research organization will "sell" an idea to top management of a manufacturing company, and the liaison officer will follow up, getting the idea or technique over "on the shop floor". Organisations in several countries can confirm the value of this type of activity.

General publicity

403. Publicity should also be obtained for the institute by articles or notes in the local Press, short commentaries on the local radio and, if a service is available, by programmes on the local television.

404. These types of publicity may well bring the results of the institute's work to the notice of those who can use them or may well actuate an entrepreneur or manufacturer to consult the institute about his problems.

405. If the institute is supported by the Government these types of publicity will also have the added beneficial effect of letting the taxpayers know that they are getting something for their money and creating a climate of opinion favourable to the institute.

406. In this connexion it is rather important that a new institute should endeavour to complete one or two short-term projects, preferably projects having some popular appeal, quite early. The resulting goodwill can be much more

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valuable in the early days than the solution of a much more important problem after two or more years' work.

Development orders

407. It is sometimes necessary in order to get production off the ground that government should guarantee orders for certain amounts of a product and it may well be, of course, that the government itself may wish to set up an industry using the results.

408. It is also necessary to get research results over to government so that these may possibly be used in government productive establishments, or that government may encourage their utilisation, by specifying products and processes utilising these results in its purchases.

409. There is no fool-proof way of getting technical information to the point of utilisation, and all methods have to be used, emphasis being placed on those which best suit local circumstances.

410. The above comments apply as much to the introduction and adaptation of foreign technology as to the introduction of new processes and new ideas, the only exception being that sometimes the foreign technology is subject to patent and other restrictions, in which case negotiations will need to be carried out for the appropriate licencing.

"In house" publicity

411. It will be necessary for the research institute to hold periodical seminars at which the possible application of research results can be described and discussed, and it will also need to hold periodical "at homes" or "open days" where industrialists and other potentially interested persons can be invited to visit the institute and see what is going on there. At such times they can discuss, in a preliminary way, any problems they may have with members of the staff, and this may well lead to sponsored assignments later on.

Extension work

412. Whenever a new process or modification is introduced, it is highly desirable that the research institute follow the progress of the introduction and be ready to endeavour to solve any problems that arise. This is done by frequent visits

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from the staff of the research institute to the industrial organization; and is helped by visits from the members of the industrial firm to the research institute.

413. Trouble-shooting is very important, and may involve considerable work on the manufacturer's premises or further research work at the institute or possibly reference to manufacturers in other countries to learn how particular difficulties were overcome. Frequently, these references to other countries can better be made by the research institute staff than by staff of the manufacturer.

414. During this period, the staff of an industrial research institute is likely to acquire considerable information of a proprietary nature, and great care must be taken about the disclosure of these and other such particulars. In order to avoid unfortunate repercussions, use of data and information should therefore be in accordance with policies established between the institute management and clients.

Effect on morale

415. The successful commercial application of the results of an institute's work is, of course, of great importance to the institute as well as to the manufacturer, because it is by this that the reputation of the institute is created and maintained and the morale of the staff is built up. Those dedicated to careers in applied science find their real professional satisfaction in seeing the studies they have conducted put into practice.

Unsuccessful projects

416. Inevitably there are cases when the results of a project lead to disappointing conclusions. But negative results are not necessarily useless results. The institute's work can prevent a client from wasting money by undertaking work of his own on such a project. In such cases the institute will explain carefully to the client why the conclusions are disappointing. Sometimes it is due to the cost of raw materials; the work done may be of value at some future time, if and when the cost of this material drops. Perhaps there is difficulty in obtaining advice on equipment; such obstacles should be explained fully so that the client may, at some future time, be able to use the results of the work should any of the circumstances change.

417. It may well be that an advance in some apparently unrelated field and recorded in the literature may enable the staff of an institute to return to a previous project and bring it to a successful conclusion. This happens quite frequently in scientific work and there have been numerous examples of "fall-out" from defence research carried out in the advanced countries that has enabled commercial operations to be initiated economically, though previous work had been unsuccessful.

Development institutes

418. Several countries have now set up development institutes to study in detail the factors governing the development of their country. These are technological, economic and sociological.

419. A recent innovation has been a co-ordinated study in some advanced countries of the factors affecting development, especially in developing countries. In 1966 the Ministry of Overseas Development in the United Kingdom established an Institute of Development Studies in co-operation with the University of Sussex. The following is a quotation from a brochure concerning this Institute, published very recently:

> **(a) The Institute's main purpose is to conduct teaching and research on the problems of the developing countries and on international co-operation in relation to them. One of its special characteristics is that it aims to gather together in one organisation experts in each of the main fields of development studies.**
>
> **(b) Teaching and research: The teaching will be principally directed towards two categories of student or course participant: mature people, mainly from government service in the United Kingdom and other countries, who will attend short group courses, or in some cases pursue individual courses of study, under the supervision of the Institute's staff; and post-graduate research students both from the United Kingdom and overseas. In many cases it will be possible to arrange for these students' work to be associated with the Institute's research projects. The Institute does not, for the present at least, contemplate awarding its own degrees or diplomas. Research students who wish to read for these can, however, apply for enrolment by the University of Sussex through the Director of Graduate Studies in Arts and Social Studies.**
>
> **(c) The Institute's staff, in addition to teaching, will be engaged on research in development problems. In this they will collaborate with experts from developing and other countries and from international organisations as well as from other institutes in the United Kingdom, some of whom will be appointed as Visiting Fellows and Associates.**

420. No doubt many of the subjects studied at the Institute referred to above and at other institutes in other countries will cover many of the matters already discussed in the present report and as a result of such studies, modifications to the procedures and practices advocated in this report may become desirable, in order to bring them even more into line with the requirements of the developing countries.

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Conclusion

421. It is now well established that Research and Development are powerful factors in the development of a nation's economy. They are, however, expensive processes, and it is as easy to waste money on R and D as on any other activity. It is only by following proper practices that investment in R and D can be made to pay. It is therefore important, especially in the new countries which have no money to waste, that their R and D efforts should be canalized along productive lines.

422. The key to good research is good research staff, coupled with good organization, and an attempt has been made in this paper to show how productive research can be organized, provided that good staff can be obtained. Good staff and poor organisation will produce something; good organization and poor staff will produce little; but good staff and good organisation will produce much.

423. In the advanced countries the scientific revolution of the last 300 years, since the advent of the scientific paper, has gained continuous momentum, so that the volume of scientific work in these countries is doubling itself every ten to twelve years. Naturally, this cannot go on indefinitely, otherwise in countries like the United States, the USSR and the United Kingdom, the position would soon be reached where everybody would be a scientist. However, in the developing countries with their present very small reservoirs of skilled scientific workers, the exponential growth could soon be even greater than in the present advanced countries. It certainly will not take the developing countries more than a small fraction of 300 years to reach the present standard of the advanced countries.

