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LIMITED

ID/WG.[illegible]/14
15 February 1970

ORIGINAL: ENGLISH

United Nations Industrial Development Organization

Expert Group Meeting on the Development
of Engineering Design Capabilities in
Developing Countries

Vienna, 11 - 15 May 1970

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id.70-898

The importance of developing engineering design capabilities cannot be overstressed, for as world population increases and the world's resources are devoured more voraciously, so there is a need to create new artifacts to aid survival. These in turn alter man's environment and so further change occurs. In short, technology is self-propagating - technology begets technology, and it is technology that has helped to bring about the increased population. A vicious circle has thus been set up whereby increasing technology generates additional survival problems. (pollution, etc). These new problems are solved by further technology. Unfortunately two concurrent effects are taking place. Firstly, the technology demanded is becoming very costly and requires immense effort and, secondly, unless all the previous stages of development have been passed through, it is impossible to tackle some of the problems posed and, therefore, technological advance has become very uneven throughout the world. The latter effect is a real problem for developing countries. If they are to reduce the technological gap they must carry out a massive educational campaign and encourage creativity. Then they must increase productivity of the right kind and this requires a creativity being applied in the engineering field.

At the moment the production gap between the developed and the developing countries is about 12:1 in terms of production per head. On present prediction this will widen to 18:1 by the end of the century unless active steps are taken now. To stem and reduce the growth of this gap it would seem to be desirable to arrange for the less advanced countries to go through the process of industrialisation that Europe and North America have passed through in an accelerated form.

An essential element of such industrialisation is engineering design of all types. One creative ability that the developing countries possess that is rapidly becoming absent in the higher standard of living areas is their ability to 'make do and mend'. To capitalise on this the less advanced countries could be provided with equipment which has been superseded in the well developed countries. This should be possible at low cost, and would have the added advantage of 'easing' the population into creative design. They would become familiar with mechanical and electrical plant and become adept at repair, maintenance and reconditioning, and by this means would have an adequate entrée into engineering design. Unfortunately, the reverse often occurs, for, in practice a developed country will often supply its latest technology which is justified on efficiency grounds, rather than send its left off equipment. This is probably due to competition between the providers of aid, and UNIDO might well act as a vetting agency for capital goods to ensure that the most appropriate equipment and plant is obtained for the developing country concerned.

While the developing countries with their various needs are all clamouring for technological help, it is they who say what help they require, and from whom. This can be wasteful and lead to lack of building up creative engineering design. Here again, UNIDO might act as a neutral adviser so that ecological equilibria are not disturbed too violently. If too big a technological jump is taken there will be little hope of encouraging indigenous design ability and the worst features of affluent nations may well be passed on, causing an attrition of the emerging nation's resources.

The papers produced for this Expert Group Meeting cover a wide range of engineering ability. Their titles are listed in the Appendix to this report, which endeavours to bring together the main features and suggestions of all of them. Finally, some recommendations are listed which again, are drawn from the individual contributor's papers and from the general overall impression obtained while writing the report.

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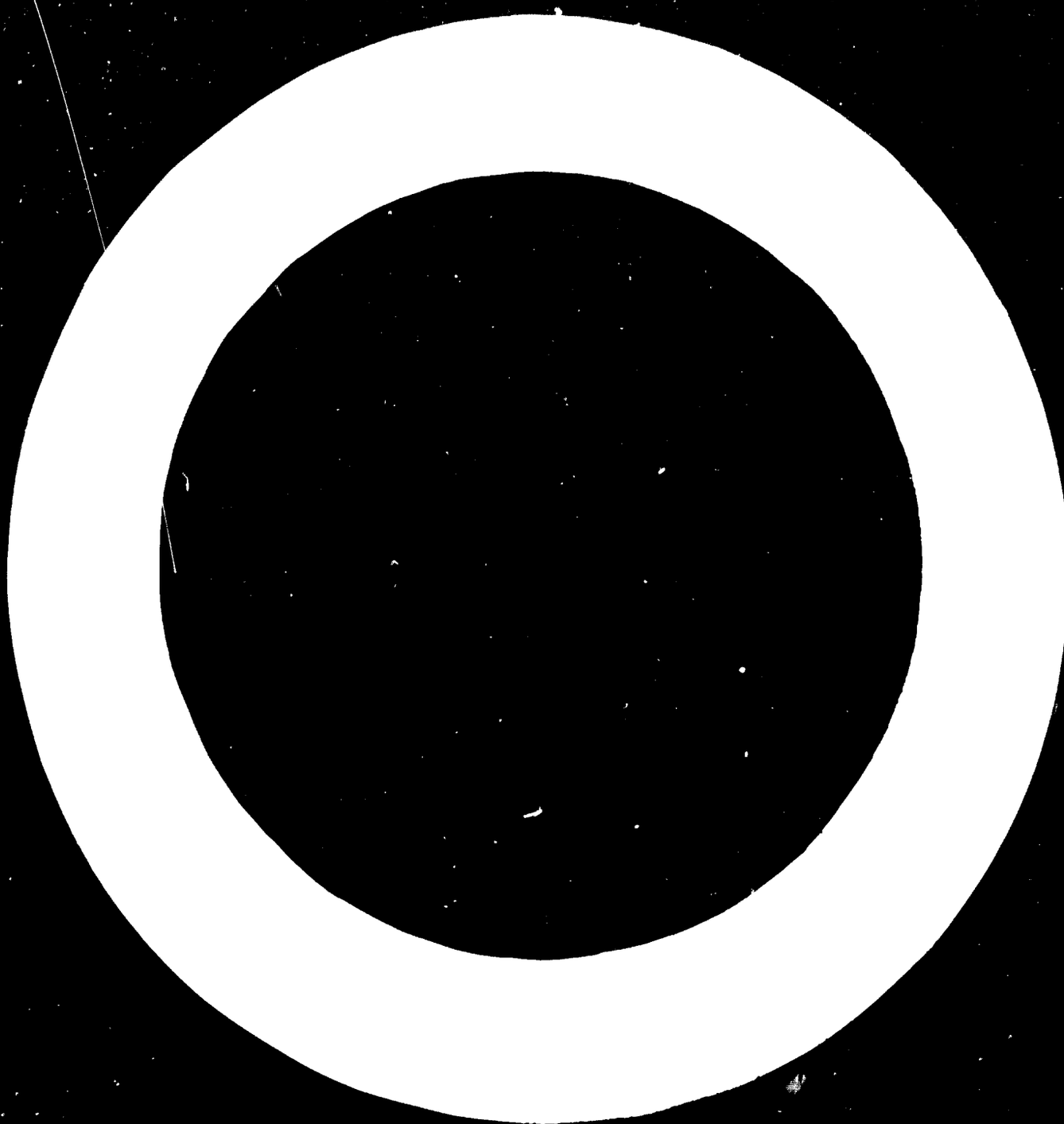

