OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

This document has been produced without formal United Nations editing. The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. Designations such as "developed", "industrialized" and "developing" are intended for statistical convenience and do not necessarily express a judgment about the stage reached by a particular country or area in the development process. Mention of firm names or commercial products does not constitute an endorsement by UNIDO.

FAIR USE POLICY

Any part of this publication may be quoted and referenced for educational and research purposes without additional permission from UNIDO. However, those who make use of quoting and referencing this publication are requested to follow the Fair Use Policy of giving due credit to UNIDO.

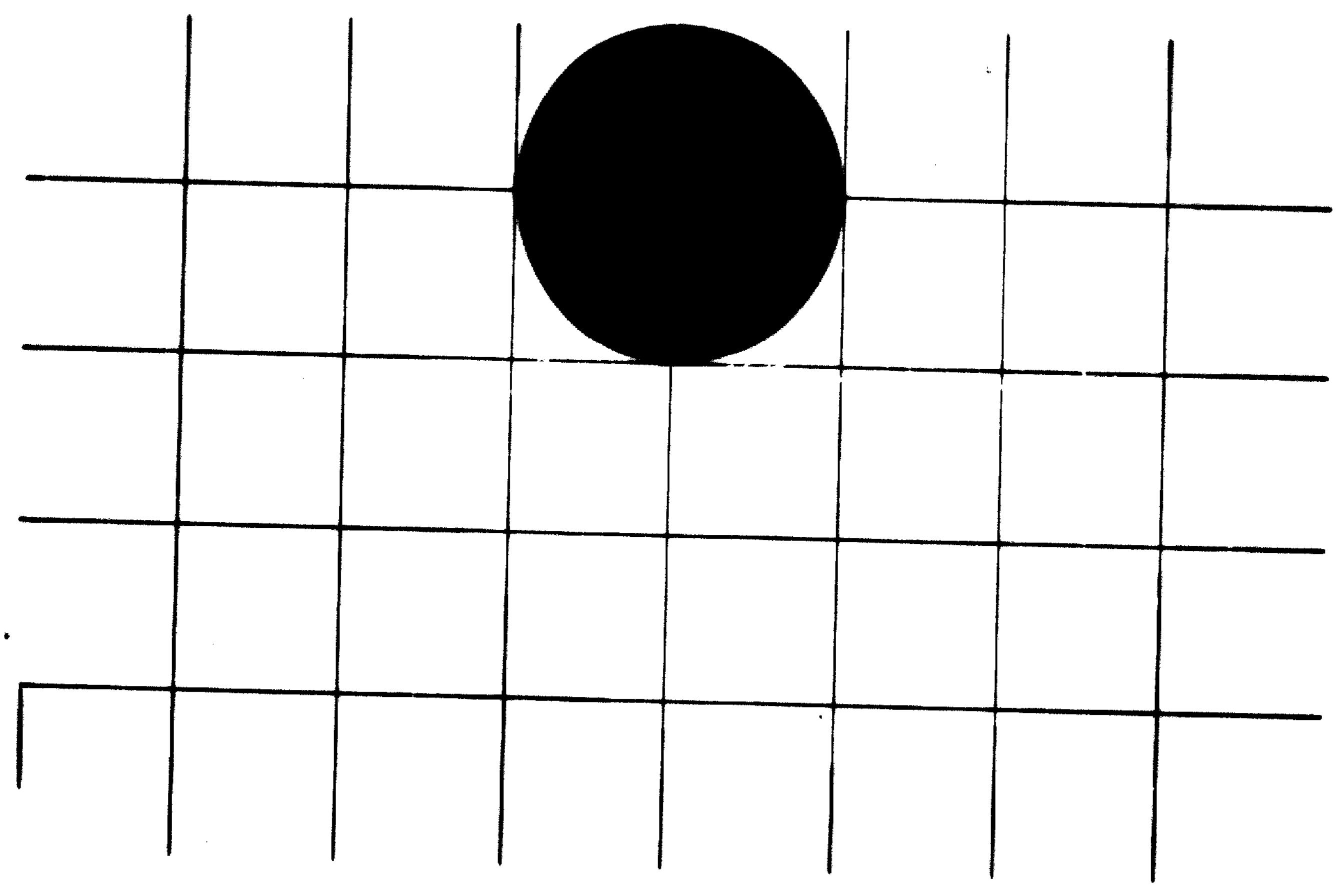
CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

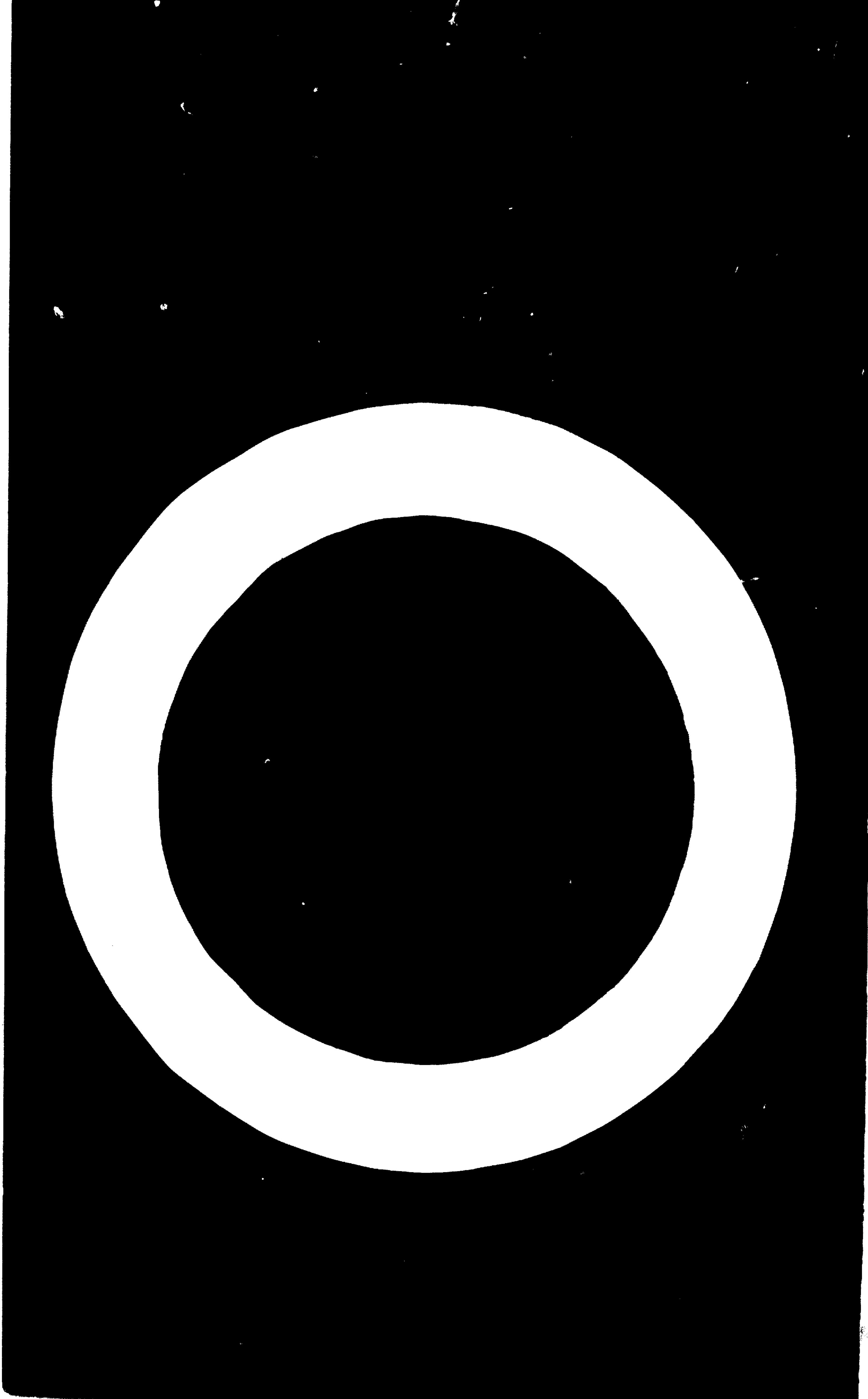
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

THE DEVELOPMENT OF ENGINEERING DESIGN CAPABILITIES IN DEVELOPING COUNTRIES



UNITED NATIONS

(77 p.)



Introduction

1. The Expert Group Meeting on the Development of Design Capabilities in Developing Countries was held in Vienna from 11 to 15 May 1970, under the sponsorship of the United Nations Industrial Development Organization (UNIDO). Its purpose was threefold: *(a)* to discuss the important problems of increasing creative possibilities in engineering design and the production of prototypes; *(b)* to exchange experience in the establishment of design centres in the developing countries; and *(c)* to work out recommendations and guidelines for decision on the future development of design capabilities and the production of prototypes of engineering products, machinery and equipment in developing countries.

2. The meeting was attended by experts from both developing and developed countries and by representatives of international organizations. The participants are listed in annex 1 to the present report.

3. Mr. O. Soskuty, Chief of the Engineering Industries Section of the Industrial Technology Division of UNIDO, served as Director of the meeting. Mr. A. F. Hussein (UAR) was elected as Chairman and Mr. E. F. Gibian (United States) as Vice-Chairman. Mr. N. Krainov (UNIDO) served as Technical Secretary, and Mr. B. T. Turner (UK) as Rapporteur, assisted by the following as members of the Drafting Committee: Mr. A. K. De (India), Mr. N. I. O. Ero (Nigeria) and Mr. R. Orovic (UNIDO). The Chairman and Vice-Chairman served on the Drafting Committee *ex officio.*

I THE IMPORTANCE OF THE DEVELOPMENT OF DESIGN CAPABILITIES

4. Engineering and industrial design[1] are indispensable for creating, promoting and maintaining industry in any country. Without viable designs industry will not flourish in a developed country and will never become established in a developing one. Design is the link between science and technology; it seeks to transform knowledge and ideas into economic goods.

5. The nature of the design process is such that it is set in motion either by the conscious identification of a need by a customer, the proposal of an engineer or scientist for the application of a new scientific advance, or the recognition by an engineer or businessman of a requirement for the creation of a new product.

6. The design process has three basic phases. The first involves the creative thinking and analytical effort of visualizing the final product. There follows the conversion of the data available into the proposed design. Finally, in the communication phase, the design intent and its solutions are transmitted to those who will execute the project. New ideas, new data and information are continually being created during this process.

7. Virtually every engineering design cycle involves repeated attempts at a solution through trial and error. Design problems are often ambiguous and open-ended. Figure 1, which gives a diagram of the design process, indicates that the designer's first task is to delineate the project in as specific and quantitative a fashion

---

[1] By engineering and industrial design, the following definitions are understood:

Engineering design is a creative activity concerned with the origination or modification of an industrial article, including the accompanying research, development and testing, resulting in specifications, working drawings, pilot models and prototypes, and in data and instructions to facilitate manufacture. In the end, the design must be acceptable to the consumer and may need to be modified from time to time to satisfy current market demands.

Industrial design is also a creative activity, the aim of which is to determine the form of objects produced by industry. "Form" in this sense concerns not merely external features but principally those structures and functional relationships that convert a system or product into a coherent unity.

The present report uses the word "design" to embrace both the above definitions. A fuller discussion of engineering and industrial design is presented in the following chapter.

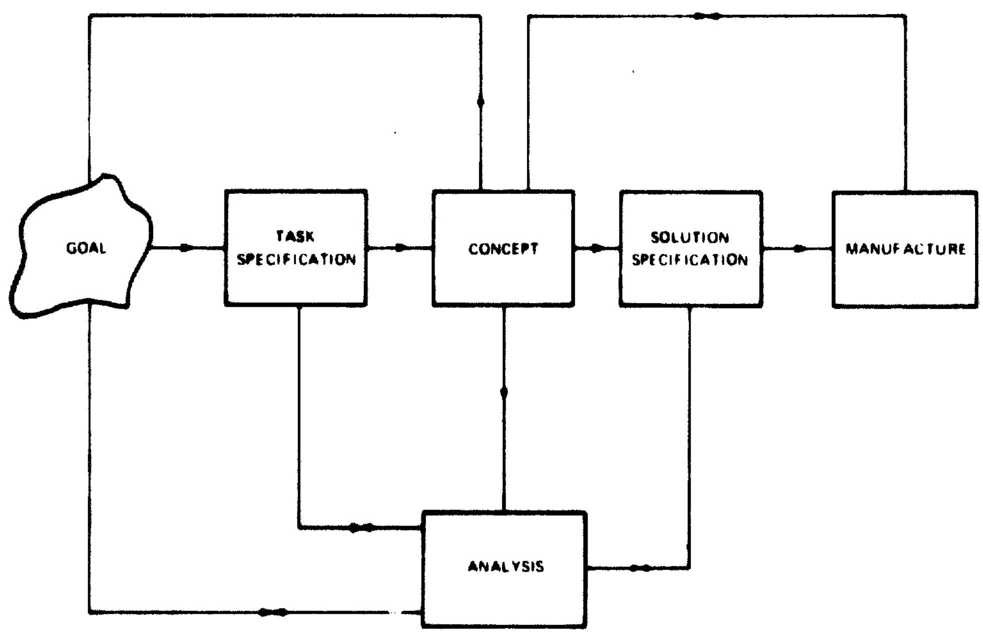


Figure 1. The design process

as possible. The specifications serve as guidelines for the activity to follow and as criteria for judging the degree of success that has been achieved when the final design is completed.

8. The designer must then outline a concept, usually in the form of a rough configuration. This is the creative phase. The concept must then be evaluated analytically. The process described does not generally occur in a simple, sequential fashion. Manufacturing considerations overlap the conceptual and analytical stages. And at each subsequent step it is possible that prior decisions may have to be changed and a new sequence initiated. Having executed the design for a given concept or configuration, the designer may choose a different concept and repeat the process. In any case, the over-all process is highly repetitive, involving loops within loops, and the designer's most important tasks are to establish the sequences of loops and to control the process of repetition.

9. Inevitably, in the early stages of the industrialization of a developing country it must rely principally on the developed countries for the means of production. However, once plants for manufacture have been established, the developing country will feel the need to introduce new ideas or to modify existing equipment to suit the natural inclinations, habits, customs and circumstances of its people. At this stage the developing country requires experienced designers. If such personnel have not been identified, trained and developed, further help must be sought from the developed countries.

10. It is vital that the development and training of designers be simultaneous with the inauguration of an industry. Competent design work is slow and often costly; much planning and care is necessary to develop indigenous designers and design teams and time is required to train them. Future key indigenous designers must begin by gaining an insight into the design process, working backwards from existing products supplied by developed countries.

The present position in the developing countries

11. The countries of Africa, Asia and Latin America that have followed the road of independent development are striving to organize and expand their national industries, establishing enterprises by their own efforts and with the assistance of other countries.

12. The material and technical base for the state-owned sector of these countries cannot be developed successfully without training native workers in the skills needed for the creation of their own national mechanical-engineering, machine-tool and other industries that are vital to the development of the national economies.

13. Some of the countries of Asia and the Middle East (Afghanistan, Burma, the Khmer Republic, India, Iran, Iraq, the Lebanon, Pakistan, the Philippines and Yemen), despite various difficulties, have increased capital investments for the development of the mechanical-engineering, machine-tool (notably in India), metalworking and oil-extracting industries and metallurgy as well as for the production of agricultural machinery and spare parts and electrical power equipment. Measures have been taken in these countries for the creation of repair shops to keep equipment in good condition as well as for the development of domestic industry. Such measures illustrate the efforts of these countries to obtain economic independence, and, incidentally, they prove a lead into design work.

14. Some countries of Africa (Algeria, Cameroon, Ghana, Guinea, the Ivory Coast, Mali, Morocco, the Sudan, the United Arab Republic) have started to develop their own machine-tool industries, and in the United Arab Republic the production of metal tubes, railway rolling stock, automobiles, tractors, various types of agricultural machinery and consumer goods (such as bicycles, radio sets and plastic articles) has been attempted.

15. These countries are thus creating the foundations for modern economies, but further development and improvement are required. Profound contrasts exist between the abundance of natural resources and the extreme backwardness of productive forces in much of Africa.

16. Of total world mineral resources, African countries mine 90 per cent of the diamonds marketed, 81 per cent of the cobalt, 62 per cent of the platinum, 70 per cent of the gold, 50 per cent of the magnesium and chromium, 36 per cent of the manganese and 32 per cent of the copper. Africa produces 66 per cent of the world production of cocoa, 66 per cent of the sisal, 95 per cent of ground nuts, and 25 per cent of the coffee beans and cotton of the world. There are rich reserves of coal, oil and iron ore. At the same time, Africa contributes only 2 per cent of the total industrial output of the world's market economies.

17. Some of the countries of Latin America (Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Mexico, Peru, Uruguay and Venezuela) have developed ferrous metal and machine-tool industries, electric power and heavy engineering industries, lifting, transport and road-building machinery, non-ferrous metal, motor-car and tractor industries and other branches of engineering production. Although the countries of Latin America are now more advanced industrially than most Asian and

African countries, their further industrialization proceeds slowly. What is required is the rapid development of national mechanical-engineering, metalworking and industrial branches.

18. Industrialization is the key factor in the economic development of the developing countries. The United Nations considers it most important for these countries to develop metalworking industries and, in particular, to establish national branches of machine-building and tool production and to manufacture general-purpose machinery, woodworking and other equipment necessary to their economies. It is also of great importance for the developing countries to participate in foreign trade.

19. The countries of Africa, Asia and Latin America must at the same time solve the problem of producing spare parts for repairing and maintaining the machines and equipment employed in the various industrial branches.

20. The branches of machine-tool and metalworking industries to be created will require the further specialization of production, extending into the manufacture of universal tools and fasteners (bolts, nuts, screws and the like), and this output will in turn make it necessary to produce metal castings and forgings, as well as to assure the co-operation of the separate branches and encourage an exchange of information among them on economic and technical problems.

21. Without access to the modern scientific and technical achievements of the developed countries, the developing countries would be unable to accelerate their industrialization. And this would widen further the economic gap between the developed and the developing countries.

22. The problem of transferring technology to the developing countries is therefore of great immediate importance. The developing countries must be able to make flexible use of the technology acquired, to adapt it to local conditions or to develop it to meet their present and future needs.

23. The solution to the problem of transferring technology to these countries can be arrived at not only through understanding the reasons for the existing lack of technological information or means to purchase it, but also by analysing the possibilities for creating a scientific and technological infrastructure that would enable them to mobilize their resources and develop their own production. Such an infrastructure would also permit the introduction of production methods based on modern scientific and technical achievements as well as the means for carrying out the necessary scientific research. For these reasons design is vital, and the training of suitable indigenous designers is imperative.

Types of design in industry

24. The development of design capacities should be undertaken by a central enterprise (or enterprises) and should proceed slowly and carefully at first, owing to the complex nature of the field and the difficulty of building up a competent design staff. Expansion could be effected later, according to priorities.

25. There are two basic types of design, namely, industrial design and general engineering design, and they should be given equal attention. They should be developed simultaneously, and institutes or places for teaching both, either independently or together, should be established.