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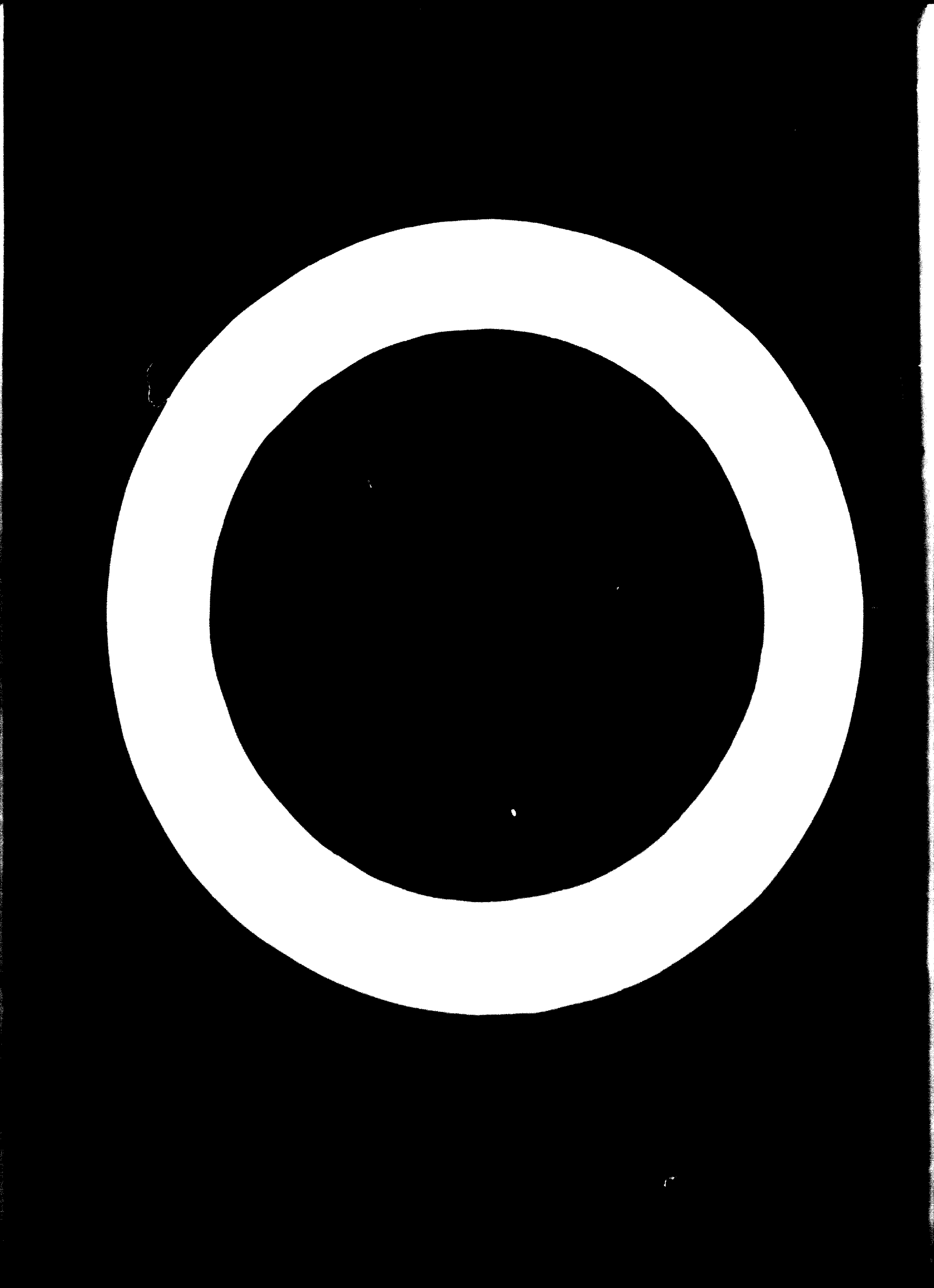


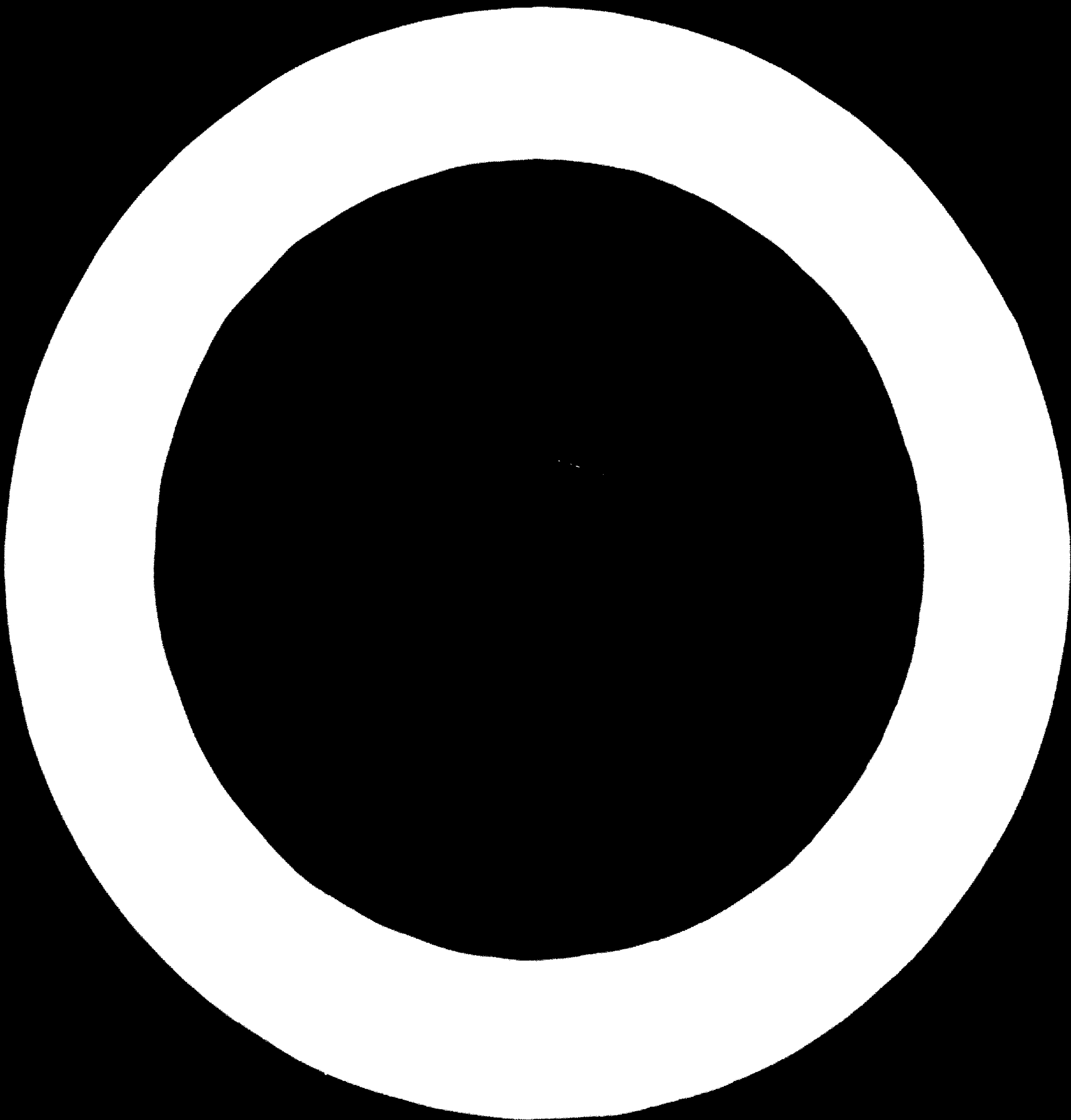
ANNEX I

Table

Services Offered by Industrial Research Institutes (Arranged in Order of Countries) a/

Name of Institute	Basic Research	Raw Material Utilization	Process Development	Feasibility Studies	Pilot Plant Operation	Plant Location Layout	Plant Management	Productivity Studies	Market Studies	Testing	Personnel Training	Trouble Shooting
1. CAMEROON Ministry of Development & Internal Economic Planning, Buea	X			X								
2. CANADA New Brunswick Research & Productivity Council, Fredericton, N.B.		X	X			X	X					X
3. COLOMBIA Institute for Technological Research, Bogotá		X	X	X	X	X		X	X	X	X	X
4. CHINA (Republic of) Union Industrial Research Institute, Hsinchu, Taiwan	X	X	X	X	X					X		
5. DENMARK Danish Meat Research Institute, Roskilde	X	X	X	X	X	X	X	X	X	X	X	X
6. GERMANY (Federal Republic of) Battelle Institute eV, Frankfurt	X	X	X	X		X		X	X			
7. ISRAEL Standards Institution of Israel, Tel Aviv		X	X	X	X			X		X	X	X
8. JAPAN Tea Research Station, Kanaya, Shizuoka	X	X	X					X			X	
9. NORWAY Norwegian Pulp & Paper Research Institute, Oslo	X	X	X		X					X	X	X
10. SOUTH AFRICA (Republic of) Leather Industries Research Institute, Grahamstown	X	X	X	X	X	X	X	X		X	X	X
11. SWITZERLAND Institut Battelle Centre de Recherche de Genève, Geneva	X	X	X	X	X	X			X			
12. UNITED KINGDOM Research Association of British Paint, Colour & Varnish Manufacturers, Teddington, Middlesex	X	X								X	X	X
13. Arthur D. Little Research Institute, Inveresk, Midlothian	X	X	X	X		X	X	X	X			X
14. UNITED STATES OF AMERICA Interamer Research Corp., New York		X		X		X	X	X	X			
15. Battelle Memorial Institute, Columbus, Ohio	X	X	X	X	X				X			
16. Battelle Memorial Institute, Pacific Northwest Laboratories, Richland, Washington	X	X	X	X	X				X			
17. URUGUAY Instituto de Tecnologia y Quimica		X	X							X	X	

a/ Industrial Research News, No. 2, Vol. 1.



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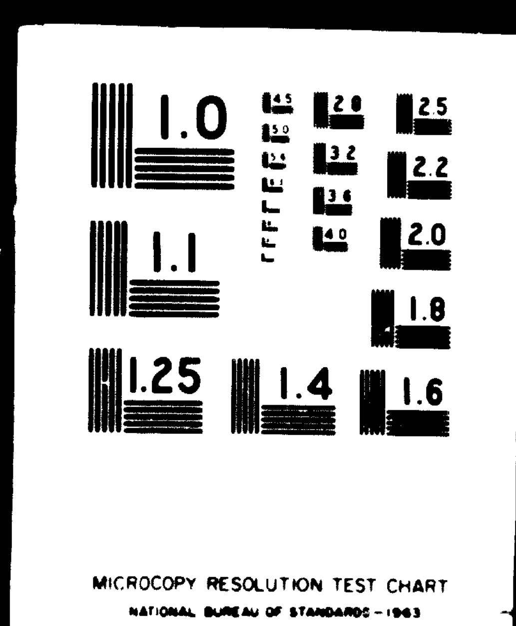

1.0
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2.0
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2.5
2.8
3.2
3.6
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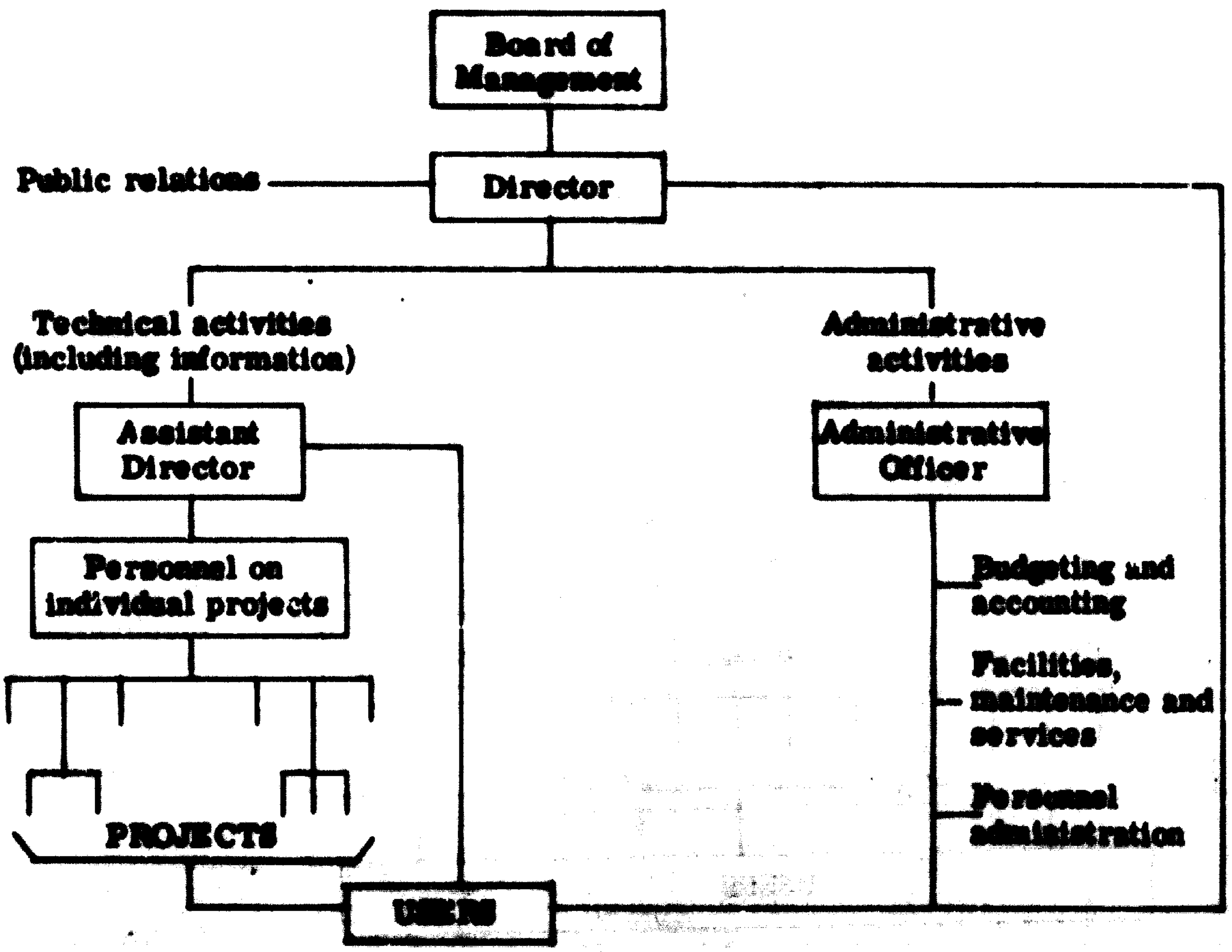
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS - 1963

ANNEX II

Chart 1

Simple form of organization of an industrial research institute[a]



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a/ "Manual on the management of industrial research institutes in developing countries" (United Nations publication, Sales No.: [illegible]), p. [illegible].