The total design requirement

26. Design is an essential factor for a balanced and lasting industry. The problem of developing design is not an easy one, and much planning is required if it is to succeed.

27. Before attempting to develop design, the procedure for training indigenous designers and design teams must be well studied, and no effort should be spared to foster an atmosphere that will stimulate and encourage natural creative instincts. Design development, the training of designers and the build-up of the design staff must begin no later than the start of industry.

28. Design work for any developing country must relate to its specific needs. The interaction between engineering design and society is increasing. Optimal engineering design should, more than ever, take into account sociological, economic and political implications as well as purely engineering factors. Equipment designed in a developed country is often unsuitable for a developing country because of the differences in customs and culture. Unfortunately, the latest technology is often supplied, resulting in too great a technological jump and possible disturbances to the environmental balance. It is therefore imperative for all developing countries to seek to establish their own corps of designers and to train and develop them to meet their own needs. The present status of design capabilities in some of the developing areas of the world is presented in annex 4 to the present report.

The effect of design on industry

29. It is clear that industrial design can have a marked effect on the utilization of a country's resources of both raw materials and manpower. It can also affect profoundly the quality and scale of whatever production may be undertaken. Good design can contribute another economic advantage by making possible the utilization of the excess machine capacity that is frequently found in developing countries while poorly co-ordinated industrialization results in the duplication of machine tools in newly constructed plants.

30. Good design should make it possible to produce the articles actually required by the people, thus giving domestic industry more staying power in the local market, with a favourable effect on the general economy. It could also solve the chronic problem of shortages of the special tools most needed for production.

31. Design can solve the problem of how to provide the spare parts needed for all services in the country public, agricultural and industrial and can minimize the pressure on the limited amount of foreign exchange available during these first stages of development.

32. Design can also help to point the way for the private entrepreneur, the creative thinker and small-scale industries, with the aid of showrooms for new designs and the provision of protection by patents to protect new designs. Handicrafts and village industries can be sustained and improved by new designs. It should also be recognized that the design of equipment of pilot plants needed to study the characteristics of indigenous raw materials is an important step towards improving the economy of a country.

II IDENTIFICATION OF NEEDS AND FINANCING

33. Before any design work is begun, it is important to ascertain the real needs of the country in order to avoid wasted effort and to ensure that priorities are properly ordered. In-depth surveys conducted by competent market research people are therefore of prime importance. Developing countries will have to rely initially on outside help for this work.

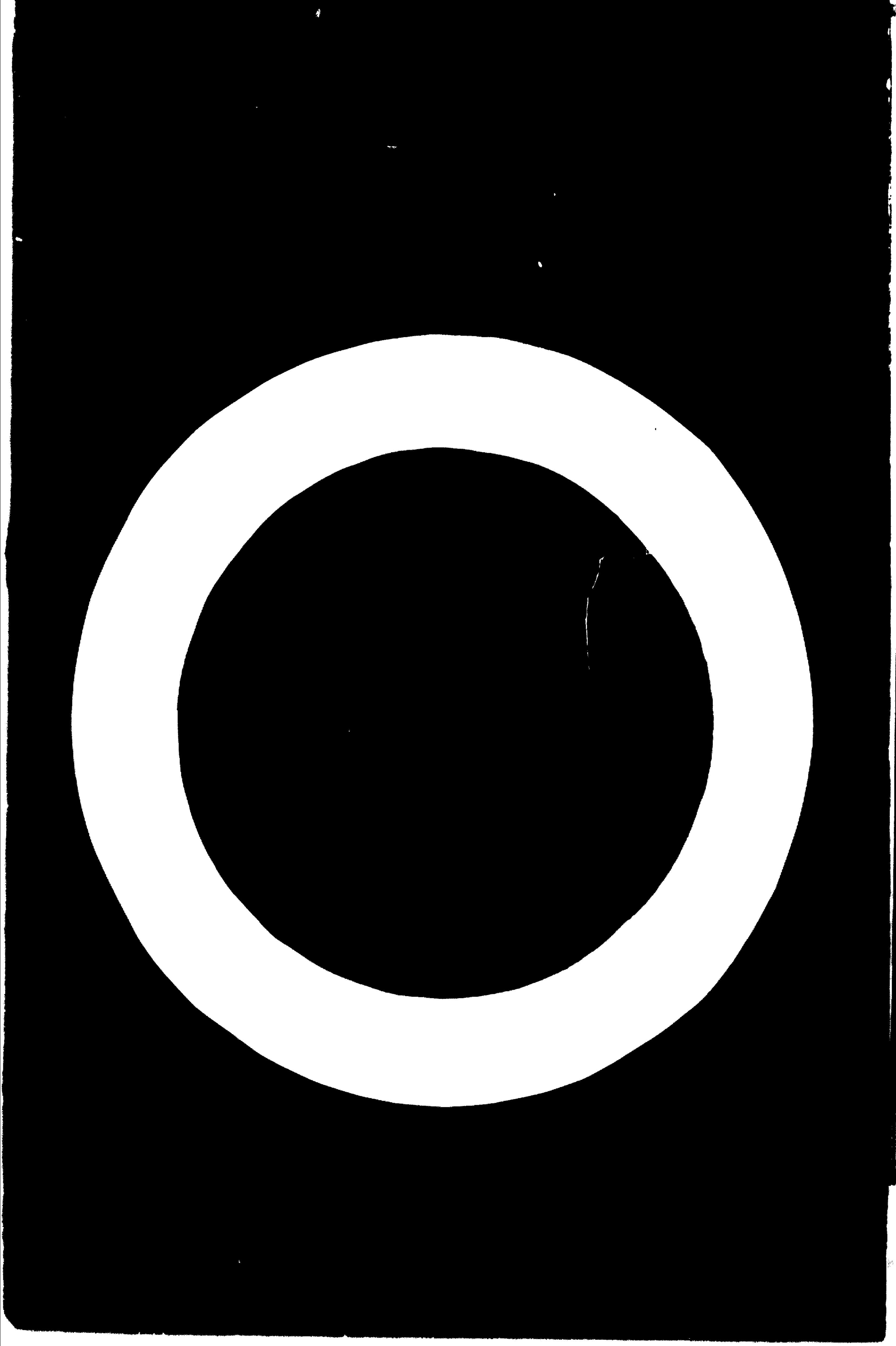
Identification of areas requiring design

34. In order to establish a system of priorities for design requirements, it is essential to carry out a complete survey of all possible projects, systems and products. Governmental priorities must be known so that the survey can begin with an over-all master plan based on national needs and work downward from this to an analysis of markets for individual products. In this task UNIDO field advisers could assist the corresponding governments or even initiate such action themselves. Feasibility studies are often needed to ascertain the capital or consumer goods required. In some instances, a government may even wish to create a demand for a certain product or project that calls for a design. Moreover, although a developing country may have statistical data on imports, consumption etc., it might well need expert assistance in processing these data, which UNIDO could provide.

35. Engineering products do not usually go into production before an exhaustive investigation has been made covering market analysis, model design, model testing and other related subjects. In a limited sense, engineering products consist mainly of machine elements, such as clutches, couplings, bearings, control devices, drives, linkages, springs and seals. In a broader sense, however, an engineering product may be defined as a manufactured economic good; it is usually the result of a commercial activity. In what follows, this broader definition of engineering products is taken as the basis of the discussion.

Market analysis

36. The starting point for every modern engineering development and design is the analysis of the market for which the product in question is intended. Without it, the management of a factory would not know what new designs were needed and expected by the prospective customers, and it would thus be unable to give the engineering department general instructions and guidelines to follow.



37. A new design is usually a modification of an existing model, requiring the redesign of industrial machinery, equipment and consumer goods, except where an entirely new product is to be developed. The latter cases are rare, however, and are often the result of new inventions, although inventions may also occur along with the modifications and improvements of existing engineering products.

38. For example, the new models of automobiles that appear on the market yearly in the developed countries are normally modifications of the previous year's models, perhaps differing in styling only or in such improvements as power steering, automatic window opening or new safety devices. Similarly, in the field of industrial machinery, machine tools are being constantly improved.

39. Two types of market analysis can be differentiated: general market analysis, which usually concerns matters of an economic nature such as supply and demand; and special market analysis, which covers the engineering aspects in conjunction with the financial considerations.

40. General market analysis deals with such problems as predicting the financial gain that conld result from a design change. It predicts possible new competition, and assesses the new sales and advertising effort required and other matters important to the progress of the enterprise.

41. About 75 per cent of the industry of the United States regularly uses general market analyses, and another 12 per cent employs this method occasionally. Questionnaires are mailed to a representative cross-section of the prospective customers, or a special agency is employed to interview a variety of consumers in various parts of the country. If export of the new design is anticipated, the market analysis is extended to the prospective foreign markets also. The results of general market analysis are usually reliable, provided that statistical methods are used in the evaluation of the answers received.

Encouragement of local design capabilities

42. At the level of national policy, perhaps the most effective way to encourage local design capability is through the control of imports. If impartially and effectively applied, this policy has the effect of obliging or encouraging producers to use locally made parts, whose design must often be modified. This modification could and should be assumed by local product designers, and would have the indirect advantage of enhancing their capabilities. A similar situation exists as regards awards and concessions for exports where the exporter must meet international standards and higher levels of quality.

43. At the institutional level, the desired effect can be achieved in various ways. For example, publications and meetings can be important means of disseminating general information and technical know-how. Professional institutions should be encouraged to assist in the establishment of acceptable standards for the performance, safety and testing of materials and products. Common testing facilities can be established in various institutions.

44. At the enterprise level, the creation and effective use of independent commercial consulting services is perhaps potentially the most fruitful field for improving product design. Development can also be accelerated through manufacturing under licence, and this approach should not be discouraged at the policy or enterprise levels. Equally important to all industry is the establishment of local design capabilities, either through central design centres or within the enterprise itself. It should be noted that these approaches are not mutually exclusive.

45. UNIDO is already active in promoting all of these strategies in many ways, including export promotion, the dissemination of technical know-how, the establishment of standards and quality control, the provision of consulting services, and assistance in licensing and in the establishment of design centres. Examples of these activities are given in annex 4 to the present report.

Classification of design work

46. The spectrum of design in product engineering is broad, varying from small consumer items to large capital projects. All require the same basic design process, but the order of magnitude differs widely.

47. Both engineering and industrial design are required. The two are parts of a whole; they can be differentiated only by the nature of the work that they involve. By way of illustration, the architect and civil or structural engineer collaborate in the field of construction work, while the industrial designer and mechanical or electrical designer have the same relationship in the manufacturing and processing industries.

48. The work of the two types of designers is complementary and must be united in the design of the product or system throughout the entire life of the project. It is useless to call in an industrial designer to make an engineering design look well and handle and operate well at the end of the design process; he must work in harmony with the design team from the outset.

49. Further divisions of design may be identified as project, systems and product design.[2] Product design refers here to the design of a single product that may form a component of a system. Essentially, it may be defined as a piece of equipment with a single function. Systems design, on the other hand, relates to a collection of products so arranged that they contribute to the required over-all function. The system so formed may be designated as "closed" if it adjusts by feedback of its output, which is then compared with the input and automatically corrected. If, however, the input is simply transformed into output with no attempt to correct errors, the system is designated as "open".

---

[2] *Project design* takes into account the entire plant consisting of all the various assemblies, sub-assemblies and units required for a particular process, and details the complete specification of the equipment, including the cost analysis.

Systems design covers units such as electrical, hydraulic, pneumatic and mechanical control units connecting the various assemblies so that the entire plant functions as an integral unit according to the desired programme requirement.

Product (equipment) design refers to the engineering part of the design of individual components, machines or devices.

50. In a sense, all products form parts of systems; even a domestic appliance must fit into an existing energy supply. Hence, the designer must understand the essential nature of the input to his new creation, what output he must obtain and how this creation will fit into an existing plant configuration. Strictly speaking, however, systems engineering is concerned with large units that have a multiplicity of inputs and outputs and many sub-systems.

51. The classification of engineering products required by any developing country will depend upon its state of development and hence upon its essential needs and the support it can receive from other countries. There will be certain requirements for process industry work, but, in addition, there will be basic requirements for the metalworking industries. For the latter, a classification was produced for UNIDO at a conference held in Moscow in 1966.[3]

52. The metalworking industries produce goods for the following sectors of the engineering industry as classified in the International Standard Industrial Classification (ISIC), Rev. 2:

Manufacture of machinery, except electrical (ISIC 382);

Manufacture of electrical machinery (ISIC 383);

Manufacture of fabricated metal products, except machinery and equipment (ISIC 381);

Manufacture of transport equipment (ISIC 384);

Manufacture of professional, scientific measuring and controlling instruments (ISIC 385).

53. The corresponding classes of the Standard International Trade Classification (SITC) are:

Machinery, other than electric (SITC 71);

Electrical machinery, apparatus and appliances (SITC 72);

Manufacture of metal, N.E.S. (SITC 69);

Transport equipment (SITC 73);

Professional, scientific and controlling instruments; photographic and optical goods, watches and clocks (SITC 86).

54. The function of product design activities is to provide or adapt products to meet the particular requirements of a market associated with a specific area or peoples. The successful application of these activities has an important over-all influence on industrial development. Perhaps the most important aspect is the direct question of suitability of products. A specific example is the power tiller specially designed for paddy rice cultivation in tropical areas, since the conventional tractor ploughs commonly used for dry cultivation of rice are practically useless in wet cultivation.

---

[3] *Report of the Interregional Symposium on Metalworking Industries in Developing Countries*, Moscow, 1966, United Nations publication, Sales No.: E.68.II.B.9.

55. Improvement in reliability is another aspect of design activity. The redesign of suspension systems of road vehicles for rougher roads is a simple example of the kind of improvements that are necessary. While products should be designed for local climatic conditions, it is surprising how often this obvious requirement is not fully met. Considerable work has already been done on adapting equipment for the tropics, and the stage has been reached where most equipment is designed for tropical use as a routine matter. However, the adequacy of cooling and ventilation of equipment and vehicles still needs attention.

56. The less tangible, but nevertheless important, needs of the market in styling, in higher comfort factors and in acceptable standards of quality play a significant part in product design.

57. One application of product (and plant) design, which is often overlooked, is the proper presentation of instruction manuals and the marking of parts for identification. This problem involves language and reasonable degrees of literacy. In addition, further work is necessary in the design of both equipment and maintenance manuals that are oriented towards the simplification of fault diagnosis. These considerations are related to the maintainability of both plant and product.

58. Quite apart from the design or adaptation of designs for local markets, there is the need to adapt a local design for the export market. An example is electrical equipment, which may have to be redesigned to meet the differing safety and other wiring standards of several countries.

Criteria for product design in developing countries

59. Certain conditions prevail in most developing countries that affect the design of products made in them. Among the most important of these is the relatively small quantities involved in series production. An example is the use of wood rather than plastic for radio and television cabinets, where the initial cost of plastic injection moulding equipment is extremely high. An efficient local manufacturer will naturally look to the export market if the domestic market is too small.

60. The need to exploit local raw materials and components is frequently a factor to be considered in product design, and one often made necessary by import controls. For these reasons, adaptation of designs should be a continuous process aimed at supporting allied industries.

61. One important impediment to local design of products is the inadequacy of local standards. This consideration is particularly important where equipment must be integrated into an existing system, or where the product is destined for export. Internationally accepted standards, such as those of the International Electrotechnical Commission (IEC), are important, but thus far only to a limited extent. Also, even where such standards exist, it is sometimes not possible to check products against them, owing to a lack of testing facilities.

62. Product design leading to improved reliability and ease of maintenance is receiving attention and is becoming increasingly important in most developed countries. For example, improvement in component reliability is being achieved through studies of product failures. The need to improve product reliability in developed countries arises from the high cost of the labour needed to undertake repairs. This need is equally important in developing countries but arises for the opposite reason; namely, the lack of skilled labour, at any price, to do this work. The degree of reliability required in the products of both developed and developing countries can therefore be assumed to be about the same. In practice, both of these reasons have led to designs incorporating sub-assemblies and simple means of fault identification.

Potential for improved product design

63. There is a need to improve product design so that the product is better suited to the customer's local climatic and other conditions, and has a longer life, with improved styling, comfort and quality, easier maintenance, and an export potential. Clearly, this is a continuous need, and the strategies proposed later in this report are aimed more at promoting and creating design capabilities than at providing solutions to specific design problems.

64. It is difficult to establish a general level of demand for new or improved products to be designed locally. Perhaps the best approach is for governments to set realistic targets for levels of raw materials and other content available locally in goods for the home market and for export. This approach would, among other advantages, have the effect of setting the higher levels of achievement necessary in the design field and, in turn, of defining the needs in terms of design requirements.

The need to establish sectoral design centres

65. Once market surveys have been conducted, their findings analysed, and the range of goods to be produced has been decided upon, an institute or centre to perform the needed design functions should be established. Such a design centre could be set up as an independent body or as a part of an existing organization or industrial enterprise.

66. The value of such centres lies in the importance of best utilizing the inevitably limited number of designers who will be available initially. It would be pointless for them to be scattered around among various industries, since designing is best done by teams. The design centres could help to form such teams and give them an opportunity to develop their capabilities. A design centre for automotive products could serve many related plants, such as those that produce bearings, seals, brakes, clutches, springs and the like, and that have been carefully situated near the automotive industry.

67. Similarly, a design centre for agricultural machinery would be essential. Here the first step might be for designers to consider the use of indigenous materials, for example, and then to proceed to the more difficult task of designing machines better

suited to the local terrain and conditions. Likewise, appropriate design centres would be necessary for the mining and petrochemical industries that may exist in a developing country. In such cases design would be concentrated on pumps, valves, pressure vessels, mechanical excavators and the like.

Setting up a new design centre

68. In setting up a new design centre, it is important that the appropriate steps be taken in the proper order. The needs must first be identified and defined, and the plans and agreements must be well formulated. A group undertaking such a project must truly "see the end from the beginning", not only in visualizing the end result, but also in properly anticipating the problems that will arise, so that measures to counter tham can be taken quickly. The following, then, are the steps to be taken.

The preliminary survey

69. The purposes of this first survey are:

To determine the need and justification for such a centre;

To determine the assistance required and the feasibility of providing it;

To explore the types of sponsorship that might be available;

To evolve a preliminary plan of operation.

70. The people who are to conduct the survey should have the following qualifications:

A knowledge of the country;

Experience with its manufacturers;

Familiarity with the industry in question and its problems;

Knowledge of the types of governmental and international assistance available.

71. These people must be selected with great care, as their conclusions and reports will strongly influence the events that follow.

72. The information to be incorporated into the report should include:

The type of product to be considered;

The nature of the assistance that is recommended;

The suggested geographical location of the design centre;

The size and capacity of the design centre;

Recommendations as to sponsorship of the design centre.

73. When the above facts have been assembled and the report prepared, it should be reviewed with meticulous care by the proposed administrating agencies, and a firm decision should be made as to whether the plan should be put into operation.