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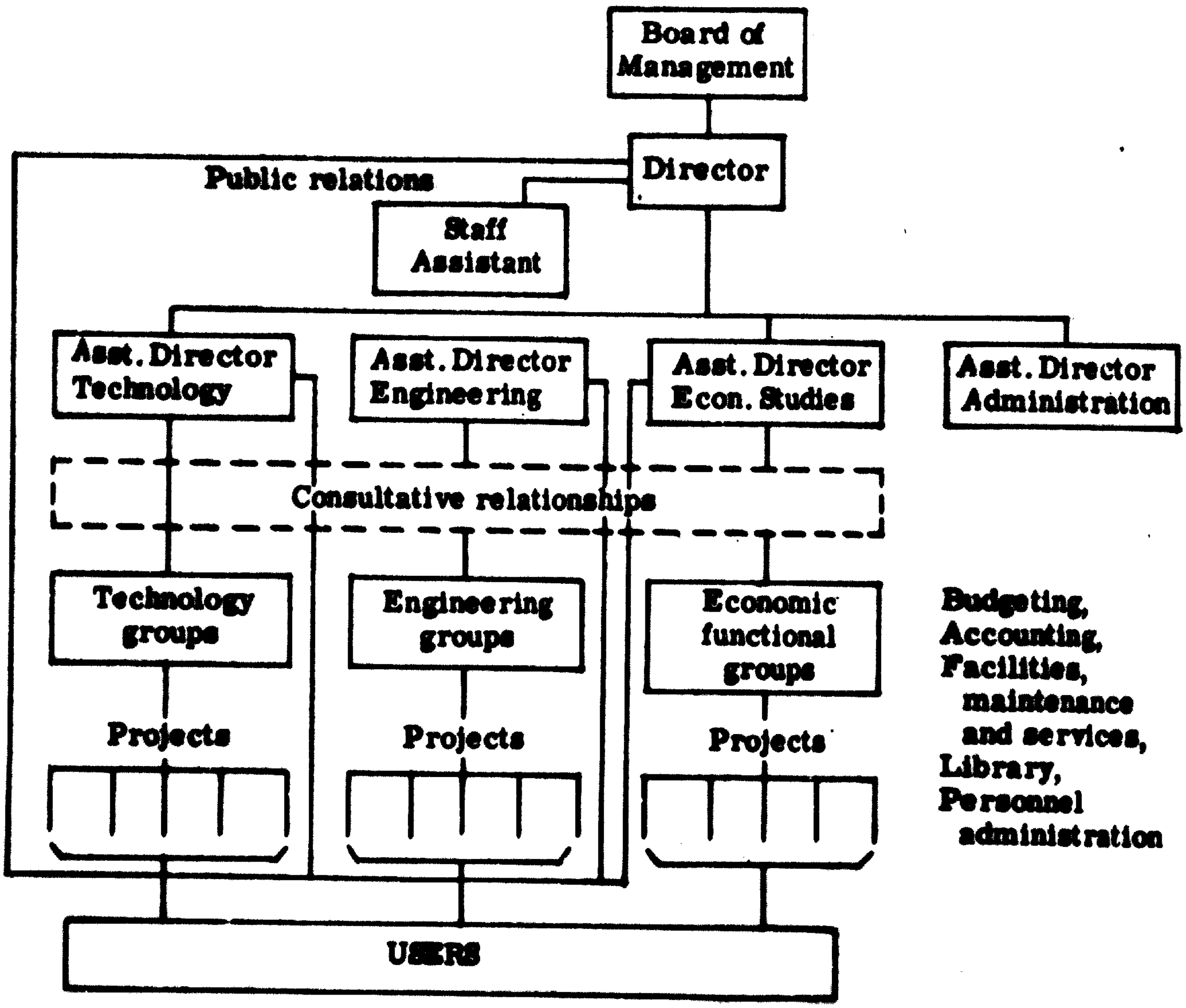
Chart 2

Organisational plan of a comprehensive industrial research institute[a]



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a/ Ibid., p. 21.

Mechanical engineering design

Chart 3

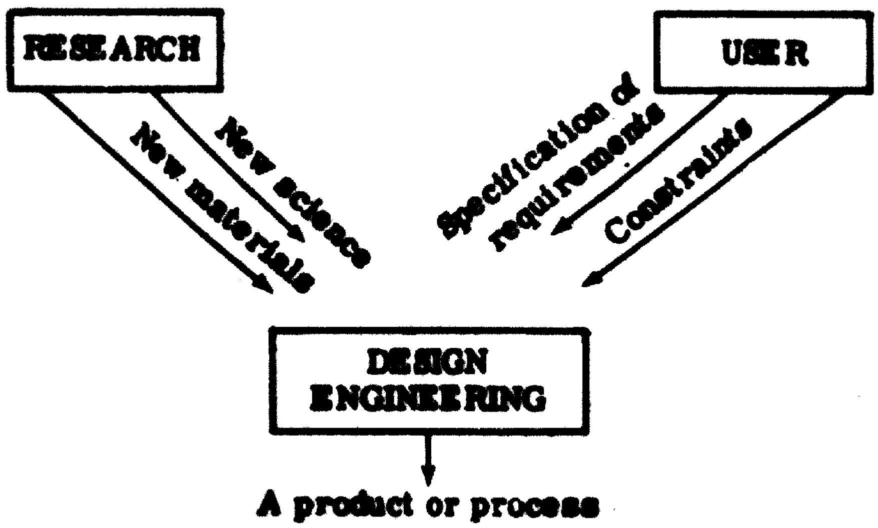
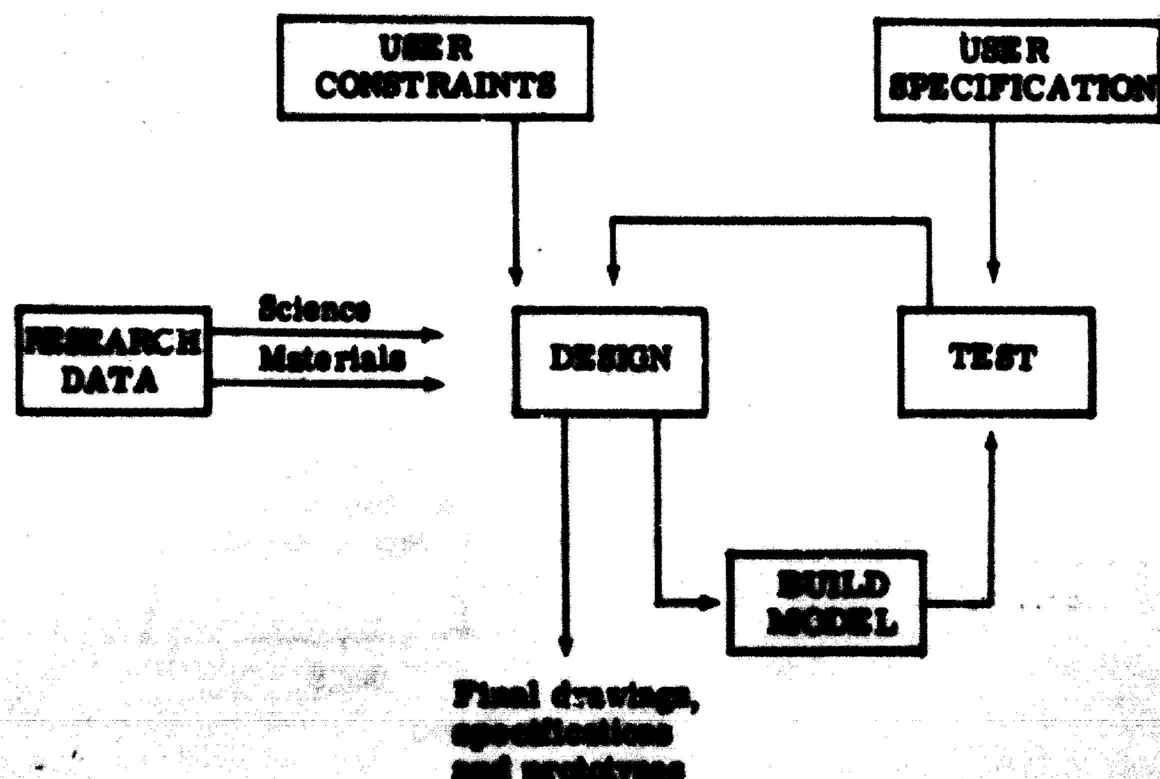
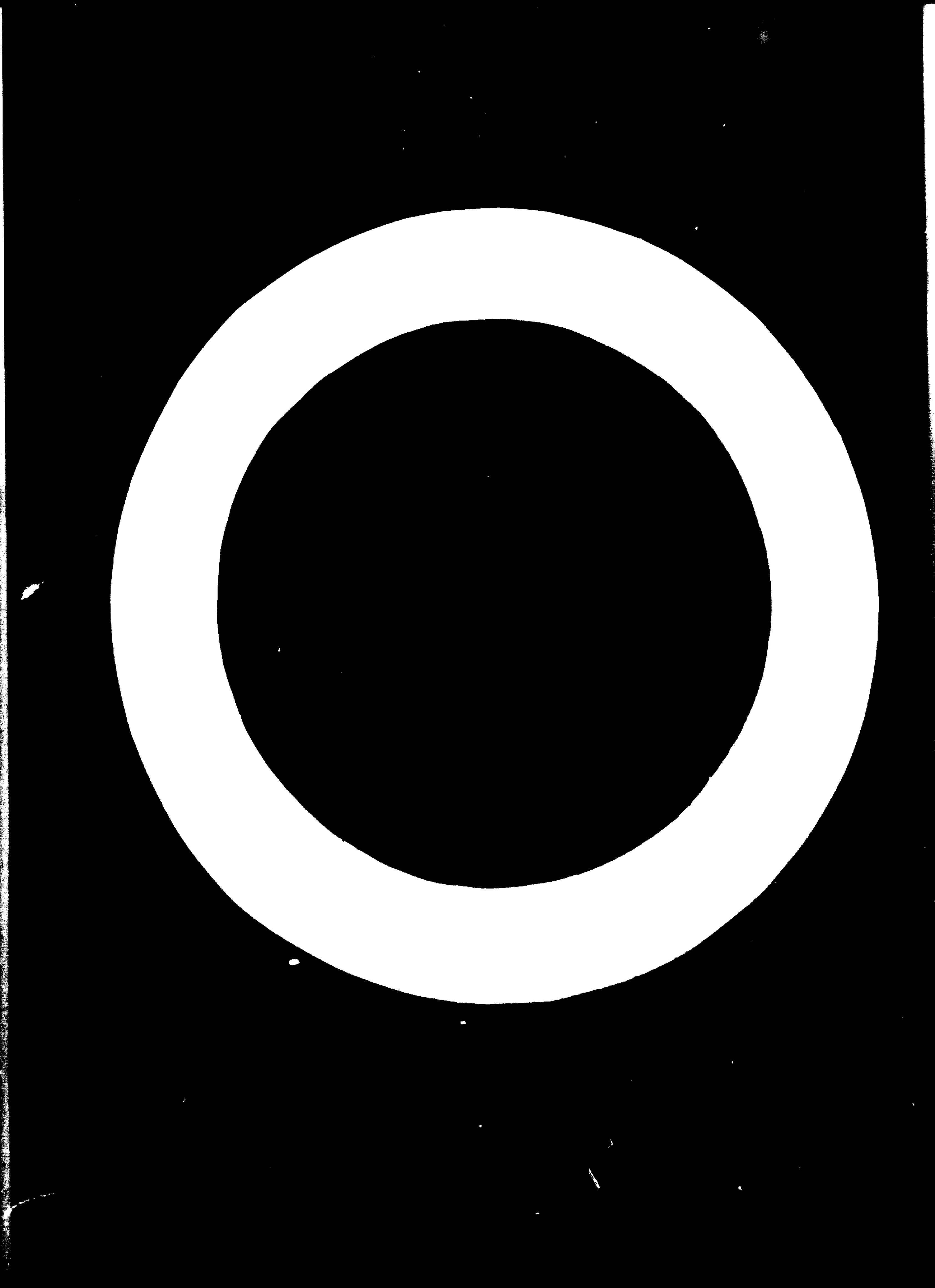