The plan of operation

74. As its name implies, the plan of operation is a basic outline of the project from start to completion and should serve as a guide for the entire operation. It should define the purpose of the project and actually be a charter of the scope of its operation. It also serves as a contract or agreement in the event that it is co-sponsored by two parties, such as the government of the developing country and an international agency such as UNDP, outlining the obligations of each party.

75. The ideal plan of operation should delineate the work plan and provide a budget summary, including a list of the equipment and a breakdown of the expense contributions of each party. Enough detail of the organization must be included to establish salaries, duration of service and the like.

76. A tentative schèdule of operations should be included; the timing and efficiency of the project can be measured against this. This document should be signed by the two parties as a binding agreement, and copies should be placed in the hands of the responsible directors, managers, advisers and experts to serve them as a working guide for the conduct of the centre.

Financing the design facility

77. It cannot be expected that such a design centre will be self supporting; certainly, in its initial stages, there will be no source of income other than the support of its sponsors. These sponsors will normally be the following:

The government of the developing country

78. Since public finds are not plentiful in most developing countries, it is unlikely that the government will assume complete financial responsibility for a design centre. In event of the usual dual sponsorship, the government normally provides personnel, services and equipment available locally. Its contribution usually includes:

Salaries of director, indigenous officers and other personnel;

Local salaries of fellowship trainees;

Land and housing for the centre;

Equipment and supplies produced within the country;

Transportation and handling of imports.

International agency

79. The contributions of such agencies as UNIDO and the UNDP Special Fund are usually comparable to that of the government, depending somewhat on the circumstances. Typical of these contributions are:

Salaries of the project manager or chief adviser, and the professional staff of foreign experts.

Machine tools and mechanical equipment not available locally;

Laboratory and electrical equipment of a precision not available locally;

Miscellaneous technical aids, such as:

A library of books, publications, and technical information;
Audio and audio-visual aids;
Calculators, computers etc.

Private industry

80. Although not usually involved in the setting up of design centres, private industry can provide assistance in various ways. This type of assistance, by its very nature (so as to avoid competitive situations) must be in the form of joint ventures and can operate most effectively through manufacturers' associations, supported by the contributions or dues of manufacturer members. They can provide dissemination of technical knowledge, assistance in standardization activities and common facilities for materials testing.

Fees for participants

81. When a new design centre has increased in sophistication and expanded its service to the manufacturing industry, it can then receive some remuneration from those who make use of it. This income would be in the form of fees for consulting services, for the use of designs and drawings provided by the centre and for tool designing.

82. While this source of revenue may not be large, it has other corollary advantages. For example, it tends to discourage some irrelevant and superficial consultations. The participant manufacturer, by paying proportionately for services rendered, will limit his requests to the most necessary types of assistance.

Approval of financial authorizations

83. Provisions for prior approvals or the expediting of specific approvals should form a part of the original agreement. However, even when such agreements have been incorporated into the plan of operation, individual approvals for specific expenditures often involve lengthy delays and require considerable follow-up.

Type of organization

84. Considerable thought must be given to devising an organizational structure that will provide the greatest co-operation among the participants and the most efficient operation of the centre. In view of the usual dual (international and national) nature of sponsorship and operation, the interests of both, as well as those of other organizations, should be represented in some of the following ways:

An advisory committee, consisting of:

Representative(s) from the relevant government ministry;
Representative(s) from the co-operating international agency;
The project manager or chief adviser;
The director;
Industry representative from local or state government;
An officer of the manufacturers' association;

Formation of a corporation or society so as to permit a certain degree of autonomy in providing authorizations and approvals.

The project manager or chief adviser, who would be responsible to the international executing agency and would provide the initial direction and guidance.

The director, appointed by the government, who would be responsible for indigenous operations, facilities, maintenance etc.

The administrative officer, who would be responsible to the director for handling such administrative matters as accounting, records, stores, purchasing and payroll.

The professional expert staff, who would be directly responsible to the project manager and would consist of foreign experts for each of the major fields covered by the project.

The counterpart professional staff consisting of nationals with some training and experience relevant to the projects; they would work with the foreign experts but be responsible to the director.

The management staff, which would include the local officers and managers who work under the supervision of the director and administrative officer to conduct the business and the physical operations of the centre.

Selecting the site for the design centre

85. The following major considerations should determine the location of the project site:

Population centres and transportation;

Concentration of the industries involved;

Availability of land and or buildings.

86. For the most effective operation, the design centre must be readily accessible and be near a source of skilled or semi-skilled manpower. It should also be located as centrally as possible with respect to the major groups of industries that it will serve.

87. To keep initial costs as low as possible, the availability of suitable unused buildings or of undeveloped land, possibly owned by the government, should be given careful consideration. Building costs are high, but the construction of new buildings of the most suitable type is normally preferable to the adaptation of existing buildings not suited to the project. However, rather than delay a new project for the erection of new buildings, temporary housing should be considered. Quarters could thus be provided for the responsible personnel, who could plan more effectively for the permanent facility.

Selection of personnel

88. For the foreign professional expert staff, it is necessary to select people who are, by both training and experience, capable of performing the functions of the design centre. Formal education is only one criterion; even supervisory experience may not be of a kind to meet the needs of the centre. The expert must be all that the

name implies, and there is no substitute for personal experience and involvement in the kind of work to be performed. Also, since the expert may have had only limited access to technical or design information or to the more sophisticated types of equipment, resourcefulness is an important quality in experts selected for such a project in a developing country. The primary sources of recruitment of such experts are: industry in the more developed countries, development or research laboratories, and universities and other educational institutions.

89. The locally recruited counterpart staff must also be selected carefully. While manpower is usually plentiful in a developing country, experienced manpower is usually scarce. The exigencies imposed by time and cost dictate the use of the most experienced personnel available. As with the experts, it is important to select as their counterparts persons with suitable educational qualifications, with some experience in the same or related fields, and with native skills, who with minimal training can perform the necessary task or supervision. It must be kept in mind constantly that these men will eventually operate the design centre by themselves after the terms of the foreign experts have expired.

Cost of design and sources of finance

90. The ultimate aim should be for all designs produced to be viable and, wherever possible, to obtain a considerable cost/benefit advantage. However, in the early stages of a country's development it is difficult to achieve this, and it is thus often necessary to subsidize design centres. UNIDO might be able to help, possibly with direct financial grants of various kinds.

91. As the design centres gain experience, it should be possible for design budgets to be developed. Design target costs could be set up, and designers would be expected to operate within them. If the designers exceeded their budgeted allowance, a special case would have to be made in order to sanction additional expenditures to complete the design work.

THE DEVELOPMENT OF ENGINEERING DESIGN CAPABILITIES IN DEVELOPING COUNTRIES

III DESIGN PROBLEMS

92. Initially, it might seem desirable to deal with simple designs that would yield quick benefits to the whole population of the country concerned. Furthermore, it is important to try to use indigenous resources wherever possible. Some already existing handicraft industries could be greatly helped if they were provided with suitable portable tools that would permit production to be rapidly increased. New design solutions for such cottage industries could give them fresh impetus and possibly attract additional foreign customers.

93. In the earlier stages of industrial development, designs are required primarily for the manufacture of equipment, components and spare parts for the existing industries of a country. In many cases it is necessary to adapt foreign designs to meet specific domestic requirements. Over the long term, however, project and systems designs are required. Basic processes must be bought, and indigenous design confined in the first instance to simple equipment. With the passage of time and the development of industry, the role of the indigenous designer becomes increasingly important.

94. It should be kept in mind that design and development of products is a long-term task. Design work is costly, requiring time, money and able, experienced designers whose training requires a minimum of five years.

Adaptive designs for domestic needs

95. It should be possible to adapt the existing designs of developed countries to local needs by taking out manufacturing licences. Where this is done, it is important to recognize that the licence and the attendant documentation might not supply all the required know-how. Indigenous designers might need to work closely with the licenser, visiting his plant in order to understand its operation. Clear and careful documentation is necessary, and the organization and management of design adaptation should be efficient. Where the level of technology in the licensing country is appreciably higher than in the country that buys the licence, it might be necessary to modify the design and, in many cases, the production processes, possibly lowering performance but none the less allowing the introduction of manufacturing locally. Problems involved in the changeover could be overcome with the help of the licensers. It might also be possible, because of cheaper labour, to produce economically in spite of low productivity. The testing of the modified design must also be carefully controlled, and prototypes must be tested environmentally.

Other requirements

96. The developing country should establish its own patent agency, if it does not yet have one, not only to protect original design work, both domestic and imported, but also to provide local industry with information on the latest technological developments. The importance of keeping up to date cannot be overstressed, since technological changes can and often do modify design practice. This is especially true of new manufacturing processes. (Some current examples are laser cutting and welding and plasma spraying.)

97. Designers live on information; their appetites for new technical data and related facts are insatiable. Any developing country should set up a library and technical information centre to cope with the enormous and ever-increasing amount of published data. Subscriptions to all pertinent technical publications should be acquired, and it would be helpful if some sort of regular publication, listing current accessions etc. were available. Wherever possible, it would be particularly advantageous to have a unified classification system so that the collation and retrieval of information could be expedited and, in the years ahead, could be computerized, if need be. Initially, such an information centre might be located at the design centre; later regional information bases will be required for local industries. After a time, it might be well for particular regions to specialize in information of certain kinds.

98. The need for systematic recording and analysis of product defects must be given high priority. The nature of the defects and failures indicate where design should be up-dated and improved. It is thus essential for countries to set up simple and effective defect-reporting systems as early as possible in their industrialization.

Creative designing to satisfy domestic needs

99. The situation becomes more complex when the stage is reached at which the copying of foreign products no longer suffices and new designs must be created. Even management must then participate rather than confining itself to administration. It must take great pains to ensure that all factors receive due consideration, and that the optimal design solution is achieved in a specific set of circumstances. Since time is usually a critical element at this stage, the use of computers with graphic inputs might be helpful. New systematic approaches should probably be adopted, and the staff of designers should be well versed in the latest methodologies.

Standardization and technology in design

100. A standard may be considered as a single solution to a recurrent problem. Like specifications and codes of practice, standards are among the primary tools of the designer. The design standards adopted by the developing countries must be expressed in metric units, since standardization makes possible the interchangeability that is vital in all modern design work.

101. Standardization can be approached on three different levels:

International (International Organization for Standardization, ISO);

National (e.g. British Standards (BS) in the United Kingdom); American Standards Association (ASA) in the United States; Deutsche Industrie Normen (DIN) in the Federal Republic of Germany;

Enterprise (company) standards, which should be developed from the international and national standards.

It is not unusual to find a standardization organization already established in a developing country. If this should be the case, the new design centre should be eager to become part of it.

102. One of the main tasks of the standards section of a new design centre is the careful selection and limitation of the list of standards to those that will be really needed. Such a selection is imperative, since for machine screws alone there are at least 12 material classifications, at least 10 diameters, more than 13 lengths (in each of the above diameters), at least 20 forms of heads, points etc., and various surface-treatment possibilities, in all yielding tens of thousands of different items. Only a minor fraction of 1 per cent of the total number of standardized screws could serve the centre and its associated enterprises adequately. The same principle holds true for materials classification, stock sizes and the like.

103. A further broad field for the standards section is the range of tools to be used by the design centre as well as by the participating enterprises. This matter requires close co-operation with the production department, because even an able tool specialist could hardly cover all of the many different kinds. The production department might request more than 3,000 different tools for its own work; and in this event the standards section should try to reduce this unrealistic number by negotiations with the production department's tool-design, toolroom and production-planning sections. Production cost must be calculated on the basis of what is most economical: the use of the most appropriate tools or tools with slightly higher working times. The second alternative is often preferable, because the purchase, storage and maintenance of tools is more costly than wages in most developing countries. However, this might not be true of tools for use in conjunction with a valuable, highly utilized machine, whose work cannot be done by other machines. Other tasks of the standardization section might include the preparation of production regulations, inspection rules, conditions of supply, and performance manuals. Considerable effort is needed to sift, collate and store all this documentation in a way that permits its easy retrieval. Such an organization ultimately may require mechanized systems or even electronic data processing equipment if rapid and accurate information retrieval is to be achieved.

The role of the computer in modern design

104. Among the technological developments that have affected design the computer has made the most far-reaching impact. As noted at the beginning of the present report, the designer's most important tasks are to establish the loop sequences and to

control the reduplication that takes place during the design process. Any part of these tasks that can be done practically and economically by a computer should be done so. The engineer should expend his energies and talents only on those aspects of the problem that he is best equipped to handle, that is, those involving concept generation, modelling and the establishment of specifications and acceptability criteria. The particular attributes of the computer are speed, memory and reliability; it performs computations and logical decisions at a rate that is difficult to comprehend. It is essential that the computer and the designer serve as partners in the design process; the successful and wide use of computers in engineering design implies a highly interactive man-machine configuration.

105. The flow of information between man and machine must be rapid, and the information must be accessible to both. However, the man is confronted by two major obstacles: the first is the availability of the computer with respect to time and physical location, and the second involves the question of communicating with the machine. Prior to 1957, the engineer had to learn special computer languages in order to communicate with it. Algebraic computer languages such as FORTRAN and ALGOL represented a major step in easing the communication problem. Then came the problem-oriented languages such as STRESS, COCO, and finally PLAN. Although these new languages represent a breakthrough in the process of man-machine configurations, they, too, have shortcomings. While they more nearly match the natural problem-solving orientation of the engineer, they still fall short of a truly natural form.

The impact of graphics

106. The engineer works in graphic as well as in mathematical terms. When he must translate his graphic expression (perhaps a drawing) into a linear stream of letters, numbers and special characters, he is consuming precious time, quite probably making errors that are not always easily detected, and he is not being creative, at least in the design sense. Graphics is the language of design, and if the engineer is to be relieved of the need to recast his thoughts into an unnatural form, graphics must be the primary part of the communication process.

107. The term "computer graphics" is very broad and includes numerous peripheral devices around the computer such as XY plotters, printers and drafting machines. These devices are used to convert computer output into graphic displays and are extremely useful because they yield a pictorial information that is more suitable to an engineer or a designer. However, even in such an environment, the engineer is no less isolated from the computer than he is when a typewriter prints out a solution in alphameric form. With the graphic display screen, a cathode ray tube (CRT) relieves the engineer's and designer's feeling of isolation and improves his productivity. He now sits in front of a CRT and, with the aid of a light pen and keyboards, he is given direct access to all the operating elements of a data-processing system. He is now in an interacting relationship with the computer, which is communicating in his natural language.

108. The major benefit of computer graphics is the possibility it offers of substantial reduction in the time required for the design process. In addition, it can provide more solutions to a design problem than was previously possible, and this in turn

should lead to a better product. It is imperative that developing nations that have limited resources in terms of manpower and that are faced with bridging the technological gap examine this new, revolutionary tool carefully. The authorities of developing countries should be aware of the possibilities offered by computers and make sure that their designers are trained to use them. At present and for the next few years, designers in developing countries must use computers in developed countries, but with the increasing use of data links, this difficulty should be overcome. Nevertheless, the unfamiliarity of designers with computer software will continue to be a problem unless or until there is adequate dissemination of programmes. UNIDO could make an important contribution in this area.

IV PROBLEMS OF PROTOTYPES

109. In order to perfect designs and set them in operation satisfactorily, it is essential to have workshops and testing laboratories in which prototypes can be manufactured and tested. Such workshops and laboratories should be located within the design centres, so that designers can see their ideas being realized and learn about any deficiencies that may occur by positive feedback at first hand. This subject is covered in more detail in chapter VII of the present report.

Organization of production of prototypes

110. The organization of a prototype workshop is really a combination of a factory of general layout, a co-operative purchase society and a technical training institution. In order that the main functions be discharged satisfactorily, there must be a general administrative unit, a production department and, in some cases, some kind of education and training unit.

111. It is essential that the prototype workshops be responsible to the design centre since, if designers do not get a clear feedback from the initial manufacture of their creations, errors and miscalculations might well be carried over into the production stage.

Provision of components

112. In certain cases it might be desirable for the enterprise building a prototype workshop to manufacture its own components according to need. Nevertheless, there will be a need in all probability to obtain certain items of equipment from manufacturers elsewhere in the country. The purchase of these items requires technical skill as well as business acumen, for cost, delivery, quality and reliability must all be acceptable. This observation also applies to parts that must be imported from other countries.

Assistance in the development of new products

113. Assistance in product development can come from many sources, such as domestic and foreign private industry, industrial associations, governments and international organizations, including UNIDO. Designers in developing countries should keep in touch with all of these sources, by correspondence and, when

possible, by personal visits. In this connexion, it is important for a new design centre to make its work and experience known to these institutions so that they may be aware of how they might help or be helped in turn. This kind of mutual support could also be useful in the modernization of existing products or where an enterprise or government sees a new need arising or discovers a useful improvement in a product or process. The centre should also encourage and assist industrial enterprises in its own country to set up their own design facilities.

Introduction of modern technological processes into industrial production

114. It is vital to the economic health of a developing country that, as new processes become known and are developed at design centres, all know-how be immediately made available to its industrial enterprises. Special open days, with demonstrations, seminars and industry get-togethers, must be arranged so that industrialists can witness, at first hand, how a new technological process works, and how it may be applied satisfactorily in the country's industrial environment.

115. Even in developed countries, new processes are often evolved in government research establishments and remain unused for years, owing to the absence of liaison with industry, poor publicity, and lack of insight on the part of the originators into the real problems of industry. The centres should assist industrial enterprises in organizing production.

V PRODUCTION PROBLEMS

116. Adequate inspection of prototype manufacture at all stages must be provided to ensure proper feedback to design of any conformance discrepancies. Similarly, thorough testing must be made of models, mock ups and complete prototypes.

117. When prototypes have been successfully produced and adequately tested, the normal practice then is to pass the design and production instructions over to the manufacturing units assigned to produce these articles in quantity.

Co-operation between design centres and production units

118. Design and production should never be in self-contained departments but should rather form part of the same continuum. Too often, in the industries of some developed countries, an unhealthy dichotomy has evolved, whereby design is separated from the place of manufacture of the hardware. While it is not always possible to have design and manufacture in the same geographical location, it is essential to ensure that there are very good communication links between these two activities to foster co-operation, for no design can be economical unless it takes cognizance of the manufacturing capabilities of the producing concern.

119. The designer cannot work in splendid isolation. It is now an accepted practice for the manufacturing engineer to become involved in a new project even before the design engineer prepares the drawings of a prototype. Correspondingly, the design engineer's responsibility does not end when his new product enters the manufacturing stage. The person who designs a given product is often responsible for following it through the production process. Inevitably, problems arise and changes are required. For example, a change in material could relieve a procurement bottleneck or speed up a manufacturing operation. The design engineer seeks to develop a design best suited to perform its intended function. The manufacturing engineer co-operates with him from the start, to incorporate in the design features that will facilitate the manufacture of the product and perhaps even improve its performance.

Quality control, testing and adjustment

120. Quality control requires particular consideration throughout the process of manufacture. Since adequate sampling checks must be made of incoming materials, components and sub-assemblies, some effective form of goods-inward inspection is required. Also, appropriate quality checks must be applied during manufacture and

assembly. Adequate instrumentation for this purpose must be provided and incorporated into the production process if the best utilization of materials, manpower and equipment is to be achieved. Problems may arise in this work since it often entails instrument design.

121. Final inspection must be thorough to ensure that a minimum of faulty products leaves the factory. Again, facilities for the proper recording of defects and effective salvage should be provided. Similarly, all adjustments and re-settings of the equipment must be documented and kept up to date. Generally speaking, the primary problems in this area concern the acquisition of the most appropriate measuring instruments and gauges and provision for adequate and accurate documentation and its skilful analysis. These activities require training and considerable experience. An important aspect of product testing concerns items of equipment, capital goods and products whose reliability and safety over an extended period must be known.

Problems of metrology

122. The designer should state on his drawings, clearly and completely, in specifications and sets of tolerances, his requirements for the proper operation of the component that he has designed or modified. At the outset of production of such a part, it should be inspected with special care and accuracy, and the results of the test should be written down and filed. (This does not imply, however, that such testing and reporting need not be performed when serial production gets under way.) Ignoring this essential rule can result in many errors, including a completely erroneous evaluation of the component; malfunctions that are attributed to design deficiencies are often merely undetected defects in manufacturing. In an engineering design centre, inspection metrology is of prime importance.

123. Inspection metrology has two aspects. One is basic metrology, whose function is to preserve and certify basic standards of length, flatness, linearity and shape. It may extend further into certifications of weight, pressure, force, and the like. The second is works metrology, whose precision is guaranteed by basic metrology. Its purpose is to measure or test parts and tools submitted by the prototype or pre-production worksh[illegible]. The main function of inspection metrology is to ascertain the dimensional characteristics of engineering products and to ensure that they conform to the design requirements. The requirements readily apply to all types of engineering products such as machine tools and instruments.

VI EDUCATION AND TRAINING FOR DESIGNERS

124. While designers are creative people, creativity is a broad concept that is more easily recognized than defined. H. G. Conway, Chairman of the Council of Engineering Institutions in London, has defined the word as it relates to engineering, as follows.

> "Creativity in an engineer is an ability or aptitude, probably basically innate, which allows him to think of, 'dream-up', visualise or imagine new or unusual solutions to problems. Generally these involve methods of design or construction, but in the broader context include solutions to mathematical or abstract problems."

Selection and development of creative people

125. Creativity does not appear to be linked directly with intelligence, which is measurable to some degree, and there are as yet no valid tests to measure it, although research is proceeding. Also, there is no formula that ensures creative thought. Undoubtedly, much more research is needed to understand how the creative person operates and is motivated. Such study should be carried out in both developed and developing countries.

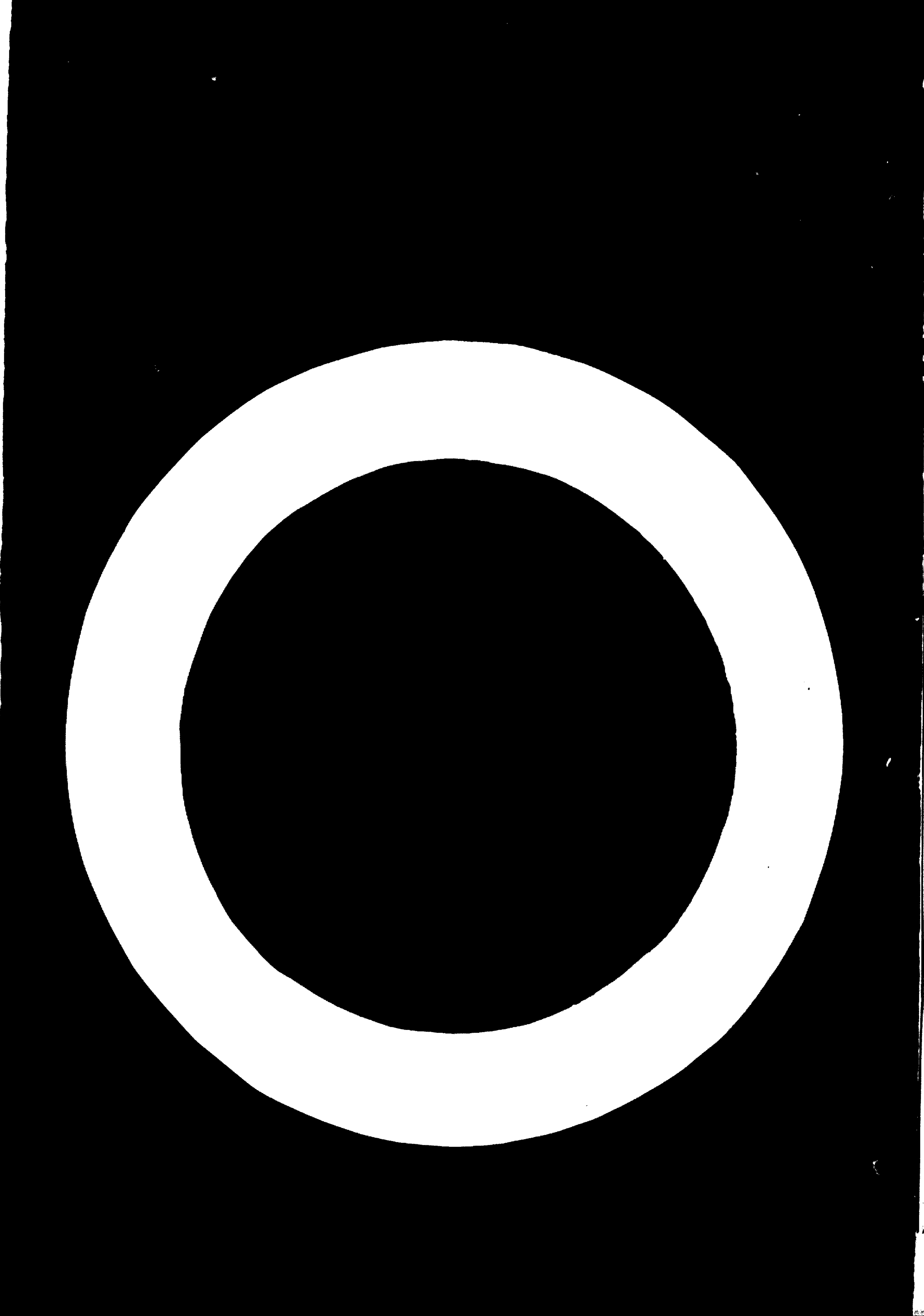
Project work in schools and institutes

126. The project method, especially if carried out by heterogeneous groups, can provide a very useful learning situation. For engineering, the design-and-make project exposes the learner to all of the problems involved in turning an idea into hardware. Experiments carried out at the English Electric Management Training Centre at Rugby, England, have demonstrated the value of this approach on a number of occasions.

127. School projects have also been very fruitful. As a country develops it should be possible to introduce projects to be undertaken by groups of students at the top classes of the schools. This practice has the benefit of widening the horizons of the students and of introducing them to the process of design early in life.

In-plant training and research

128. Much is to be gained by effective on-the-job training for designers. In this regard, management should recognize that it is an integral part of its function to train



and develop subordinates. A great deal can also be accomplished by formalized training whereby designers from one firm are transferred to other firms for a time to study and to contribute to their design methods. This approach is also useful in research, but here the transfer needs to be of at least two years' duration.

129. Where training centres are attached to design centres there must be adequate facilites to provide practical experience. Especially in a creative engineering-design centre, practical knowledge and some actual industrial production experience in the instructing of designers is absolutely essential. The trainees must be able to develop complete designs including all the practical details and aspects, such as selection of the most suitable materials and determination of the appropriate tolerances. The practical workshop training should include an introduction to all manual operations and training in the use of the various machine tools under the guidance and supervision of a workshop instructor or expert.

130. For young draughtsmen working at the centre, the design of spare parts and other practical jobs for the industry, which are usually of a simple nature, provides very good training opportunities to familiarize them with the design standards of the centre, or of the country. Later they can proceed to do more advanced and complicated design work in connexion with the production of new engineering items.

131. It might be advisable for UNIDO to sponsor scholarships to permit capable students in developing countries to visit and study design work in developed countries. Certain basic training in design could also be carried out in the design centres of developing countries after these centres are established.

Design methods and aids

132. Systematic methods of design have been developed extensively during the last decade, and this trend will probably accelerate as creative thinking is better analysed and understood. These systems must be adapted to the particular product or systems design concerned and to the particular working environment. A good example of such adaptation was the development of PABLA (Problem Analysis by Logical Approach) from the Fundamental Design Method, which had been worked out by a governmental research office in the United Kingdom.

133. All designers should be made aware of the latest mechanical aids in the design process. It is sometimes from quite simple aids that the greatest benefit may be derived models made from cardboard or balsa wood, sketch pads for making quick drawings, perspective grids and the like. Specialist engineering designers must also become familiar with both digital and analogue computer operations.

Education and training of future designers

134. Much care and thought will need to go into developing the education and training patterns of developing countries. Initially, once they have been identified, the best designers should be sent for training to the design centres and industries of

the developed countries so that they will be able to absorb what is already known and understand design in the light of modern technology.

135. Eventually, however, there must be a properly recognized educational pattern for designers in the developing countries; and the sooner one is established the better. If possible, the country concerned should seek to make this career pattern widely known and attach status to those who are successful in the field. Too often, designers in developed countries are looked upon as inferior engineers; most of the prestige is attached to research and development engineering work. Developing countries have a good opportunity to reverse this trend or at least to make for parity of status between the two.

136. The teaching of engineering in developed countries frequently tends to downgrade design ability (creativity). Curiosity, the desire to find out for oneself and the use of one's imagination are often stifled. As Albert Einstein once remarked, "It is nothing short of a miracle that modern methods of instruction have not yet entirely strangled the holy spirit of curiosity".

Successive stages in design work

137. It is possible to break down design work into several discrete steps; certain intellectual skills and abilities are called for at each stage. First, the firm accepts the problem situation and is prepared to undertake to resolve it. Next, the main problem and related problems are identified; this step can be arduous, requiring careful interrogation of the client or customer and other sources. The problem, once identified, must be accurately presented, since good engineering design depends upon the specificity of this statement.

138. The design process continues with the generation of possible alternative solutions. Here creativity comes fully into play as ideas are brought forward by a team of designers. In this phase of the work a number of design methods become available that can stimulate freer, unstructured thinking. Some of these are described later in this report.

139. After examination and application of the various approaches, the best solution, taking into account the constraints and the reconciliations that must be made, is chosen, and work is begun on a detailed design. Manufacture and assembly take place as the process continues, and feedback occurs on a continuous basis. The iterations will inevitably have repercussions on the design process as design is extended into manufacture and testing. In the testing and inspection phase, designers have an opportunity to see their creations in operation and to make last-minute adjustments. If the object designed requires construction at another site, this phase may be regarded as an extension of production. Finally, delivery to the customer of the product and/or its system takes place, which, in turn, alters the environment in some way. It can be seen that, as activity progresses down the line, the scope for making changes diminishes.

VII ORGANIZATION OF DESIGN/DEVELOPMENT CENTRES

140. Advanced design development is generally undertaken only in those areas where engineering problems can be recognized clearly and early. Such work may require basic and applied research, which may be conducted at design institutes. The purpose of such development work is usually to add to existing design information and to determine the economic viability of projects in the early creative stages or to provide feedback earlier in the process. The need for such work may also arise from error in design, lack of method or data, or, worst of all, lack of adequate specifications.

141. A characteristic activity of design development is to reveal any discrepancy between performance and specification and to suggest ways of reducing or eliminating it.

The aims and objectives of design centres

142. For the reasons given in chapter II, it seems desirable to introduce design/development centres as complementary to sectoral design centres. From an organizational point of view, design centres should be situated adjacent to industrial enterprises so that frequent direct personal interchange can take place and thus ensure a rapid feedback of information. For developing countries design centres should be of particular use in certain specific areas. These are discussed below.

Design adaptation

143. The development of consumer durables and industrial components is usually an evolutionary process, and in the past it has been fairly slow in developed countries. Successive versions of a product may differ as availability of materials, skills and customer preferences change. These differences are often quite small, and the effects can then be absorbed easily. Such work calls for design adaptation, and developing countries need to have development centres to ensure that adapted designs will really stand up to environmental conditions etc. A good example is a vehicle's suspension system, which might well need adaptation in order to be suitable for the terrain of a developing country.

Design creation

144. Large and complex design projects are usually undertaken when an existing system of goods, services or information no longer fulfils the customer's need. The

new project might be so remote from what is now possible that very deliberate means would be required to achieve its realization. In this situation, design creation is required, and development tends to become the critical phase of the process.

145. Development work is necessary when parts of a system are being designed. The specifications to which a given part is being designed have generally been derived from a larger and more comprehensive project. Although there may be doubts as to how well this project has been designed, the number of uncertainties involved can be kept to a minimum if the performance of the part meets the specifications. Hence, hardware made to the design must be tested and, if necessary, changes made in it.

146. Such large projects will not be undertaken initially in developing countries, but it must be borne in mind when setting up design/development centres that such work may have to be undertaken ultimately. Also, when parts are actually being made according to new designs, the first results are often poor. Typical reasons for this are: inadequate instructions, lack of skill, inappropriate tools, unsuitable materials, or merely that the method of manufacture is simply impractical. Obviously, not all such shortcomings can be corrected by changes in design, but whatever action is taken generally needs the support of design development.

147. Finally, there will be need for development work when the system is put together for the first time. Interconnexions, which were imagined by the designer, now exist in reality as mating plugs and sockets etc. The performance of the system will have been deduced from earlier separate tests of several co-operating parts. The inputs to these parts were, in all probability, provided by signal generators (i.e. sources of electrical or mechanical power), and the outputs were fed into measuring instruments.

Construction of experimental models or prototypes

148. While prototype models are needed for experimental testing, the pilot models[4] that may have been made up during the design process to test for strength, vibration and deflection can be even more important. Experimental production workshops or prototype centres are needed for these tests. The main purposes of a prototype centre should be:

- To develop machines for serial production in the affiliated enterprises;
- To provide technical advice and services to all enterprises in its vicinity;
- To improve the quality and performance of goods produced in the country;
- To render assistance in the design and production of tools and dies.

If a prototype centre is to be truly successful, the local counterpart personnel should join the foreign experts as early as possible.

149. The production of prototypes by design centres is possible in countries that have already achieved a certain stage of industrialization but where factory

[4] A pilot model is the first model, made in the best way possible, to check the feasibility of the design proposal.

organization and the quality of middle-level management need further development. The market should be large enough to absorb the output of serial production.

150. Simple consumer goods such as household utensils, builders' hardware, furniture, stationers' goods, toys, plastic and rubber components should not be selected for introduction by prototype centres; only complicated and skill-requiring units such as machine tools should be chosen. These are demanded in great variety, are produced in batches on the same or at least similar machines, and are very suitable for introduction by a prototype centre.

151. Before starting such a venture, all related questions should be fully clarified. These questions may concern the following:

Availability of foreign co-operation (technical assistance, licence documents);

Means of financing of the project (investment and recurring expenses);

Availability of a suitable location (labour, power and water supply, transport);

Form of organization (responsibilities for technical and administrative matters);

Availability of local co-operation (sub-suppliers and participating firms);

Availability of a sales organization for the goods produced (e.g. a machine tool manufacturers' organization).

152. In general, foreign co-operation with an industrially advanced country should be sought and maintained for a number of years. The financing of fixed capital costs is usually more easily secured than that to cover recurring expenses. Hence, budgets should be drafted about two years ahead to make sure that necessary funds will be allocated. It is very important to incorporate in the fundamental four main departments design, production, training and administration – the following sections: standardization (tool design, toolroom, tool maintenance), production planning, materials testing, and heat treatment. Skills and facilities in these lines in countries suited for a prototype centre generally require more serious upgradings and improvements. The quality of products of local supplies must be checked and improved as well as the performance of participating firms.

153. When it has been decided to establish a prototype centre, the financing has been secured and all other questions clarified, care must be taken in selecting machinery, equipment and personnel. Machines and equipment must be suited to the climate and conditions of the country. Complicated and sophisticated machines should be used only if unavoidable, and then their maintenance and supply of spare parts must be ensured. When personnel is engaged, it should be assured that they not only have the required technical skills and know-how but also instructing and teaching qualifications. A qualified skilled worker is not necessarily also a qualified foreman.

154. Before starting production in the centre, licence documents must be adapted to suit the conditions and possibilities of the country, and materials must be ordered in advance in sufficient quantities. Nevertheless, training and theoretical teaching can be started promptly. If at all possible, the metric measuring system should be adopted in

a developing country as early as feasible. The old system of inches and pounds is being phased out; even the United Kingdom plans to change over to the metric system in 1975. Dimensions, tolerances, preferred sizes, material specifications, selection of stock parts and many other tasks are the field of work for a standardization section. For inspection and testing, a carefully selected range of measuring instruments and facilities must be available, and the personnel must be trained to make use of them.

155. The special tools, jigs and fixtures necessary for production either can be obtained from the licensing firms or, preferably, be designed and manufactured in the centre. The toolroom of the centre will be expected to serve other enterprises also; hence it should be well equipped and neatly stocked with tool steels of various dimensions and qualities as well as with other materials. The toolroom should be the first section of the centre to begin operations.

156. The production of prototypes starts with pattern-making and the machining of components. Care should be taken, when machining cast iron, that it already be somewhat seasoned, and that some time elapses between rough and finish machining. Hardening facilities for steel components and for tools should be provided at the centre, so that a facility for testing hardness should be installed. The planning of early production should include provisions for sub-assembly of group components so that the workers can see how parts work together and where the maintaining of tolerances and surface finish are most important. Scheduling and checking of delivery dates for subcontracted parts is an inevitable must for the early stages of the centre. The final assembly of a machine tool, even if it incorporates a large proportion of imported components, will be an occasion for pride.

157. In the early stages a prototype centre spends much time in training its personnel. This training must be extended later to the foremen of the participating enterprises as well as to designers, draftsmen and production-line personnel. The purchasing section must be made conversant with materials specifications, supply conditions and related subjects. The workers must be trained and retrained in the correct handling and reading of measuring instruments.

158. The transfer of the production of components to participating enterprises could start soon, but not before the first two batches of a particular machine have been assembled at the centre. All potential sources of trouble must be fully checked, and all problems must be solved, whether they concern materials, production, tolerances, assembly, painting or packing. To the highest degree possible, production, assembly, testing and painting should be done as closely together as possible to avoid unnecessary transportation with its concomitant costs and delays.

159. Testing requires special attention in developing countries; the right kind of measuring equipment and environmental test equipment must be available. In some cases special apparatuses are necessary. Aesthetic and biotechnological factors must also be considered in the final testing phase of prototypes. For consumer products, potential customers should be asked to try the products and comment on how well they serve their purpose and what, if any, eye appeal they have.

The introduction of prototypes into industry

160. To achieve the maximum contribution to the economic development of an industry, the selection and production of the prototypes to be produced is very important. The main danger lies in developing "attractive prototypes" with no guarantee that the industry is really in a position to manufacture them, and perhaps without there being any real demand for the planned product in the country concerned.