Chart 4





ANNEX III

Distribution diagrams

Figure 1
Number of occurrences

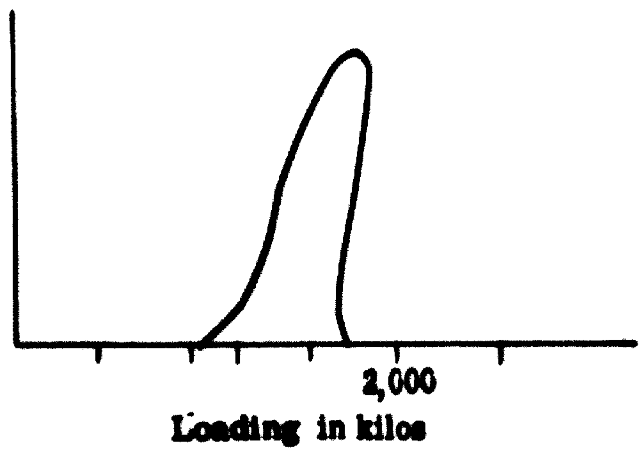
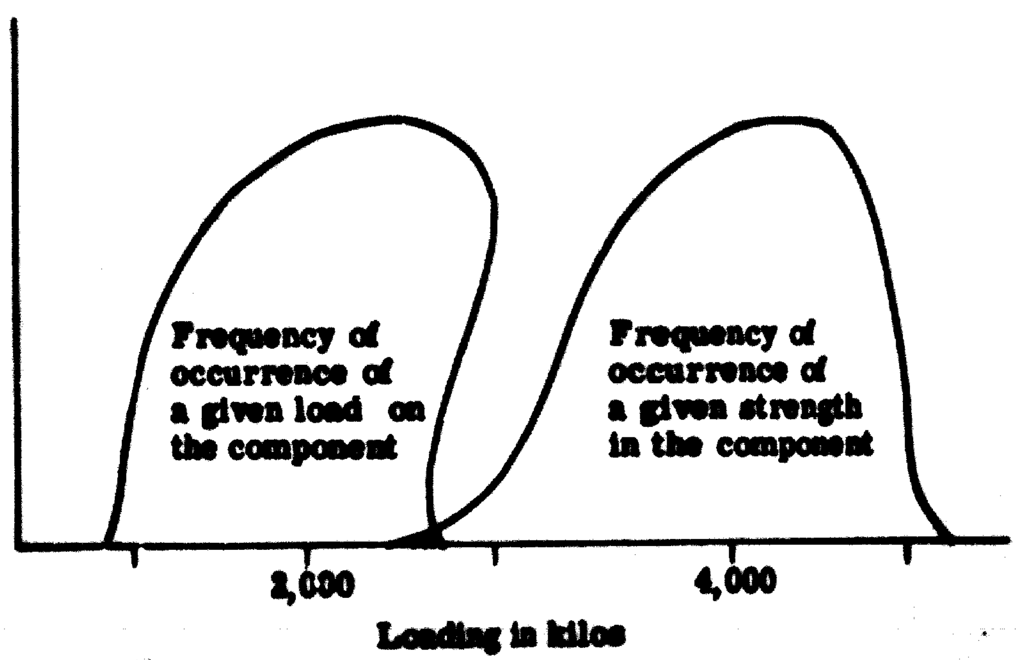


Figure 2
Frequency of occurrence



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THE ORGANIZATION OF INDUSTRIAL RESEARCH IN DEVELOPING COUNTRIES 1/

By

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* This document is a summary of a background document of the same title, distributed for the symposium as ID/CONF.1/B.14.