161. This warning is necessary because often in developed countries products that have successfully passed prototype testing have been rushed into production only to result in a failure that has proved costly to put right. This often happens because the prototypes are constructed by very skilled fitters, craftsmen and technicians who adjust the parts without feeding back to the designers information about the alterations that are made in the testing process. Furthermore, the plant capabilities in the factory are often vastly different from those of the machines in the experimental workshops that make the prototypes. Also, environmental testing and accelerated testing under extreme conditions of use may be a requirement, as is usual with automobiles. Some automobile manufacturers even allow customer trials of prototype vehicles on actual roads before they undertake the production and sale of new models to the general public.

The structure of design/development centres

162. There are two ways of establishing design/development centres. The first is to set up a completely separate, self-contained organization containing all the necessary divisions, such as design, marketing, production (industrial) engineering, documentation, laboratories, packaging and manufacturing. The second is to plan a centre closely connected with industry and training institutes, which has the necessary facilities to produce prototypes and which can make use of all manufacturing capabilities.

163. There seems to be no reason why a training centre should not also be placed alongside the design/development centre so that the latter becomes a teaching laboratory. The whole complex would then be responsible for new designs and their development as well as for training experts in industrial and engineering design and development and the whole gamut of industrial production. The logistics of the placement of individual industries and their relationships with one another is important to developing countries. The developing countries can learn much about industrial organization by observing the changes that are taking place in the countries where sophisticated technology is being developed, where take-overs and mergers lead to concentration and specialization.

164. The advantages of the relationship of production plants to design and prototype centres should be carefully studied. There seems little doubt that one of the major educational and training failures of the developed countries in the field of engineering design has resulted from the divorcing of academic, theoretical training from "live" practical work. If this tendency could be avoided by developing countries that seek to establish all-embracing design centres, great benefits could accrue in the future.

165. For developing countries the setting up of centres of excellence rather than separate teaching/training centres would seem to be highly desirable. These centres could supplement existing teaching establishments by conducting short courses, seminars and symposia to keep the top designers up to date. Initially, it would be desirable for such centres to be set up with UNIDO expert help in establishing training programmes for the nationals. In this connexion, it is imperative that the right kind of initial work be selected for the centres. As noted previously, it would be self defeating to try to produce the most advanced engineering items and far better to start with the simple and very useful articles for day-to-day domestic use.

Technical staff

166. The most important asset of any organization is its staff: it is essential to select good technical people who not only have adequate qualifications but also the necessary human qualities. It is recommended that candidates be given certain psychological tests, conducted by qualified persons, so that these qualities can be gauged. It would be the responsibility of the director of the centre to select a well-balanced team of technologists and technicians. A teaching aptitude test would also be desirable, although not absolutely essential, but the candidates must have good all-round industrial experience.

167. In all probability, there will be an insufficient number of candidates with adequate qualifications and abilities in design and production. It is therefore recommended that UN experts be chosen to fill key positions initially. At a later date these positions can be taken over by local nationals when they have gained sufficient experience.

168. It is vital to the well-being of such a centre of excellence that good salaries be paid that are above the equivalent offered by industry so as to avoid well-qualified staff being lured away. If such centres are really to thrive, they must preserve their qualified manpower. Also, it is highly desirable for the good of the centre to allow the professional staff time off to do consulting work, so that they can keep in touch with the industrial practice and situation in their countries.

169. A further factor regarding technical staff is the ratio of technologists to technicians, that is, to para-professional engineers. Designers may well need to draw upon the expert knowledge of technologists such as mathematicians and metallurgists, but they also require technicians. In developed countries the ratio of technicians to designers varies according to the nature of the work, but a good average is two or three technicians to each designer.

Buildings

170. It is generally more satisfactory and less costly in the long run to design and construct a new building rather than to try to modify an existing one to accommodate a design centre. Also, the selection of an appropriate site is easier after evaluation of the traffic and transport situation, as regards both staff and materials.

171. On completion of a feasibility study a detailed building programme, with specifications and functional charts showing the optimal flow of men and material, must be prepared in order to find a suitable layout and physical design. The structure should be economical and flexible and allow for easy expansion in several directions. High quality functional buildings must have an adequate working environment, with appropriate lighting, acoustic and colour treatment, and they require canteen facilities as well as servicing and maintenance facilities. Proper air conditioning may well need to be provided, depending upon the climatic conditions of the site.

172. The position of the office complex should be central, with laboratories, workshops and environmental test bays etc. arranged around them. This arrangement makes for easy access and good communications. All utilities should be run in ducts, with loose covers placed on the sidewalks for ease of access. Adequate capacity for growth of all installations must be considered.

Equipment

Workshops

173. Their form depends upon the nature of the work to be undertaken, but certain standard equipment is required at all such development centres. Caution is necessary, however, to avoid choosing automatic machine tools, for they are not suitable for prototype manufacture; general purpose machines are required. It is far better to have conventional machine tools of high quality, with all the necessary accessories to make possible maximum utilization. Cutting tools of standard type and the attendant grinding machines to maintain them are also necessary. In certain cases small computers may be needed; initially, they could be rented rather than purchased outright. A suggested list of equipment for a typical design centre is presented in annex 5 to the present report.

Laboratories

174. All centres need standard measuring equipment, and special laboratories need additional equipment for materials testing, and general rigs for testing mock-ups and prototypes.

Design and technical offices

175. Here a proper layout is essential so that competent designers will have adequate work stations. Equipment includes draughting machines, layout tables, workbenches for modelling (paper, balsa wood etc.), cameras (Polaroid type) and calculating machines.

176. Adequate graphic reproduction equipment is also needed, and it is recommended that microfilm facilities be provided so that prints can be produced, read and stored easily. The early acquisition of this equipment would avoid the kind of trouble that is now emerging in some developed countries, where storage and adequate retrieval of microfilms have become problems.

177. Drawing offices should be spacious and open-plan in style, with the designers' offices placed round the periphery. It is important to form the latter with moveable partitions to give added flexibility. In addition to each senior designer's own workbench, there might in certain instances, be a need for a separate mock-up and model shop to serve the whole design office. This facility should be located adjacent to the main drawing office.

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
VIENNA

THE DEVELOPMENT OF ENGINEERING DESIGN CAPABILITIES IN DEVELOPING COUNTRIES

Report of Expert Group Meeting
Vienna, 11 - 15 May 1970

UNITED NATIONS
New York, 1972

VIII RECOMMENDATIONS

178. Towards the close of the meeting, the participants made a series of recommendations for steps to be taken to promote the rapid establishment of effective design centres in developing countries. Some of these recommendations were addressed to the developing countries, some to the developed countries, and others to UNIDO. They are outlined below.

179. TO THE DEVELOPING COUNTRIES

1. The development of design capabilities should be promoted by the establishment of design centres.

2. Design work should be restricted initially to simple applications in order to build up technical know-how and confidence. The applications should be appropriate to the country's requirements and resources, and especially should make use of locally available materials. Value engineering and analysis could be utilized as working tools for components.

3. If licences are acquired to produce articles of foreign design, local designers and production engineers should make the utmost use of them to gain experience.

4. Designers must be acquainted with the manufacturing capabilities of their own countries and the facilities that are likely to be added in the future, in order to ensure that realistic and viable designs are produced. They must also promote knowledge of relevant production techniques in their own countries.

5. At an appropriate time, prototype manufacturing shops should be established within design development centres to enable the designers to validate their creations and gain confidence in their work, which could be exploited by industry.

6. Due attention should be given to training institutions, to the philosophy of designing to suit environmental and social conditions, and, particularly the design that takes into account economic factors.

7. A number of supervised travelling scholarships should be established to enable both industrial and engineering designers from developing countries to observe directly and participate in the work of design teams in other countries.

8. Selected personnel should be sent to small and medium-sized industrial firms in developed countries to do design research that is directly related to problems encountered in the developing country concerned, and experts in design from developed countries should be invited to give specialized advice and help with domestic training.

9. When necessary, standardization and patent institutions should be introduced. The permanent exchange of technical information between industries in developing and developed countries should be encouraged.

180. TO THE DEVELOPED COUNTRIES

1. Technical assistance to the developing countries in the development of design capabilities should be provided by recruiting experts for the training of local engineers and technicians.

2. Trainees in design from the developing countries should be accepted in industrial and educational organizations.

3. Information relevant to design work, including education and training, should be supplied both directly to developing countries and to students from them.

4. Consulting services should be provided for specific design problems encountered in developing countries.

181. TO UNIDO

1. Expert assistance in market surveys should be made available to the developing countries. Priority lists of engineering products designs could be established on the basis of the findings of these surveys.

2. Technical assistance to the developing countries for the improvement of design capabilities, based upon the experience of the developed countries, should be provided.

3. Technical assistance in the establishment of engineering and industrial design centres on the national or regional levels should be provided. It would be of key importance for such centres to work closely with industry.

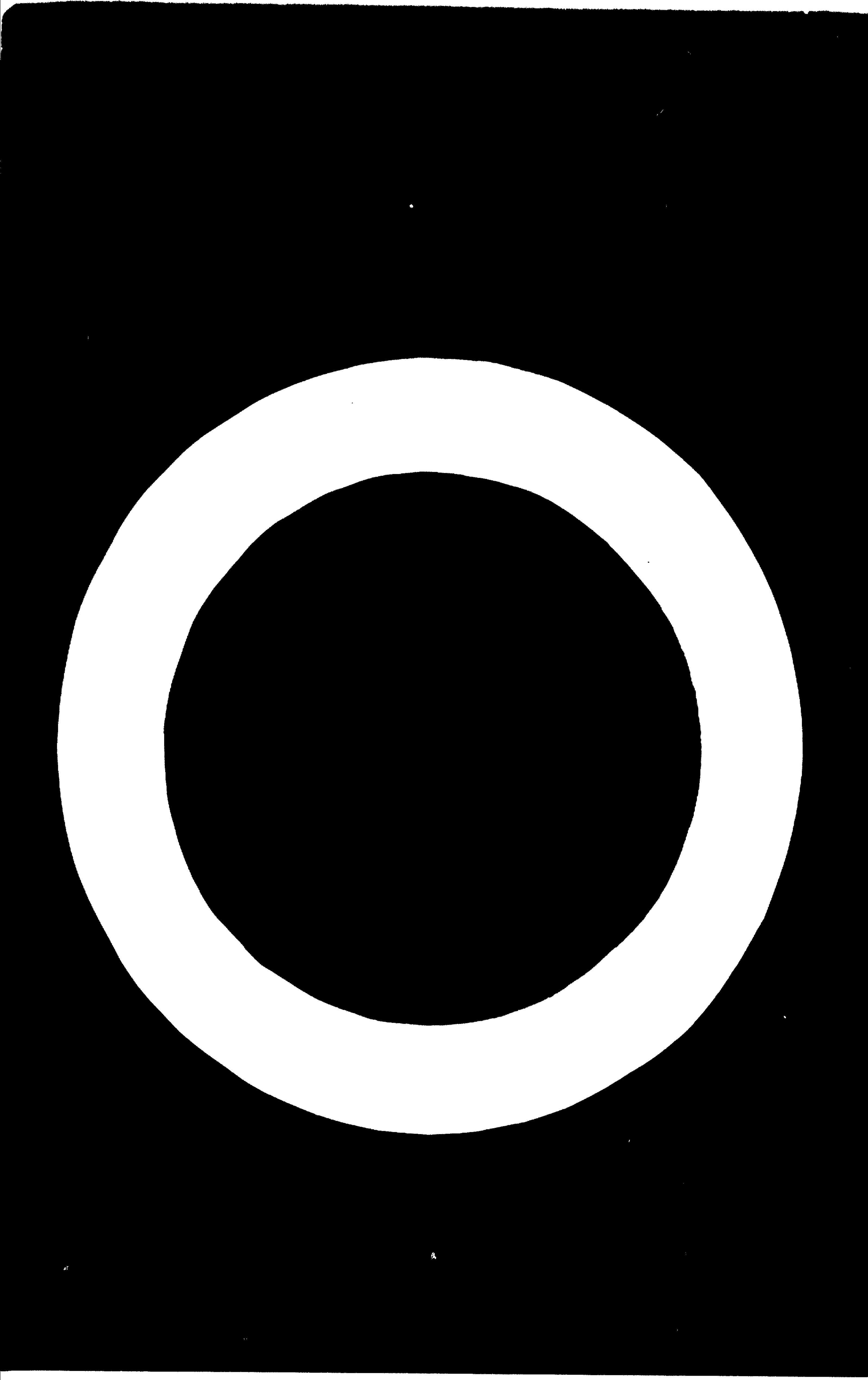
4. United Nations experts should be sent to developing countries to train local personnel in industrial design and the production of prototypes.

5. Assistance in setting up patent systems should be made available on request.

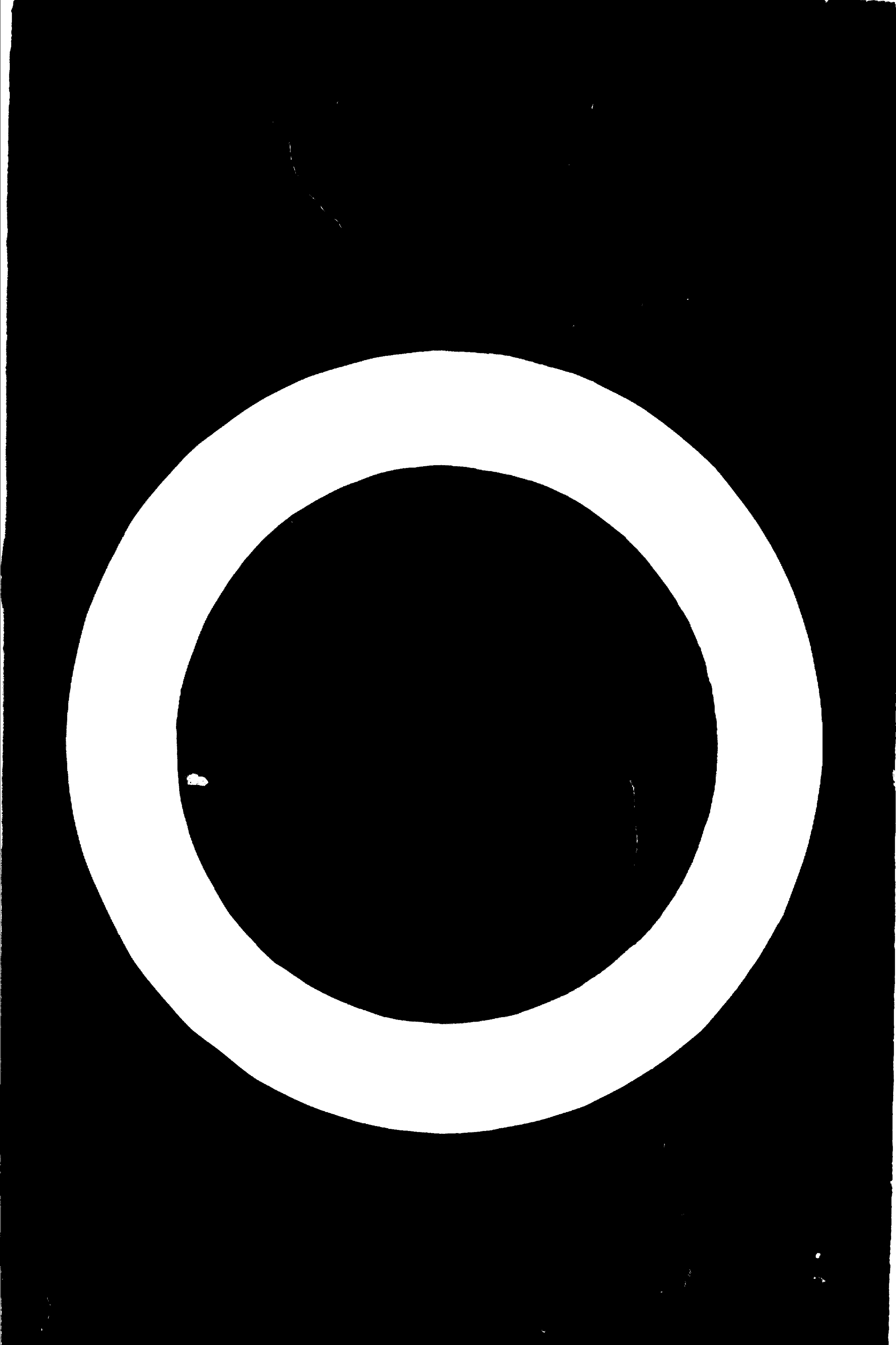
6. Technical information and technical books on the latest design methods, processes and equipment should be provided.

7. Research work on methods for identifying and selecting designer trainees should be sponsored.

8. UNIDO should co-operate with ICSID, ILO and UNESCO, through the medium of their training programmes, in the improvement of the design capabilities of the developing countries.



ANNEXES



Annex 1

LIST OF PARTICIPANTS

AUSTRIA	C. M. AUBOCK Board Member International Council of Societies of Industrial Design (ICSID) Vienna
	C. BLANKENSTEINER Secretary General Austrian Institute of Design Vienna
	E. KUNST Chief Engineer, Technical Secretary Heid AG Vienna
	E. E. LETHMAYER Managing Director International Institute for Industrial Planning Vienna
	M. SCHOBEL General Manager Heid AG Vienna
BRAZIL	J. A. R. FROTA Centro Technico de Aeronautica São Paulo
BULGARIA	A. I. ANGELOV Director Institute of Instruments Design Sofia
FEDERAL REPUBLIC OF GERMANY	D. V. AHUJA Graphics Representative IBM Germany Munich

FRANCE	G. L. MALLERET Consultant Automobile Citroën S.A. Paris
HUNGARY	E. BACSKAI Section Leader Institute of Engineering Technology Budapest
	L. BALINT Director Institute of Engineering Technology Budapest
	S. BORSZEKI Chief Engineer Ministry for Metallurgy and Machinery Budapest
INDIA	A. K. DE Director Central Mechanical Engineering Research Institute Durgapur, West Bengal
IRAN	V. S. TOUBA Technical Adviser Industrial Development and Renovation Organization Tehran
ITALY	L. U. VINEA Department of External Relations Fiat S.p.A. Turin
NIGERIA	N. I. O. ERO Senior Research Officer Federal Institute of Industrial Research OSHODI, Lagos
THE NETHERLANDS	H. N. C. ST[illegible] Director International Technical Education Media Services Aerdenhout
UNION OF SOVIET SOCIALIST REPUBLICS	V. S. BELOV Deputy Director Experimental Scientific Research Institute for Machine Tools Moscow
UNITED ARAB REPUBLIC	M. F. HUSSEIN Engineer Consultant Heliopolis, Cairo

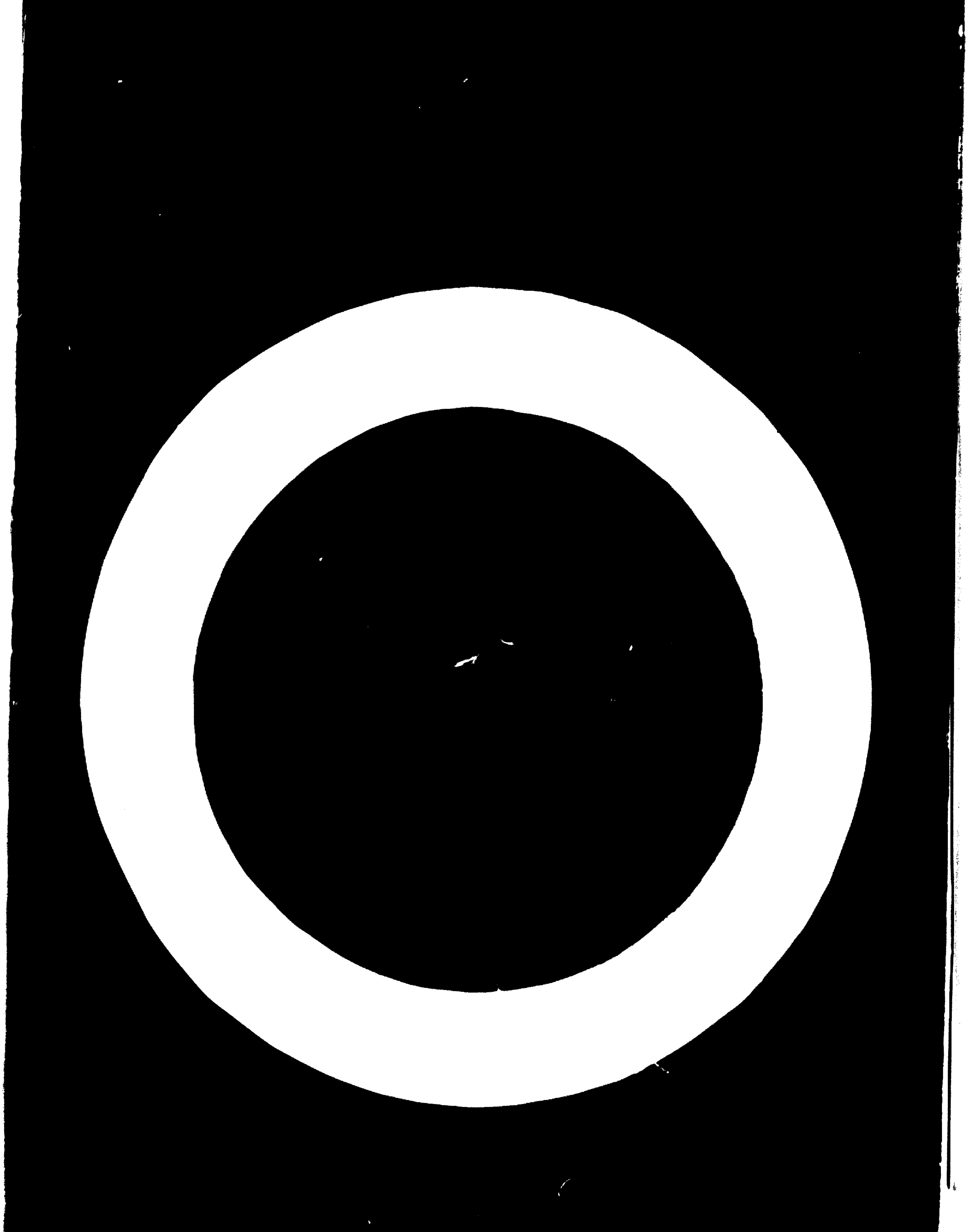
27-11-74

ID/67
(ID/WG.56/28)

UNITED NATIONS PUBLICATION
Sales No.: E.72.II.B.2
Price: $US 1.50 (or equivalent in other currencies)

CONTENTS

ANNEXES



Letter of transmittal to the Executive Director of UNIDO

The Group of Experts on the Development of Engineering Design Capabilities in Developing Countries, which met in Vienna from 11 to 15 May 1970 at the headquarters of UNIDO, respectfully submits its report.

All participants agree that successful industrial growth in developing countries depends to a considerable extent upon indigenous capacity to create and develop engineering design, as well as to adapt the designs of various kinds of products to be manufactured under licensing agreements in accordance with domestic needs. The engineering design capabilities of nearly all developing countries are either lacking or at early stages of development. To permit the optimal use of available technology, this capability should be increased in these countries, whatever their present level of development.

In the course of the meeting we have discussed such important matters as the identification of areas requiring design, costs of design and problems of prototype production, training in design, problems in the organization of design centres in these countries, and the role of UNIDO in rendering technical assistance to these countries for the development of their capabilities in industrial design. We have also worked out recommendations on the future development of design capabilities and the production of prototypes.

We recommend that the attention of the Member Governments of the United Nations be drawn to this report, and that comments be invited.

In submitting this report, we have served in our personal capacities and not as official representatives of organizations or Governments.

We thank the management of the Maschinenfabrik Heid A.G. for making it possible to visit their plant in Stockerau, and wish also to express our appreciation to the Industrial Technology Division of UNIDO for collecting and contributing the papers that formed the indispensable background for our discussions, for preparing the draft report, and for other help that made the preparation of the present report possible.

(Signed)

Members of the Expert Group

2 / 2

74 ST 0054

UNITED KINGDOM	B. T. TURNER Director Industrial and Commercial Techniques Ltd. London
UNITED STATES	E. F. GIBIAN Consultant TRW Executive Officers Cleveland, Ohio R. K. ROWELL Industrial Consultant Lynn, Massachusetts
YUGOSLAVIA	P. VOGRIC Chief Design Engineer Automatic Development and Application Division Litostroj, Plant for Production of Industrial Equipment Ljubljana

United Nations Industrial Development Organization

UNIDO secretariat	N. K. GRIGORIEV Director Industrial Technology Division N. N. KRAINOV Industrial Development Officer Engineering Industries Section Industrial Technology Division P. L. NAGY Industrial Development Officer Engineering Industries Section Industrial Technology Division O. V. SOSKUTY Chief Engineering Industries Section Industrial Technology Division
UNIDO project managers	W. F. MASON Design Centre for Electrical Measuring Instruments Bombay, India R. OROVIC Engineering and Industrial Design Development Centre Cairo, United Arab Republic P. VIALE Centre de développement d'outils et prototypes A. M. S. Sousse, Tunisia

However, largely for historical and sociological reasons, little original design work is done. Most of the larger and more important enterprises obtain their designs by collaborating with foreign enterprises, and many of the smaller ones merely attempt, with varying degrees of success, to copy foreign-made articles. Research and development work is done within some enterprises some of it with notable success. However, the intensely competitive nature of Indian business makes most entrepreneurs unwilling to invest much time or capital in product development. Indeed, only one electronics company in India is known to follow the procedures of a progressive development programme.

Nevertheless, both business and Government realize that something is wrong; even today, after a quarter of a century of national independence, technology must still be imported on a large scale. This problem is constantly discussed in the press and debated in Parliament.

Another significant positive influence is the defence establishment, which is setting rigid standards of acceptability for its equipment purchases. Furthermore, the Chief Inspectorate of Electronics is working to upgrade the quality of technical products manufactured in India.

Of especial importance – and of particular interest to the participants at this meeting – is the new Institute for Design of Electrical Measuring Instruments, situated in Bombay. A UNIDO Project Manager was assigned to it in December 1968. Its plan of operation, which was signed early in 1969, envisages a five-year programme costing US$ 833,000, with counterpart contributions of about the same amount. The project is to have seven UN experts and thirty professional persons on the counterpart staff, as well as about eighty non-professional Indian staff. Twelve fellowships will be offered.

The facilities are to include a mechanical workshop, a heat-treatment shop, an inspection unit, an electroplating shop, a paint shop, a calibration and testing laboratory, a mechanical drafting office and a technical library. A training section will be set up for sixty trainees on three levels: engineers, supervisory staff and skilled workers. For short-term results, the education of young designers in advanced subjects in the field of technical instrumentation is to be attempted. This educational programme will be explained to the entrepreneurs at special meetings, and their suggestions or approval will be solicited.

It is confidently expected that the work of this institute will stimulate Indian industrial design capabilities, thereby reducing the country's dependence on foreign sources of technology.

In conclusion, while the Indian instrument companies are not lacking in basic mechanical training and manufacturing ability, they are deficient in modern engineering management techniques as practised by the more industrialized countries. On the other hand, the Indian entrepreneur is exceptionally capable, and no one knows better than he what suits the Indian market at any given time. Assisting agencies, including UNIDO, should demonstrate methods that may be regarded as more advanced than those in current use, but the final decision as to what is to be done must naturally rest with the local entrepreneur.

Iran

Since industrialization is still in its early stages in Iran, no design centres have yet been created. Nevertheless, a gradual approach to engineering design is being made. For example, work is in progress to produce domestically designed machinery for the manufacture of welded beams.

Nigeria

The bulk of the new products manufactured and marketed in Nigeria are produced by enterprises that are the local representatives of foreign organizations. The equipment and some of the raw material requirements of these firms are imported; the principal Nigerian contribution is the manpower required. This pattern tends to hold true of some firms jointly owned by Nigerian and foreign capital. Enterprises of this kind process local raw materials such as cotton, oil seeds, cocoa and limestone. The local development of new products and the design and fabrication of prototypes are still in their earliest stages, but some interesting and potentially important design work is being accomplished.

The growth of universities in Nigeria in the ten years since national independence has given impetus to the steady growth of Nigerian technological manpower. Of the five universities in Nigeria today, three have successfully established really good engineering departments, albeit with limited fields of specialization. The University of Ife, a young institution, is presently developing its Chemical Technology Department, while the University of Ibadan is now planning to set up its own Institute of Technology. Meanwhile, Nigeria has continued to use the facilities for technological training provided by foreign institutions. Although the College of Technology of Nigeria has been training engineers for more than twenty years, institutions abroad have trained the bulk of Nigeria's technical and engineering manpower.

The establishment of a centre for creative industrial design, with the corresponding workshops and laboratories for testing models and prototypes, in a developing country like Nigeria would give a decided impetus to this creative activity. The gain would be in applying these skills to the practical activity of industrial designing, fabricating and testing of new products.

In setting up such a centre, advantage could be taken of the existing facilities which, when augmented, should be capable of attaining maximum scope and coverage of the local industrial scene. The Federal Institute of Industrial Research at Oshodi already possesses such facilities for thorough investigation of design problems. It maintains a design section which, although badly in need of funds for equipment, has succeeded in identifying and tackling fundamental design problems. If, on the other hand, such a centre is created separately, it will have the initial disadvantage of high start-up costs and the long-range effect of committing the United Nations to a protracted presence in Nigeria. A regional industrial design centre to satisfy the needs of several adjacent nations would curtail the undue proliferation of such centres in a small geographical region and provide the advantages of scale and economy of costs. Furthermore, where such a centre is to operate for an appreciable length of time under the auspices of the United Nations, the argument that it be set up within an established research institution becomes compelling.

Tunisia

The problem of engineering design is not yet well recognized in Tunisia, since most of the existing industries are connected, more or less closely, with the industries of the more developed countries which supply them, or which have supplied them in past years, with the fundamental drawings of the parts to be produced. This dependency results from the fact that most Tunisian industries have come into existence relatively recently, that is, within the last ten years. For this reason, at present, Tunisian manufacturers still either do assembly from imported components or work on the basis of imported drawings. Consequently, no Tunisian industry has yet developed studies in the field of engineering design; even for spare parts and special tooling, they still remain dependent on foreign industries. Some small attempts are being made to begin something new on a local basis, but these efforts are very isolated, primarily because of the nearly total lack of personnel qualified to do this kind of work.

Perhaps the most apparent needs are still those connected with the manufacture of the spare parts needed for agricultural and textile machines, automobiles etc. Engineering design is thus limited to the copying of parts already known; it is only a question of discovering their characteristics and reproducing them in mechanical drawings.

An industry that would provide even greater scope for industrial design is the manufacture of plastic articles for domestic use. Tunisia already has several establishments in this industry. There are also industries that produce kitchen utensils, household electrical appliances, and agricultural and domestic tools, and that already need engineering design departments. The manufacture of radio and television sets, which at present is limited to assembly from imported parts, may now be considered ready for the local production of certain components.

Finally, a general need is now strongly felt for the conception and manufacture of the special tooling needed to complement the machine tooling used in the mass production of parts in the above-mentioned industries.

In Tunisia, the tooling centre that is being established under UNIDO project TUN 27 can cope with the country's requirements during the next four to five years, but it is foreseeable that the need will arise for a centre specialized more in the creation of prototypes of local origin.

The United Arab Republic

This country has been industrializing rapidly for the last fifteen years. Large investments have been committed to building and equipping new factories and new industries, including the production of automotive vehicles, domestic appliances, agricultural machinery and steel. A great number of foreign licences for the production of various manufactured goods have been purchased from well-known foreign firms. This rapid industrialization has brought many benefits to the country, but it has naturally created a concomitant series of problems, one of the more important being the lack of engineers well enough qualified and with the experience and know-how necessary for work with the licensed products and processes.

As in practically all other developing countries, primary attention had been paid to the erection of suitable buildings, to acquiring the best up-to-date equipment necessary for production, and to production itself. These are important concerns, but others, such as design development and production engineering, have been neglected, resulting in some cases in old-fashioned products and non-economic production.

The first step taken by the Government to overcome these difficulties was to strengthen and increase the capacity of various training centres, technical schools and universities. At present a sizable number of young experts are being furnished to industry.

The creation, with the assistance of UNIDO and of the United Nations Development Programme Special Fund (UNDP/SF), of the Engineering and Industrial Design Development Centre (EIDDC), in Cairo, is another effort to help industrial enterprises in design and development and production engineering activities, and to provide a place that can serve as a model for similar departments in factories, as well as one where engineers are able to obtain experience.

The Centre is a service-to-industry project and, to the extent possible, concentrates its efforts on products that are needed in increasing quantities. It trains experts in design and development of serially produced products, in prototype execution and testing as well as in planning, technological processing and tooling of the production by doing the actual job for smaller or bigger workshops and factories.

The permanent staff of the Centre is composed of both national and UNIDO engineers. They assist experts from the shops and factories in which specific jobs are being done. The work is performed either on the premises of the Centre or in the factories. In the first case, after the factory engineers have had advice or training at the Centre, they return to their plants, taking with them the documentation prepared in the Centre to complete their work. In the second case, EIDDC engineers go regularly to the factories, where they advise and assist factory personnel. In addition, a number of junior engineers are employed at the Centre, where they work in various divisions to acquire the preparation for their own areas of specialization. Later they may be transferred to the corresponding departments in shops and factories.

Centre assistance to the factories is granted on the condition that the latter set up design and development and engineering departments, if these do not already exist, which could later assume the task begun by the Centre, thus making possible future independent product development and organization of production.

In addition to its management, FIDDC consists of four substantive divisions, devoted respectively to product development, industrial design, engineering, and prototype execution.

The Products Development Division handles all aspects of development and design of a variety of products when these are to be manufactured in great quantities (that is, by serial or mass production). It provides the Engineering Division of the Centre, or other factories and shops, with technical documentation (consisting of assembly and detail drawings, parts lists and specifications). When requested, it can construct and test prototypes. Together with the Industrial Design Division it is responsible for the aesthetic as well as the functional qualities of products.

The Standardization Section of this Division is responsible for introducing national and international standards in designing as well as reducing, through the Centre's internal standards and regulations, the number of a great variety of parts used in products. A further responsibility of the division is to supply all FIDDC experts with necessary data concerning patents and to secure patents for products and processes invented at the Centre.

The development and design work in this division is organized into various design groups that have been formed to accommodate various groups of products. UNIDO experts are attracted to the management of the division and serve as consultants to all of its sections and groups.

The Products Development Division is also responsible for the Technical Documentation Archive, which prints, stores, distributes and records technical documents.

The Industrial Design Division handles, in close co-operation with the Products Development Division, all aspects of creating the external form of products designed at the Centre or, when necessary, outside of it. Sketches, photographs, models (made of clay, plaster, wood and other convenient materials) etc. prepared in this division help in choosing the best model, thus enabling the Products Development Division to prepare the necessary documentation for future production

The Industrial Design Division co-operates with specialized institutions outside the Centre and with their experts in order to utilize their skills and experience.

The Engineering Division is responsible for production engineering and for the planning and evaluation of production. It is concerned only with products that are to be produced on a serial or mass-production basis in specific shops or factories. The technical documentation (drawings) of products that are to be handled by this division may come from the Products Development Division or directly from a shop or factory, in which case the other divisions are not concerned. In both cases, however, drawings, specifications, parts lists etc. should already have been proved through the construction and testing of prototypes.

These tasks are purely service-to-industry work, and the division performs them through the following sections:

The Production Planning and Processing Section, which

- Prepares processing sheets for the parts to be produced, giving all necessary data needed, such as sequences of operations for manufacturing and data concerning equipment and tools;
- Lists necessary machine tools and equipment on the basis of data received from the processing sheets and time-study charts;
- Makes machine tools and equipment layouts;
- Projects the organization of production.

The Time Study and Cost Evaluation Section, which

- Determines the working time for each phase of production on the basis of technical drawings and processing sheets for each part and product;

Evaluates the cost of production for each operation, part and product on the basis of data about the enterprise where the production is going to take place and documents received from the other divisions and sections.

The Tool Design Section, which

Designs non-standard tools, dies, jigs, fixtures, gauges and special equipment necessary for production;

Takes care of and helps in the production and testing of tools designed by them, and supervises the initial production together with planning and processing engineers.

The Standardization Section, which

Supplies the division with national and foreign standards dealing with the processing and tooling, and standardizes, so far as possible, parts, materials, semi-finished products, standard parts etc. of the tools to be designed and produced both within the Centre and outside of it.

The Technical Library, which

Acquires, stores and records the necessary technical books and documents and makes them available to the experts.

UNIDO experts are attached to the management of the divisions, serve as consultants and give help to all sections.

The Prototype Execution Division (prototype workshop) is responsible for producing both prototypes and tools, this being the most suitable and economical system during the formative period of IIDDC.

The prototypes are constructed on the basis of the technical documentation received from the Products Development Division, with which there must be close collaboration during the construction and testing period. The Prototype Execution Division is responsible for organizing the testing of prototypes. This work is carried out in collaboration with the Products Development Division.

Prototypes may also be constructed on the basis of drawings that originate outside of the Centre, in which case the Prototype Execution Division deals directly with the corresponding outside designers.

Some of the non-standard tools required for serial production outside the Centre are also constructed in the tool-room of the prototype workshop, according to its capacities and on the basis of the documentation received from the Tool Design Section of the Engineering Division, with which the Prototype Execution Division co-operates closely.

The duties of this division are performed through

The Prototype Department, which

Does the machining, welding and assembling of prototypes.

The Tool and Die Department, which

Builds up non-standard tools, dies, fixtures, gauges etc. and does machining on its special machine tools, heat treatment, fitting jobs and the sharpening of cutters.