1/ The views and opinions expressed in this paper are those of the consultant and do not necessarily reflect the views of the secretariat of UNIDO.

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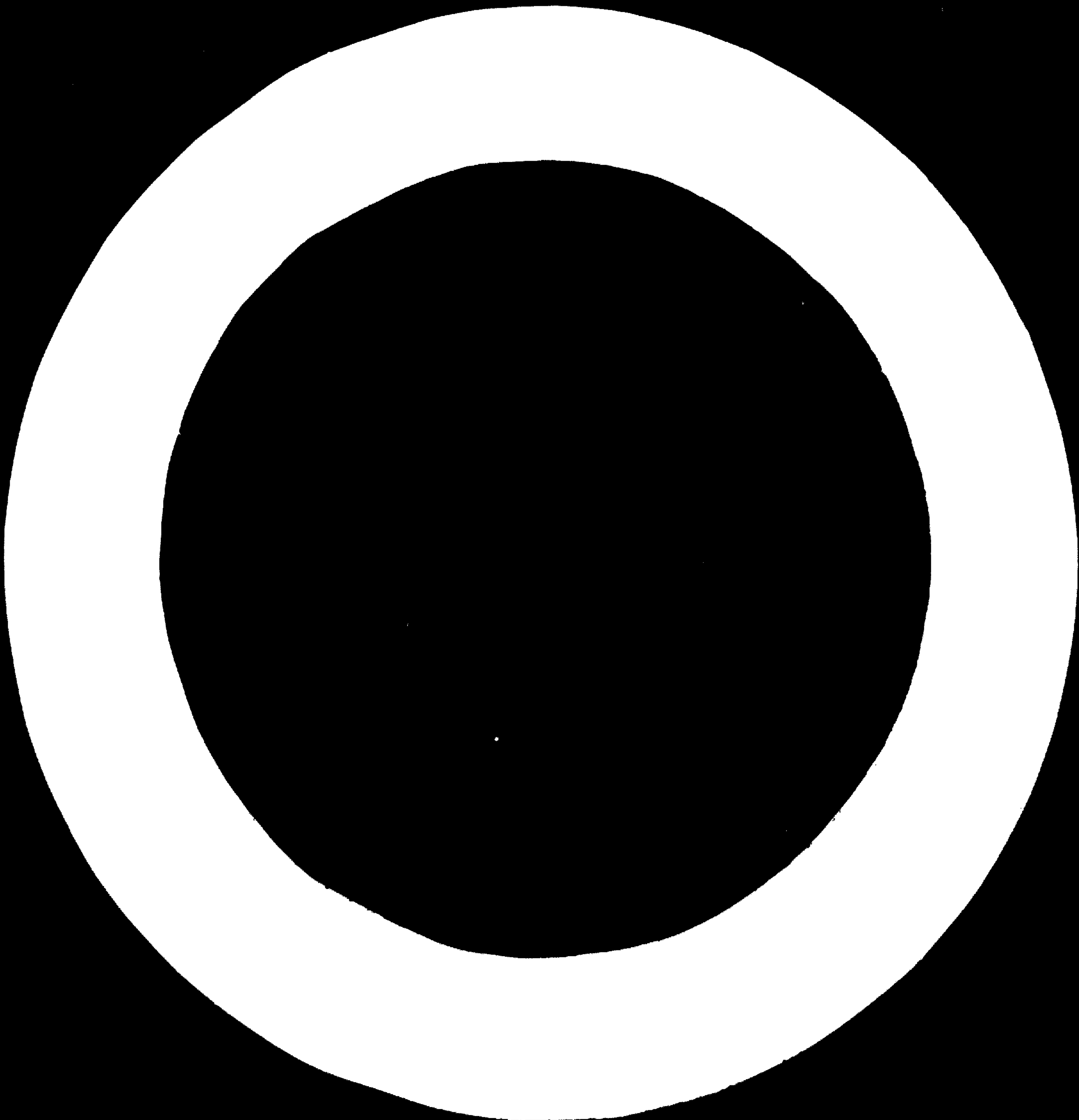

Contents

Introduction

1. Research and development (R and D) are now regarded as two of the most potent factors in economic development. In developed countries this is well illustrated by the fact that the amount of money spent on those activities and the number of men engaged in them have doubled about every twelve years. The growth pattern has increased to such an extent that in some of the most highly developed countries it now appears that it will level off. In the developing countries the same growth pattern may be expected but with a steeper rise.

2. In some of the advanced countries 50 per cent of the funds earmarked for R and D come from the Government even though industry carries out the work. Very large sums spent on defence and space projects are unlikely to affect significantly most of the developing countries. Sums spent in 1962 on R and D in the majority of advanced countries ranged between 1.0 per cent and 3.1 per cent of the gross national product.

3. It is not, of course, feasible for developing countries to spend such amounts on these activities because of their lack of trained scientists, technologists and engineers. But as educational systems develop, dependence on and therefore expenditure on R and D will increase.

4. A feature of R and D even in advanced countries is the part played by the Government and, a number of Governments are the biggest single source of R and D funds and the largest single employer of scientific and technical labour. Therefore government policy has a decisive effect on encouraging investment in R and D through fiscal measures.

5. The nature and complexity of the technological problems vary considerably from area to area. Weather, natural resources, tradition and social structure are some of the conditions that could influence technological change. Therefore, no generally applicable pattern can be set forth. But general principles can be derived from experience which, appropriately modified, could be used to initiate practices that contribute to industrial growth.

6. In addition to good R and D and the identification and proper evaluation of the type of R and D to be used, the availability of developed segments of the infra-structure and of technically and administratively trained people are essential for industrial development.

Institutional research

7. Research can be broadly divided into fundamental, oriented basic, applied and developmental; it consists generally of team work. Those developing countries that are in a very early stage of industrialization will need mainly development work, whereas others may also require applied research. However, in the last forty years much basic research has been undertaken in order to set traditional industries, such as leather, iron and steel, on a scientific foundation.

8. In practice, studies and research by scientists of many disciplines are necessary since many advances in the industrial field fall across traditional scientific disciplines. The value of a research institute is, therefore, that it brings together people trained in various disciplines who can pool their knowledge and skills for the solution of problems.

9. Developing countries seldom require completely new technologies and therefore work should concentrate on:

(a) Development of new processes and improvement of existing processes;

(b) Development of new products, new uses for existing products and survey and development of existing raw materials;

(c) Improvement of industrial productivity with a view to reduction of price;

(d) Scrutiny of economic and social aspects of processes being developed.

10. It is highly desirable in the development of products that there should be a home market as well as a potential export market. The former is then able to buffer the fluctuations of export market prices. The position of cocoa in the Ghanaian economy is a good example.

11. Among the activities of industrial research institutes in developing countries, should be the organization of standardization programmes, and advisory services on the specifications, sources and costs of industrial equipment. They should also provide technical-economic consulting services, including market research and reviews of nationally available infra-structures.

12. Funds should also be made available for extra-mural research work, and the institute should carry out sponsored research and development work, provide extension and technical services to its clients, and maintain an updated reference library.

Types and functions of industrial research institutes

13. Some industrial research institutes are of the "multi-purpose" type covering a wide variety of fields, and others are of specialized types, either in a particular scientific discipline such as physics and chemistry, or aimed at a particular product or process such as rubber or silicate. Such institutes are called "unipurpose" or sometimes "commodity" institutes. Institutes covering additionally to the scientific and technological fields such other fields as economics and sociology, management and marketing, could be designated as "comprehensive".