The Inspection Department, which

Performs all metrological, metallographic, metallurgical and chemical tests and analyses within and outside the Centre, according to need;

Does all necessary inspection of parts and materials for the Centre on the basis of the technical documentation;

Assists in solving, when necessary, inspection problems that arise in shops outside the Centre.

The Materials Store, which

Stores, handles and keep records of the materials and tools of the division.

UNIDO experts are attached to the management of the division and serve as consultants to its sections and groups.

On the basis of the organization and principles described above, the actual work of the Centre is organized in two ways:

(1) It concludes contracts for long-term co-operation with factories which call for its assistance in improving the organization of departments of design and development and of engineering, if they exist, or starting them if they do not. In addition, concrete problems of design and redesign of products during production, as well as problems concerning the organization of planning, processing and tooling of production, are handled in co-operation with the personnel of the factories.

(2) Products that the management of the Centre find are needed on the market are designed independently of the factories. It is the responsibility of the Centre to find suitable manufacturers for such items. (Examples are electric irons, solar water heaters and cigarette lighters.)

The Centre has had no difficulty in finding real tasks to handle. Its experts were welcomed when FIDDC was introduced to the factories and after factory chairmen and technical managers had been made thoroughly acquainted with its possibilities. Several meetings between the Centre and factory managements were organized initially by the Ministry of Industry to familiarize factory personnel with the purpose of the Centre.

Since unsolved production problems in such areas as processing, production planning and tooling influence the productivity and quality in practically every factory, the Centre is frequently approached with requests to provide assistance in solving them. The question of further development of products has been of secondary importance, owing partly to restricted imports and the protection of local industry and partly to the fact that production problems requiring immediate solutions absorb nearly the entire time and effort of the insufficient number of engineers and technicians in the factories. Nevertheless, the concepts of design and development are gaining increasing strength, and the efforts of the Centre in these fields are beginning to bear fruit. In order to explain the problems of product development, the Centre is preparing to give courses. In 1968/1969 a booklet giving data about the Centre's activities was prepared and distributed among the industrial enterprises of the country.

As noted above, industry has been adversely affected by the lack of experienced engineers, and the Centre has also suffered from this dearth. Hence, one policy adopted has been to accept many young, newly graduated engineers and to let them work on the actual problems of the factories, together with UNIDO experts and the smaller number of more experienced national senior engineers. This policy has proved successful and after a certain period of time a number of younger, experienced engineers will be available.

The experience gained with FIDDC should be useful in planning new centres in other countries, since the basic principles concerning design and development activities are the same. It is important to make the future working programme of the institution quite clear: that is, to decide whether it is to take care of processing industries and unit production or of serially produced products, since the way of working and the training of experts is completely different for these two different jobs. If it is possible to specialize the projects even more in the future (for example, automotive, machine tools or domestic appliances), so much the better, but in most cases this would be unlikely.

It is important to emphasize that such centres are conceived to work and co-operate with industry, that is, in the plants and factories, and not to become parts of administrative bodies.

In this connexion, it might be advisable in some cases to attach the projects to existing large factories that have a number of sub-suppliers and that are of great importance to the economy of the country. Such a solution should result in the establishment of strong design and development departments, as well as engineering (processing, tooling, time study) activities in the "mother" factory. It ought certainly to result in stimulating the creation of similar organizations and ideas among the smaller sub-suppliers.

In the present case, the idea of having both a Design and Development Division and an Engineering Division to take care of the production problems of the factories has proved to be very successful, since the exchange of opinion between designers and processing and tooling engineers during the design period is of the utmost importance. In addition, unsolved current production problems in the factories now preoccupy factory personnel so much that they need help; if left without it, they simply could not devote enough time to developing their products.

Too much attention has been paid in the past to the establishment of large and well-equipped prototype workshops. Almost everywhere the prototype workshops are sections of the design and development offices and serve designers as a means of checking their drawings, both in dimension and function. Nevertheless, organizing the capacities of workshops to suit the number of designers and the quantity of design work is rather difficult, especially when the designers are practically without experience and when the products are rather simple. In many cases, when co-operating with the factories, EIDDC has found them willing and able to produce their own prototypes. The logical conclusion would be to establish only small prototype workshops with basic equipment, and to use to the maximum the various already existing shops, factories, training centres and other facilities, and to allocate as much funds as possible for UNIDO experts and fellowships.

As a conclusion, it should be emphasized that engineering and industrial design development centres could be very useful institutions in starting and creating design and development activities in developing countries, provided they are given the necessary support and understanding by their Governments and are supplied with able and experienced international experts.

On the other hand, it would be self defeating to expect that such relatively small institutions (having 25 to 30 engineers, corresponding to the development department of a medium-sized factory) could solve the design and engineering problems of the country's entire industry. Miracles in the field of product design and development are not happening anywhere, but these projects should reasonably be expected to achieve the following goals:

To establish a model of good organization and to spread the idea of the importance of the development work;

To start the nuclei of similar institutions in the factories; and

To train a number of engineers, thus making possible the continuation of their work when the United Nations assistance, normally in the early stages of development, is discontinued.

Annex 5

ORGANIZATIONAL STRUCTURE AND TECHNICAL EQUIPMENT RECOMMENDED FOR A TYPICAL DESIGN/DEVELOPMENT CENTRE

When setting up a design/development centre, a skeleton organization of the type shown in Figure 2 is recommended. While it is impossible to list all of the equipment that might be required in such centres, the following lists contain most of the essential items. The names of manufacturers are given only where they apply.

A. Machine section

	Accessories
6 Lathes (Schaublin 102 VM)	Coolant equipment Set of collets Drill chuck Driving plate 3-jaw chuck 4-jaw chuck Grinding attachment Face plate Steady rest Movable steady rest
5 Toolmaker lathes (Schaublin 102 90)	Set of collets Drill chuck Driving plate 3-jaw chuck Thread-chasing attachment Milling attachment Grinding attachment Turret attachment Conical turning attachment Spherical turning attachment
5 Toolmaker lathes (Habegger 2)	Set of collets Drill chuck Face plate 3-jaw chuck 4-jaw chuck

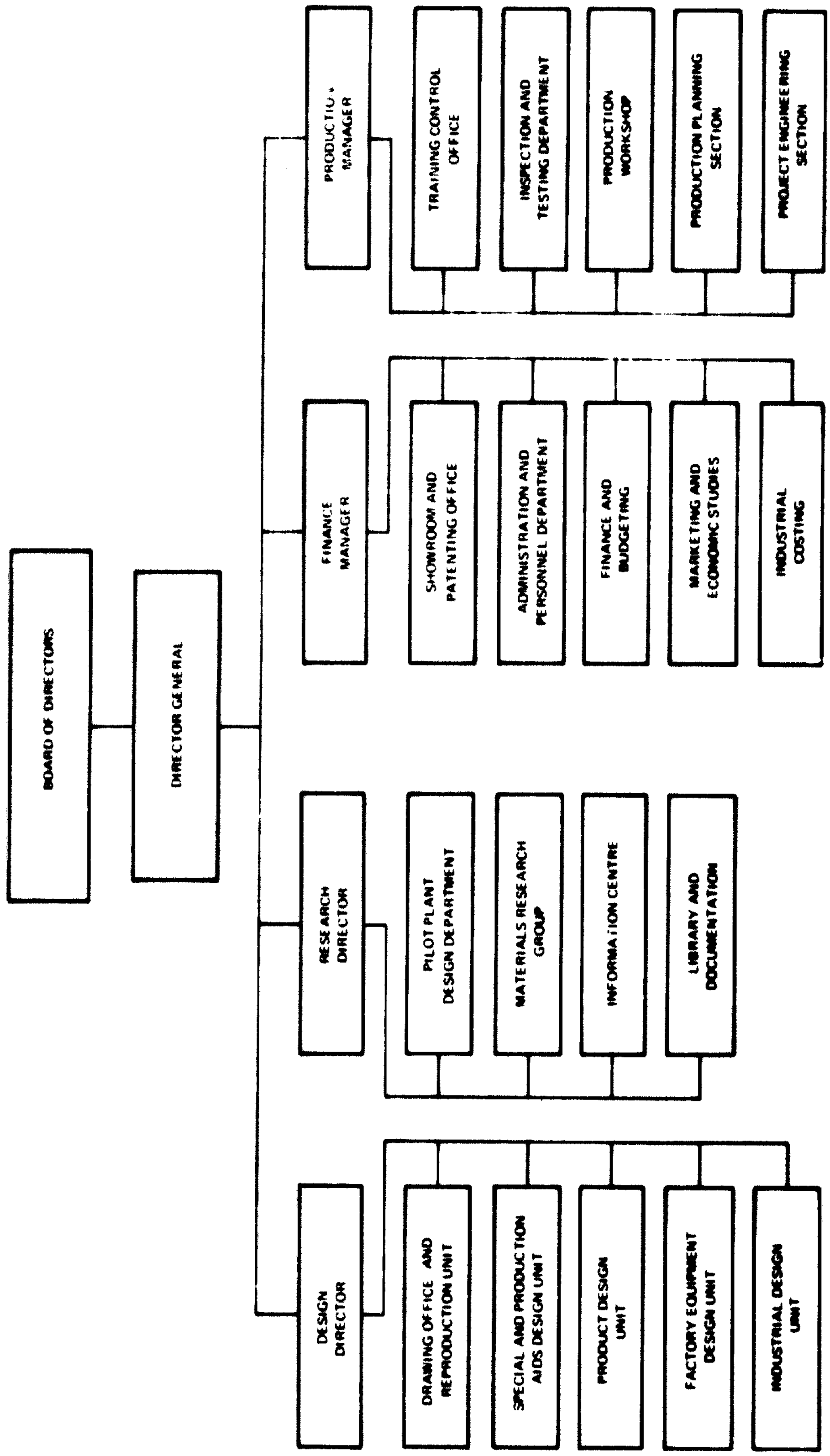


Figure 2 **Proposed organizational structure for design development centres**

2 Toolmaker lathes (Schaublin 70)
- Set of collets
- Drill chuck
- Steady rest
- Driving plate
- 3-jaw chuck

2 Lathes (Simonet 450)
- Coolant equipment
- Set of collets
- Face plate
- Driving plate
- Steady rest
- Drill chuck
- 3-jaw chuck

2 Lathes (Menziken 185)
- Coolant equipment
- 3-jaw chuck
- Face plate
- Steady rest
- Movable steady rest
- Driving plate

1 Lathe (Gallic 14)
- Coolant equipment
- Face plate
- Steady rest
- Movable steady rest
- Conical turning attachment
- Drill chuck
- 3-jaw chuck
- 4-jaw chuck
- Driving plate

7 Universal milling machines (Schaublin 13)
- Coolant equipment
- Universal table
- Vertical milling head
- Set of collets
- Parallel vice
- 3-jaw chuck
- Rotary table
- Dividing equipment

1 Universal milling machine (Schaublin 53)
- Coolant equipment
- Swivel parallel vice
- Set of collets
- 3-jaw chuck
- Vertical milling head
- Rotary table

2 Universal milling machines (Sixis 103)
- Coolant equipment
- Vertical milling head
- Parallel vice
- Set of collets
- Slotting head

International organizations

F. CLAUS
Delegate
Swiss Foundation for Technical Assistance
Zürich, Switzerland

D. LOCKWOOD
Manager of Programmes in Engineering Technology
International Centre for Advanced Technical and Vocational Training
Corso Unita d'Italia 140
Turin, Italy

F. F. PAPA-BLANCO
Chief of the Research Section
International Centre for Advanced Technical and Vocational Training
Corso Unità d'Italia 140
Turin, Italy

G. VALLE
Vice President
International Council of Societies of Industrial Design (ICSID)
1050 Brussels, Belgium

1 Multi-purpose machine (Meyer and Burger)	Coolant equipment 3-jaw chuck Face plate Steady rest Dividing equipment Set of collets
4 Shapers (Gack)	Machine vice
1 Shaper (von Roll SH 500)	Machine vice
1 Hobbing machine (Mikron 102)	Coolant equipment Cutter support Set of collets Set of cutters Set of exchange gears
1 Surface-grinding machine (Maegerle F-7)	Coolant equipment Magnetic chuck Universal vice
1 Surface-grinding machine (Tripet MHP 500)	Coolant equipment Magnetic chuck Dial indicator Wheel-balancing device
1 Cylindrical grinding machine (Studer-1/universal)	Coolant equipment Dial indicator Wheel-balancing device Internal grinding attachment Steady rest Set of collets Face plate Grinding vice
1 Cylindrical grinding machine (Tschudin HTG 400/universal)	Coolant equipment Dial indicator Wheel-balancing device Internal grinding attachment Magnetic chuck 3-jaw chuck Face plate Set of collets Grinding vice
1 Engraving machine (Kuhlmann GMI/1	Dividing head Vice Set of templates

1 Engraving machine (Grafograph IT)	Dividing head Vice Set of templates
1 Band saw (Moessner Record SM 320-B)	
1 Screw-cutting lathe 60 mm diameter (Luthy)	
5 Surface plates	400X 500 mm
1 Radial boring machine (Oerlikon)	
2 Drilling machines (Aciera 22 S-1 VR)	Coolant equipment Drill chuck: 0–13 mm Drills: 0–22 mm
2 Drilling machines (Fehlmann P-18)	Coolant equipment Drill chuck: 1–13 mm Drills: 1–18 mm
2 Drilling machines (Fehlmann TB-8)	Drill chuck: 1–8 mm
1 Drilling machine (Aciera 10 K-2)	Coolant equipment Double spindle
Drilling machine (Aciera 10 K-1)	Coolant equipment Drill chuck: 0–10 mm
1 Drilling machine (Aciera 6 K-1)	Drill chuck: 0–6 mm
1 Tapping machine (Aciera ET-3)	
1 Drilling machine (Aciera E-3)	Drill chuck: 0–3 mm
1 Hand shearing machine (von Arx)	
1 Hand bending machine	
1 Tube-bending machine (Bykart AG)	
1 Slitting saw (Adige P-60)	
1 Power hack-saw (LWB)	
2 Arbor presses	
2 Marking tables	

B. Tool-grinding section

1 Tool-grinding machine (Kellenberger 57 – W)	Coolant equipment Dividing equipment Internal grinding attachment Machine vice
1 Universal tool-grinding machine (Dubied – 564)	Coolant equipment Dividing head Vice Inclinable table
1 Cutter-grinding machine (Kuhlmann SU – 2)	
1 Tool-grinding machine (Ifanger Senior)	Coolant equipment Twist drill-grinding attachment
4 Tool grinder (Ifanger)	
1 Polishing machine (Reishauer)	

C. Testing and control room

1 Measuring machine (SIP Type MUL 300)
1 Electronic length-measuring instrument: 1/10,000 mm (TESA)
1 Universal hardness tester (Hauser)
1 Profile projector (Hauser)
1 Temperature-humidity recorder
1 Gear tooth caliper
Gear tooth micrometers: 0 – 50 mm
Thread micrometers: 0 – 50 mm
Slip gauges, quality DIN 1: 0.5 – 100 mm
Slip gauges, quality DIN 0: 0.5 – 50 mm
1 Measuring cylinder
1 Sine bar
1 Height gauge: 600 mm
1 Surface plate, scraped: 400 X 500 mm
2 Control benches, with illuminated magnifiers

D. Measuring tools (in tool crib, for general purposes)

4 Precision calipers: 200 mm (TESA)
2 Depth gauges: 150 mm (TESA)
4 Precision micrometers: 0 – 25 mm (TesaMaster)
2 Precision micrometers: 25 – 50 mm (TesaMaster)
2 Precision micrometers: 50 – 75 mm (TesaMaster)
2 Precision micrometers: 75 – 100 mm (TesaMaster)
1 Set, inside micrometers: 6 – 100 mm
1 Set, depth micrometers: 0 – 25 mm

6 Dial indicators: 1/100 mm
1 Dial indicator: 1/1,000 mm
2 Lever indicators: 1/10
4 Measuring magnifiers
Magnetic stands for dial indicators
1 Hand revolution counter

Gauges and control instruments

1 Set, plug gauges: mini-maxi: 4–16 mm diameter
1 Set, thread gauges, plugs (go/no go): M 2–M 20
1 Set, thread gauges, rings M 3–M 20
1 Set, taper gauges: 0–4 (Morse)
1 Precision straightedge
2 Star prisms
1 Control prism
1 Spirit level, square
1 Spirit level, straight
3 set, feeler gauges
4 Sets, radius gauges, concave-convex: 1–25 mm
4 Sets, thread-pitch gauges: metric-English
1 Set, thread gauges (universal gauges to grind cutting tools)
2 Slide rules (for tolerances)
4 Measuring tapes: 2 m
1 Measuring tape: 20 m
10 foot rules: 200 mm
1 rule: 1 m
5 Precision straightedges
1 Set, fitter's squares: 200 X 130 mm, 300 X 180 mm, 500 X 1,280 mm
5 Precision try squares
5 Precision try squares with bevelled edges
5 Try squares for toolmakers
2 Precision angle gauges (TESA)
2 Universal angle-setting devices
1 Centering gauge
4 Precision tracing height gauges

Electrical control equipment

4 Multimeters (CEMA IV)
2 Galvanometers (EMA)
1 Galvanometer (Phywe)
1 Wattmeter (Chauvin)
1 Luxmeter (Gossen)
1 Instant thermometer (QUARZ T–5)
1 Ph-Meter, measuring electrodes

E. Fitter-equipment (personal hand tools)

24 Workbenches with 48 vices
48 Tool cases with 4 drawers each, fixed under the workbenches, containing:
1 Universal caliper: 250 mm (TESA)
1 Micrometer: 0–25 mm (TESA)
1 Bevelled straightedge

1 Try square with bevelled edges
1 Measuring tape: 2 m
1 Foot rule: 200 mm
1 Centre punch
4 Screwdrivers
1 Marking scriber
6 Chasers
1 Bench brush
1 File brush
1 Brush, round
1 Brush, flat
1 Divider
4 Precision pliers
2 Chisels
1 Hammer: 200 g
1 Hammer: 500 g
1 Hand cutting tool
1 Parallel clamp
1 Hack-saw
1 Oil pump
1 Pair of soft-jawed pliers
1 Pair, safety goggles
15 Files: various sizes and shapes
1 Oilstone

F. General hand tools:

5 Gripping clamps
1 Set, forged presses: 60–125 mm
1 Set, carpenter's presses: 100–400 mm
2 Sets, double-ended spanners: 6–36 mm
1 Set, double-ended spanners: 5/16 in - 1 in
2 Sets, spanners: 4–7.5 mm
1 Set, socket wrenches: 5–32 mm
2 Sets, socket wrenches with plastic handles: 2–10 mm
4 Sets, Allen keys: 1.5–12 mm
2 Spanners (hook type): 180 and 250 mm
2 Sets, Philips screwdrivers: No. 01–4
4 Sets, screwdrivers
4 Sets, watchmaker's screwdrivers
4 Sets, offset screwdrivers
2 Sets, dynamometric screwdrivers
2 Universal pliers
4 Side-cutting pliers
4 Flat-nose pliers: 120 mm
4 Round-nosed pliers: 120 mm
4 Long-lever, round-nosed pliers
2 Long-grip pliers: 200 mm
4 Adjusting pliers, straight
4 Adjusting pliers, bent
1 Set, circlips pliers: inside and outside
1 Multi-grip pliers
1 Pipe tongs: 3 in
1 Vice-grip pliers: 175 mm
2 Cable stripper

4 Tweezers: pointed and straight
4 Tweezers: bent
4 Tweezers: with needle points
1 Universal spring winder
2 Sheet-metal cutters (for holes)
2 Goldsmith's scissors
2 Lever cutters
1 Set, paper scissors
1 Set, carpenter's tools
3 Sets, various hammers: steel, plastic, rubber, wood, lead
Flat chisels
Cross chisels
Groove chisels
2 Sets, chasers
1 Set, pulley and bearing pullers
1 Set, 3-legged puller for diameters up to 200 mm
2 Sets, screw removers
2 Sets, tap removers
4 Sets, hand knurling tools
4 Sets, numbering punches: 2 5 mm
4 Sets, lettering punches: 2–5 mm
1 Set, templates (letters and numbers): 60 mm
100 Sets, tool tokens
1 Electroscriber for metals
10 Sets, taps and dies: M 1–M 16
2 Sets, taps and dies/pipe threads: 1/8 in–1 in
1 Set, broaches for keyways
Various sizes and shapes of hack- and fret-saws
10 Sets, hand reamers: 0 20 mm
10 Sets, tapered reamers: 2–9 mm
10 Sets, adjustable reamers: 6–20 mm
Various brushes of different shapes
Various oilstones and Arkansas stones: square, round and triangular
10 Triangular scrapers
6 Flat scrapers
6 Hand engravers, burnishers
6 Soldering irons: various sizes
Safety goggles for: soldering, welding and grinding
Files of special shapes and sizes
20 Sets, watchmaker's files
2 Electric hand-drilling machines (Perles)
1 Electric hand grinder
1 Electric plastic-welding device

G. Machine cutting tools

5 Sets, shell-end mills: 30–80 mm diameter
5 Sets, shell-end mills for roughing: 50–63 mm diameter
6 Sets, cylindrical cutters: 50–63 mm diameter
10 Sets, end mill cutters with cylindrical shank: 2 flutes
10 Sets, end mill cutters with cylindrical shank: 4 and more flutes
4 Sets side and face cutters, plain and staggered teeth: 0,4–15 mm
2 Sets, gear cutters, module 0,5–3 mm
2 Sets, gear cutters (generating): M 0,3 2

6 Sets, T-slot cutters: 2–12 mm
5 Sets, counterborers, with guides: 5.9–30.5 mm diameter
5 Sets, counterborers, with guides: 5.9–14.5 mm diameter
Various double and single angle cutters
Various radius cutters: concave and convex
4 Sets, slitting saws

Drills

10 Sets, twist drills for steel: 0.3–20 mm diameter; steps 0.1 mm up to 10 mm
5 Sets, twist drills for brass: 2–10 mm diameter; steps 0.1 mm
3 Sets, twist drills for aluminium: 2–10 mm diameter
4 Sets, twist drills, cemented, carbide tipped: 6–20 mm diameter
4 Sets, twist drills for steel: 1/16 in–1 in diameter
10 Sets, machine taps: M 2–M 10
10 Sets, machine reamers: 1.48–20 mm diameter; for various materials and tolerances

Turning tools

10 Sets, tool bits (HSS): 8 × 8 mm, 10 × 10 mm, 16 × 16 mm, 20 × 20 mm
5 Sets, thread-cutting tools (Ifanger) 60° and 55°
15 Sets, facing tools: left and right
10 Sets, parting-off tools: various sizes
Various cemented carbide cutting tools for roughing, finishing, outside and inside turning

Miscellaneous machine tools

2 Sets, reduction sleeves, steel and plastic
3 Sets, knurling tools: different systems
3 Sets, disc-cutting tools for up to 200 mm diameter
4 Sets, turning arbors: 3–20 mm diameter
2 Sets, grinding arbors: 3–20 mm diameter
3 Sets dogs (carriers) for up to 80 mm diameter

H. Heat treatment

1 Electrical furnace, with timer (Safed–Type 10 S 42)
1 Electrical furnace, with salt bath (Safed–Type 10 M 30)
1 Electrical furnace with air circulation (Safed–Type 6 SL 30)
1 Container with quenching oil
1 Container with quenching water
1 Potassium bath
1 Exhaust fan

I. Welding section

2 Mobile gas welding sets (Continental)
1 Arc-welding generator (Brown-Boveri)

J. Painting and sand-blasting section

1 Spray-painting cabin (Napp, Zürich)
1 Electric oven
1 Sand-blasting cabin (Bremor Mb 40)

K. Electroplating section

Electroplating plant (Langbein and Pfanhauser)
Water purification plant
Refrigerator
Exhaust system

L. Smithy

Furnace, with exhaust system
Anvil
Blacksmith's vice
Various hammers and tongs

M. Sheet metal section

1 Sheet-bending machine
1 Trimming press
1 Nibbling and shearing machine
1 Creasing machine
2 Workbenches, with vices
Various hand tools, soldering irons etc.

N. Carpentry section

1 Circular saw
1 Band saw
1 Drilling machine
1 Belt grinding machine
1 Fret-sawing machine
2 Sets of carpenter's hand tools
2 Carpenter's workbenches
1 Planer/thicknesser
1 Moulding machine, with dovetailing attachment
1 Tool grinder
1 Circular hand saw
1 Hand chain-mortizing machine
1 Mitre saw

HOW TO OBTAIN UNITED NATIONS PUBLICATIONS

United Nations publications may be obtained from bookstores and distributors throughout the world. Consult your bookstore or write to: United Nations, Sales Section, New York or Geneva.

COMMENT SE PROCURER LES PUBLICATIONS DES NATIONS UNIES

Les publications des Nations Unies sont en vente dans les librairies et les agences dépositaires du monde entier. Informez-vous auprès de votre librairie ou adressez-vous à: Nations Unies, Section des ventes, New York ou Genève.

КАК ПОЛУЧИТЬ ИЗДАНИЯ ОРГАНИЗАЦИИ ОБЪЕДИНЕННЫХ НАЦИЙ

Издания Организации Объединенных Наций можно купить в книжных магазинах и агентствах во всех районах мира. Наводите справки об изданиях в вашем книжном магазине или пишите по адресу: Организация Объединенных Наций, Секция по продаже изданий, Нью-Йорк или Женева.

COMO CONSEGUIR PUBLICACIONES DE LAS NACIONES UNIDAS

Las publicaciones de las Naciones Unidas están en venta en librerías y casas distribuidoras en todas partes del mundo. Consulte a su librero o diríjase a: Naciones Unidas, Sección de Ventas, Nueva York o Ginebra.

Printed in Austria

Price: $U.S. 1.50
(or equivalent in other currencies)

United Nations publication

70-6060–April 1972–3,700

Sales No.: E.72.II.B.2

ID/67

27-11-74

Annex 2

STATEMENTS TO THE MEETING

Statement by N. K. Grigoriev, Director of the Industrial Technology Division of UNIDO

There is increasing awareness that, for the success of industrial growth, the developing countries must depend to a considerable extent on their capability to create and adapt industrial design to meet local requirements. The indiscriminate adoption of existing designs is often unsuccessful and seldom leads to the best use of available raw materials, machinery or manpower. This is particularly evident in cases where available technology on which certain designs are based is not suitable to local needs or conditions. We therefore believe—and this view has been supported by the Industrial Development Board—that the design capability of a developing country should be developed to a degree that will permit it to keep pace with its industrialization efforts. We realize that, in many such countries, these capabilities are still at a very early stage, and that efforts to create industrial design are in their infancy. It has been urged that particular attention be given to such important considerations as assuring that the design is functional, practical and in harmony with the environment. Good design should be adapted to the prevailing climatic conditions as well as assure the reliability of the product. Finally, design should be aesthetically pleasing; this is a very important consideration, not only for local markets but even more for foreign markets.

Considerable work has been done in many countries to make products suitable to the local climate; the adaptation of equipment to tropical conditions is now considered largely a matter of routine. Even so, the appropriate design of adequate cooling and ventilation devices, particularly heat-generating equipment, must be continuously under study.

Another important factor that must be considered in product design, and one often imposed on the designer through import controls, is the need to use local raw materials and components. This restriction should be given attention in new design or the adaptation of existing design. This is an important problem that we hope you will discuss in depth during your deliberations. The major potential contribution of UNIDO to developing countries in the field of design capability is assistance in the establishment of engineering design centres. Notable examples are the Institute for Design of Electrical Measuring Instruments in India, which deals with the design, production, testing and quality control of electrical measuring instruments, and the Engineering and Industrial Design Development Centre in the United Arab Republic, which was established in 1968 for the design and production of prototypes of engineering products. In Tunisia, UNIDO is assisting in the establishment of a centre for the development of prototypes and the production of metal-cutting tools, dies and metrological instruments. Other institutes whose aim is to give assistance to developing countries in design are being organized in the Philippines and in Singapore.

It is the desire of UNIDO to enlarge its assistance to the developing countries in order to increase their proficiency in engineering design. We hope that you will point the way to the most suitable means of transferring this know-how to those countries that have reached a level of industrialization at which the development of their own design capabilities would greatly contribute to their self-sufficiency.

Statement by O. V. Soskuty, Chief of the Engineering Industries Section of UNIDO

Let me outline briefly the task before us and make a few suggestions as to how this work might best be accomplished.

The agenda includes several problems connected with the initiation, expansion and improvement of the capabilities of developing countries in engineering design. Among them are design and prototype building, training in design, organizing of design and engineering development, and defining the role of design centres and other means of transferring the techniques of design to the developing countries. In submitting these problems for discussion to you, who have come from developing and industrialized countries, we hope to illuminate the problem from both sides. We hope to learn about the difficulties that stand in the way of modern engineering design in developing countries and to receive advice from the experts present from industrialized nations as to how these obstacles might be removed.

With us at this meeting are the project managers who organized the first design centres that began their operations under the sponsorship of the UNDP Special Fund. These projects were the first organized efforts of UNIDO to improve design capabilities within a specific industrial field. We look forward to discussing with these men their experiences and to receiving their advice at first hand.

In case some of you would be interested in seeing the design department of a modern machine-tool factory, we have taken advantage of the generous invitation of Maschinenbau Heid AG in Stockerau to make such a visit possible for all participants who wish to make use of this opportunity.

UNIDO looks forward eagerly to the recommendations that you will make on the basis of your discussions. These recommendations should be oriented in three directions: to the developing countries to the industrialized countries and to UNIDO. They will be formulated by your drafting committee and presented to you for your approval toward the end of the meeting. The success of this meeting will depend on these recommendations as one of the most important and immediate results. I urge you, therefore, to keep these ultimate goals in mind during your discussions.

The report of the meeting, together with your recommendations, will be submitted to the Executive Director and will be widely distributed in developing countries as an aid for the future development of their engineering design capabilities. We hope also that you will form the vanguard by bringing our conclusions here to the attention of the appropriate government authorities and the industries of your countries.

Statement by N. N. Krainov, Technical Secretary of the meeting

We have met here to discuss important problems connected with the promotion of engineering design capabilities in the developing countries, and I hope that the meeting of this group of experts will make a valuable contribution to the promotion and improvement of this important line of industry.

In many of the developed nations, the introduction of engineering design began at a late stage of industrialization, because more attention was given initially to problems of basic manufacture. Only later did these countries understand the importance of designing activities.

The developing countries can benefit from the experience of the industrialized nations by improving their indigenous design facilities simultaneously with their manufacturing process, thereby reducing the time lag in their growth to full industrial capacity.

Inevitably, in the early stages of development of a country, an industry must lean heavily on the developed nations to provide the means of production. However, as soon as centres of manufacture have been established, the developing country will feel a need for the introduction of new ideas or for modifications of existing equipment to suit national habits, customs and circumstances. At this stage the developing country requires experienced designers. If such personnel have not been identified, trained and prepared before this stage is reached, its industry will inevitably continue to depend on the developed countries for design work.

UNIDO is ready to give technical assistance to such countries by sending designers from the industrialized nations to train local personnel, as well as by establishing engineering design/development centres within the country. A few UNIDO-assisted centres are presently being established. Their purpose is to give attention to such problems as the collection of technical information about new design and production and the standardization of industrial products.

On behalf of UNIDO, I thank each of you for coming to this meeting, and I sincerely hope that you will find it interesting and rewarding.

Annex 3

LIST OF DOCUMENTS PRESENTED TO THE MEETING[1]

ID/WG.56/3 and Corr. 1 ID/WG.56/3 Summary and Corr. 1	Establishment of facilities for electrical equipment development, design and prototypes in developing countries *By R. M. Rowell*
ID/WG.56/4 and Summary Add. 1	Manufacture of prototypes by centres *by A. Sennhauser and F. Claus*
ID/WG.56/5 and Summary	The problems of adopting constructions and their production *by Lajos Bálint*
ID/WG.56/6 and Summary	Modern practice in engineering product design of various products such as industrial machinery, equipment and consumer goods *by M. Kronenberg*
ID/WG.56/7 and Summary	Production of prototypes by centres and their introduction in various branches of industry in the developing countries *by H. W. Hein*
ID/WG.56/8 and Summary	Improvement of engineering design capabilities of the developing countries (with particular reference to automotive components) *by Emil F. Gibian*
ID/WG.56/9 and Summary	Some thoughts on the creative aspects of engineering design *by B. W. Turner*
ID/WG.56/10 and Summary	Development of engineering design capabilities in the developing countries *by M. Fouad Hussein*
ID/WG.56/11 and Summary	Organization and structure of scientific engineering centres in the developing countries and the role of technical laboratories and experimental shops *by V. S. Belov*
ID/WG.56/12	Considerations on development of engineering capabilities *by A. I. Anguelov*
ID/WG.56/13	Form and design *by C. Auböck*
ID/WG.56/15	A short note on the status of engineering design capabilities in India and a proposal for a design centre for developing countries *by A. K. De*

[1] A limited number of copies are available upon request.

ID/WG.56/16 Add. 1 Add. 2	Centre for precision mechanics *by A. Jentet*
ID/WG.56/17	Engineering and industrial design development centre activities in Cairo, UAR *by the secretariat of UNIDO*
ID/WG.56/18	Engineering design capabilities in India *by the secretariat of UNIDO*
ID/WG.56/19	Computer graphics in engineering design and analysis *by D. V. Ahuja*
ID/WG.56/20	Development of engineering design in Brazil *by J. A. Frota*
ID/WG.56/21	Engineering design capabilities in Tunisia *by the secretariat of UNIDO*
ID/WG.56/24	Machine tool design and projecting office in the tool industry in Poland *by W. Uzarowicz*
ID/WG.56/25	Product design and plant design *by the secretariat of UNIDO*
ID/WG.56/26	Some aspects of industrial design development in Nigeria *by M. I. O. Ero*
ID/WG.56/27	Tridimensional approach to teaching for industry *by F. F. Papa-Blanco*

Annex 4

PRESENT STATUS OF DESIGN CAPABILITIES IN SOME DEVELOPING COUNTRIES

The participants who came to the meeting from developing areas were asked to report on the present status of industrial design in their own countries. Some of their statements are summarized below.

Brazil

This country is far enough along the road to industrialization to have initiated an aircraft industry; the first Brazilian bimotor aircraft, the Badeirante, will go into production as soon as two prototypes have been built and flown successfully. The production facility, which is government-owned, will also fabricate certain Italian jets under licence.

Although some good design work has been, and is being, done, Brazil is still largely dependent upon foreign sources of technology.

Since little precise information about industrial design in Brazil is available, it is inadvisable to generalize about it. Nevertheless, the following can be presented with reasonable confidence.

In São Paulo, IPT has developed several products that have have gone into commercial production by domestic industry. Some examples are foundry and powder metallurgy products.

A design centre, IPD, has been established in São José dos Campos, in association with the Technological Centre for Aeronautics. It comprises three departments: materials, electronics and standardization.

Several centres for industrial development have been established in the northeastern part of the country. They are basically concerned with the implantation and continued viability of industry, but with some modifications and improvements, which are now being made, some of them could be associated with design centres. A consistent and determined effort to identify and plan projects of strong interest to individual centres should be rewarding.

In several of the constituent states of Brazil, a school of engineering is associated with a technological research institute. At present, most of these institutes function much like materials-testing laboratories, although some of them, notably IPT in São Paulo, have established the conditions for becoming real design centres. In some cases, foreign co-operation could be helpful.

The central Government is actively interested in these developments; problems related to location, type of industrial support, specific purpose, financing, and recruitment and training of staff are the subjects of a series of consultations with experts.

Bulgaria

The People's Republic of Bulgaria is taking effective measures to speed up its industrialization, notably in the production of chemicals and of electrical power, in food and light industry, and in machine-building. In all of these branches, special efforts are being made to incorporate the latest developments in the fields of technology, automation and the organization of production. Also, a policy of industrial concentration and specialization of production is being implemented.

Such all-round modernization of existing industry and the relatively immense scale of construction of new industries in a country as small as Bulgaria has generated the need for a large number and great variety of devices for the automatic measurement, regulation and control of production processes. This equipment is needed not only for domestic production facilities but for plants built for export. To satisfy these demands, a series of ten plants specializing in the production of these devices has already been built, and Bulgaria proposes to complete ten more such plants by 1975.

In collaboration with UNIDO, Bulgaria has set up, in Sofia, its national capital, the Electrical Engineering Research and Design Institute. In order to ensure a maximum return on the assistance that it has requested, the Bulgarian Government has allotted this new institution a prime building site, approved the construction of a new and modern building for it, and is providing the means for equipping it with domestically produced machines.

The following forms of assistance from UNIDO are envisaged:

- The sending of experts, for periods of one or two years, assigned to the principal activities of the Institute to assist the Bulgarian specialists in organization and in scientific and technical control;
- Supplying the most important modern machines and appliances required for successful functioning of the Institute;
- Providing modern language-training equipment for the use of the specialists.

The last-mentioned of the above is of particular importance, since the number of Bulgarian specialists who have knowledge of English, French or German is rather small, so that access to the technical literature in these languages is quite limited, although special courses have been organized to cope with the problem.

By providing technical assistance and guidance to Bulgaria's burgeoning technical instrument industry, the Institute is expected to permit substantial reduction of the country's imports of both raw materials and prefabricated components, as well as to stimulate growth in related fields.

Hungary

With the end of the Second World War, the immediate problem that faced this country was that of industrial reconstruction; only after this immense task had been nearly completed could there be a change of emphasis to the design and production of consumers' goods. The production of machine tools is still regarded as the critical area of industry, but a number of foreign companies such as Grundig (Federal Republic of Germany) have been permitted to set up production facilities in the country. Some research centres already have been established; the time is now ripe for the development of design centres.

India

India already has an appreciable technical instrument industry. Indeed, some enterprises market their products abroad. Some of the firms are long established, having been founded even before national independence was achieved in 1947; others were started more recently by new entrepreneurs who recognized a need and have endeavoured to satisfy it.