14. The choice of a type of research institute can only be decided upon after a study has been made of all the circumstances. It may well start as a multi-purpose institute with a certain activity splitting off as a specialized institute whenever it reaches a certain size or complexity, for instance, the National Physical Laboratory in England. When a country or group of countries are dependent on a particular crop or mineral resource, it may well be desirable for institutes to be founded to deal with these products.

15. Comprehensive research institutes have grown up in the United States and are spreading to other countries. They have the ability to reduce their technical findings to practical matters of cost, finance and market requirement and can thus assist industry in problems involving both technical and economic considerations.

16. The main functions of an industrial research institute are to initiate and carry out research for the promotion of industry. One point, often overlooked in developing countries, is the proper preparation of products for export.

The control of research organizations

17. Whether publicly or privately controlled, an industrial research institute should enjoy a large degree of autonomy. However, until the industrial economy develops so that local business and industrial organizations are prepared to finance some or most of the work of an institute, the first step must be sponsored by the Government, thereby providing a large portion of the capital requirements and running costs, at least in earlier years of establishment.

18. Much government research is performed by laboratories of large commercial companies, or in sponsored-research establishments with subsidiaries in other developed countries or sometimes in developing countries. Generally, laboratories set up by chambers of trade test to specifications and are confined to analytical work. Another type is the industrial research association, state-aided or not, in which member firms subscribe money to maintain research laboratories to study their industry's problems, provide advisory services and operate as a technical information centre.

19. As the R and D element of any one project may well occupy several years even in a moderately important project, it can be carried out efficiently only against a background of financial and policy stability. For government-subsidized R and D, the best means to achieve this is to set up a Research and Development Board on which the Government and various aspects of the national life are represented. From this board, a much smaller executive committee would be elected, meet frequently and be the main source of support for the director and the staff. Membership of three years' duration, on a rotation basis, is usual for such a committee.

Organization of industrial research institutes

20. In a small new institute the director will guide and direct much of the work until an organizational pattern emerges. When the institute becomes of such a size that the director cannot control the whole organization, an organizational scheme is established, dividing technical from non-technical work. While divisions are established, the team approach to the solution of problems is encouraged. The divisions might be set up along the lines of scientific disciplines or in accordance with t purpose being served.

21. Small teams of research workers have assumed more and more importance in bringing about technical change. Groups are a powerful means of introducing the inter-disciplinary approach to research, an approach that is required to cope with a complexity of problems and achieve fast results. Although the inter-disciplinary approach is to be encouraged, it has been found convient, in practice, to organize divisions in such a way that staff members feel they have a particular niche in the organization. However, it is agreed that divisional

organization diminishes "cross fertilization". Interaction between various members of a team requires that members be permanently charged lest further reaction becomes slow.

22. Management of research is different from management of most other human activities and must be regarded as a facilitating rather than a control process. In spite of great development in the last twenty years, it still has far to go. Good management stimulates creativity, an important contribution to research productivity. Some ten years ago a certain divergence of opinion existed as to the most desirable characteristic of a scientist: a good member of a team (United States) versus a creative individual (United Kingdom). As it stands today, advocates of each of those characteristics have compromised and both characteristics are recognized as important.

The director and the staff administration

23. The most important appointment in a research organization is that of the director. On his knowledge, foresight, experience, energy and character, the success of the organization will largely depend, particularly in the early growth years of the institute. He must have clear definitions of his authorities and responsibilities and preferably no direct affiliations or private relations of any kind with any type of industrial, commercial, financial or political organization. No effort or time should be spared to find the suitable person. His most important functions will be to act as arbiter when differences of opinion arise; as chief assessor of priorities in regard to projects, staff money and facilities; and as decision-maker and translator of the board's decisions into actions.

24. Among the most desirable qualities of a director is to be a good staff selector and a good administrator. His scientific stature has, no doubt, an effect upon the morale of the professional staff, but in a large institute his administrative ability will have an even greater effect upon the success of the institute and consequently upon staff morale. A director should be well assisted by a competent administrative staff, and as directors have to spend much time on work outside their own walls, they should be prepared to delegate internal administration to assistants whenever necessary.

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25. The professional category of staff such as science graduates, engineers, technologists, economists and the like are the most important; they are the people with the knowledge and ideas, and to them falls the duty of supervising the work of technicians, assistants, secretaries, and supporting staff. They are in direct contact with the clients and potential users of the results of their work. It is preferable in the early years to recruit staff with subsidiary knowledge and skills in addition to their main skills, who have a bias toward applied rather than basic research.

26. Other categories include the administrative staff, the technicians or supporting staff and the workshop staff. In some research institutes a "we and they" attitude develops between the professional and administrative staff, the former preferring to operate without any administrative control and considering such control superfluous. If the administrative staff regard their function as being to assist the professionals to do their job, the result can be a harmonious relationship in which each person contributes to the productivity of the organization.

27. In a large research institute, all matters pertaining to personnel should be handled by a personnel manager who keeps the personnel records separate from the general administrative records. Salaries and wages paid to all staff must be based on an adequate system of payment and awards. Overtime should be paid to junior staff subject to prior authorization. Ad hoc payments to cover patents or outstanding performance should also be possible. Arrangements for staff pension or superannuation is also a recommended practice.

28. There should be provisions for granting justifiable leaves of absence. Sabbatical leave is a powerful means to stimulate somewhat jaded workers and older scientists and it has proved very beneficial. Arrangements should be made to ensure that employees will return to their home base for a certain minimum period of time. This arrangement should be one of other encouragements for technical staff to prevent "technical obsolescence".

Recruitment, appointment and evaluation of professional staff

29. Staff are obtained by invitation, recommendation or advertisement depending on the level. After an application has been filled out a candidate is interviewed;

interviews must be regarded as a means to assess a candidate's personality, general intelligence, alertness and adaptability rather than his technical knowledge.

30. Interviews may be organized in such a way that a candidate meets a specially selected panel of three to five members or meets the panel members individually. Special score sheets have been devised to minimize the subjectivity of the evaluation.

31. A contract is signed by a new staff member and the personnel manager representing the institute. The contract should be as explicit as possible, and should specify in detail all aspects of the engagement. The general conditions of service together with staff rules are generally incorporated in a booklet supplied to each recruit joining the staff. A period of probation is always required of new staff members.

32. Professional staff, as well as other categories of staff, should be periodically evaluated. Whatever evaluation system is adopted, it should aim to record the general scope of the employee's work, the manner in which he tackles it, the success he achieves, and finally his potentiality. Characteristics on which information is required are: scientific and technological ability, judgement, initiative, speed, accuracy and method, power of expression, personal relations and leadership.

33. An aspect of promotion which is often overlooked is the suitability of a candidate for a more senior job. A promotion often entails managerial responsibilities. As some scientists and technologists, prominent in their field, do not possess the required aptitudes, it is better for administrative purposes to attach such scientists as consultants to a group that is led by a more junior person. Dismissal, though rare and unpleasant, should also be done swiftly when it is required.

Source of problems and factors affecting their economic solution

34. The fact that industrial research is intended for application by industry makes it important that the work be carried out with reference to the economic conditions of the industries concerned. Among the many factors to be taken into consideration, the significance of the objective in relation to sales, the reduction of manufacturing costs and the timing of future developments within the industry are of overriding importance. In this connexion "the lead time" and the desirability of having it as short as possible should be considered.

35. Choosing the right problem may fall to the institute itself; or the problem may be posed by a local industrial organization. The institute should be prepared to work on the latter for a fee. The abilities required to select subjects that in the last analysis are beneficial are not reducible to an exact science, and "hunch" plays an important part in the choice. However, broad technical knowledge, commercial sense, the imagination to foresee needs and applications and the ability to take calculated risks and secure team work are the main factors involved in the successful management of R and D.

36. Sponsored work, which could be on a one-time contract or retainer basis, may be in the field of product research, economic and sociological studies, follow-up work in industrial plants, feasibility studies, information services, testing and standardizing, equipment advice and techno-economic surveys. Such work is generally covered by a contract clearly spelling out responsibilities and fees.

37. Careful choice must be made of industries for development. In new research groups quick results will be more desirable than in the case of groups with positive results already to their credit. Creating a moderate profit on a product that sells in large quantities can confer a rich reward for the research efforts.

Financing research organizations

38. The prime responsibility of financing R and D in developing countries falls to Governments. United Nations agencies or developed countries may contribute financial assistance. In order to overcome the difficulties involved in financing from public funds and by-pass delays and political changes, some countries operate on the "rolling estimate" principle which means that the budget is drawn up annually against a forecast for a further three or four years. Also it should be allowed that any surplus of allocated funds can be carried over rather than automatically absorbed by the national exchequer.

39. Funds allocated to a research organization may well be earmarked for equipment, staff, consumable materials and similar other sub-headings, but such designations should be kept flexible and as few as possible. Budget items should be well-balanced, and extreme spending of capital investment for buildings and equipment while neglecting staff, is as bad as neglecting to up-date equipment while devoting the bulk of financial resources to staff improvement.

40. Many institutes, though government sponsored, are allowed to undertake contract research for a fee. Any accrued amounts from contract research should go to improvement of the institute, including staff members' salaries, rather than to the central treasury. Some countries finance research through special taxes, for example 1/4 of 1 per cent of industrial loans or import taxes on certain commodities. It is not sufficient in development plans to only stress the need for research; provisions for it should be specifically made with all that is entailed in terms of funds, facilities and personnel.

41. It is difficult to predict the amount of various budget items. However, 60 to 85 per cent of the running costs (omitting the original capital costs of buildings, equipment and amortization) is spent on salaries and wages, so obviously these are of paramount importance. Some experts consider that the threshold at which an institute becomes productive is when it requires ten professional scientists plus their supporting staff. The effect of reasonable size on the degree of success is shown in the International Rice Research Institute in the Philippines and the Rubber Research Institute of Malaysia.

Inventions, their protection and licencing

42. Inventions, whatever their source, are generally covered by patents, if they seem destined for any practical application. Individuals or companies may make their own arrangements to acquire rights to use such patents. Much more know-how and technology transfer is generally involved in such arrangements than exists in the patent. The research institute should be aware of patents of interest to the industrial effort of the country and it should serve, in the absence of a specialized organization, as a clearing house for the use of such patents.

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43. The exploitation of an invention needs commercial expertise and a thorough knowledge of international patent law. A certain number of countries such as the United Kingdom, Canada and India have set up national research development corporations which act as clearing houses and as sponsors for inventions. They obtain patent protection for ideas that appear valuable and license them to industry on a royalty basis.

44. The management of all industrial research institutes should be alive to the possibilities of patenting findings and exploiting such patents commercially. It is worth while for one member of the administrative staff to become skilled in patent matters and to keep in touch with developments in the institute, with a view to obtaining patent coverage on any discovery.

External technical assistance

45. Often, particularly in the formative years, developing countries cannot supply the technical and managerial skills necessary for their own development, and assistance from outside has to be relied upon. Such assistance is usually supplied by the United Nations or any of its agencies, either by providing experts working under international auspices, equipment and fellowships or by organizing interregional meetings and seminars. More will be done in this connexion now that the Centre for Industrial Development has expanded into the United Nations Industrial Development Organization.

46. Much technical help is also supplied under bilateral aid programmes provided by some advanced nations. A good practice is the "pairing" or "twinning" of an established industrial research institute in an advanced country with one in a developing country, the former sharing with the latter its valuable knowledge, experience and literature.

47. Training should be geared to the requirements of the home country of the trainee. This requires a particular schedule not common in the normal curriculum of colleges and universities. Ordinarily, such training occurs in industrial establishments of advanced countries which have reached certain agreements with industrialists from developing countries for an exchange of know-how and technical assistance on a commercial basis.

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Building for research

48. Scientific and technological research requires housing built especially for this purpose. The site should not be near the centre of a city because of possible obnoxious fumes emitted by laboratories, and yet not so far from the city proper that clients and visitors would find it difficult to reach. The site should be very much larger than immediately required because of the tendency of research institutes to expand. All utilities and access roads should also be available.

49. The type and size of building to be erected first will depend on the sort of work to be carried out. However, it will nearly always contain chemical and engineering laboratories, workshops, offices for the director and his supporting staff, a lecture room and library facilities. It is also good practice to include cafeteria-style eating facilities. Early provision should be made for separating buildings housing heavy equipment that cause vibrations from other buildings designed to house high precision measurement instruments.

50. Decisions regarding the instalment of central heating and cooling systems and the allocation of separate office space to individual professional staff members should be made in the early construction stages. Cooling and heating should be provided as a rule, and junior professionals encouraged not to be in separate offices so that they do not become "chair borne". The library should provide a quiet place for writing reports.

51. Buildings should be designed with as much flexibility as possible, removable partitions have been found very practical for this purpose. Also plumbing and wiring arrangements should be such that they allow reorganization of bench space to meet further requirements and modifications as they arise.

Engineering design

52. A large research institute, especially one concerned with the physical sciences will be active in the design and production of prototypes of equipment and machinery. In this process, new science and new materials issued from research are combined with the requirements of the user and with constraints in the shape of limitations placed upon the designer's freedom of choice of means. From the inputs mentioned above the designer conceives the required product.

53. It is most important that the designer keeps close contact with the research workers who provide him with his basic science and design concepts. He should also be encouraged to study the advancing material technologies of relevance to his discipline lest his art becomes obsolete.

54. User constraints are important and generally consist of ease of manufacture, ease of access to spares, less need for special maintenance tools, interchangeability of parts, reduction in manufacturing of spare stocks and readily available design data for standard parts.

55. The design process is an iterative process; trial-and-error is its most common component. Computers nowadays are used in developed countries to carry out the more lengthy "batch" calculations and to produce three dimensional and perspective drawings of the object to be designed. Good housekeeping and tidiness are also essential for successful designing companies.

The dissemination of results

56. The problem of the application of research results arises mainly in regard to work done on the institute's own account or on behalf of official agencies for the general betterment of the industry. Results should, as far as possible, be published in the scientific press and abstracts produced and circulated as a possible means of assistance to local industry.

57. A research institute should have a publication policy suitable to the potential users of its work, put out a periodical news letter print illustrated leaflets and contribute articles to trade journals. Dissemination of pictorial communications with good text will have an impact combined with lasting effect. Movie films, illustrated with stills from the film, which the viewers could take away with them has also been found to be an effective medium of dissemination. Naturally sound tracks in the language best understood in the country would enhance the value of films.

58. It is a fact that much technical information is carried by word of mouth and many communications are made orally in meetings in offices, laboratories, conventions and symposia. Much publicity is derived from such communications. But articles or notes in the local press, short commentaries on the local radio and programmes on the local television are also an effective means of publicity.

59. Negative results on a project are not necessarily useless for they can prevent a client from wasting money and investing in unsuccessful projects. The institute will then carefully explain to the client why the results are disappointing. It may well be that an advance in an apparently unrelated field may enable the staff of an institute to come back to a project and bring it to a successful conclusion.

60. Several countries have now set up development institutes to study in detail technological, economic and sociological factors governing their development. A recent innovation has been a co-ordinated study of factors affecting development, especially in developing countries.

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