THE DEVELOPMENT OF THE ENGINEERING CAPABILITIES IN THE DEVELOPING COUNTRIES

1. THE IMPORTANCE OF THE DEVELOPMENT OF ENGINEERING DESIGN CAPABILITIES

Engineering design is one of the main foundations for creating, promoting and maintaining industry in any country. Without viable designs industry will not flourish in a developed country and never become established in a developing one. Engineering design is the link between science and technology and it seeks to translate knowledge and ideas into useful hardware economically.

The nature of the design process is such that it is set in motion by a result of either; a conscious identified need being specified by a customer, or an engineer or scientist proposing an application of a new scientific advance, or an engineer or a commercial man recognising a requirement for the creation of a new product.

Design consists basically of three main activities. There is the mental creative thinking and analytical effort to visualise the final product. Then there is the processing of available or generated information to realise the proposed design. Finally there is the communication phase to transfer design intent, or the prescription to those who will produce the design in solid form. New ideas, new data and information are continually being created during the iterative process of design.

Inevitably, in the early stages of the industrialisation of a developing country they must lean heavily on the developed countries for providing the means of production. But once places of manufacture have been established the developing country will feel the need for introducing new ideas, or modifying existing equipment to suit their people's natural inclinations, habits, customs and circumstances. It is at this stage that the developing country requires experienced designers. If such personnel have not been identified, trained and developed before the onset of this stage, then inevitably they will turn to the developed countries for further help.

It is vital to appreciate that the development and training of designers must by synonymous with the commencement of industry in the country concerned. Much planning and care is necessary to develop satisfactory indigenous designers and design teams. It must also be emphasised that design work is slow and often expensive. Time will be required to train competent designers and this is a major problem. Future key indigenous designers must start with gaining an insight into the design process by working backwards from existing hardware supplied by developed countries.

Design work for developing countries must apply to that country's needs. There is becoming an increasing interaction between engineering design and society. The optimum engineering design will have to consider more than ever, the sociological, economical and political implications as well as the pure engineering factors. Often equipment designed in a developed country is unsuitable for an emerging one, because it does not take into account the different customs and culture. Furthermore, unfortunately the latest technology is often supplied causing too great a technological leap to be taken and possibly causing a disturbance to the ecological balance which can be harmful. It is, therefore, imperative for all developing countries to seek to have their own corps of engineering designers and to train and develop them to meet their countries' needs.

2. IDENTIFICATION OF NEEDS AND FINANCING

Before any design work is embarked upon it is important to ascertain the real needs of a country to avoid wasted effort and to get priorities correct. This necessitates carrying out penetrating surveys conducted by competent market research people. Initially developing countries will have to rely on outside help for this work.

2:1 Identification of Areas Requiring Design

In order to establish design requirements on a priority basis it is essential to carry out a full survey of possible projects and products. Government priorities must be known so that they survey starts off with the overall master national plan, and works down from this with individual market analysis.

First this should be completed for capital goods and then for consumer goods. By a general market analysis is meant a study which deals with the problems of a particular country and predicts the financial gain that could accrue from a design innovation. It would also attempt to predict any possible competition and sales effort required. (Paper No.4* mentions industrial market analysis briefly in its opening paragraphs). A developing country will lack accurate or indeed, any statistical data on imports, consumption and registration of existing factories, etc. and, consequently, will need to have foreign experts available to assist them in carrying out field and desk market research work. (Paper No. 5).

2:2 Classification of Engineering Design Work

The full spectrum of design in engineering is considerable, varying from small consumer goods to large capital plant, one view of this spectrum is given in Paper No. 1 (Figure No. 3 para. 2. p.3). Paper No. 6 sets out the various kinds of electrical equipment most likely to be needed by developing countries.

There is also the aspect of industrial design and general engineering design. It must be emphasised that these two aspects are not separate, but part of a whole. They can be differentiated by the nature of the work involved in each of them. This difference has been set out in Paper No. 2 (Chapter II p.14). Here the illustration of the architect and civil or structural engineer in the field of construction work is likened to the industrial designer and mechanical/electrical designer in manufacturing and process work.

Both types of designers are complementary and need to work on the product or system design throughout the complete design process. It is useless to call in an industrial designer to make an engineering design look good and handle and operate

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* See Appendix No. 1 at the back of this paper which lists all the papers prepared for UNIDO on the 'Development of the Engineering Design Capabilities'.

well at the end of the design process. He must work in harmony with the complete design team right from the start of the design.

Yet a further division of design may be identified as system design and component design. Here component design refers to the design of a simple product as well as a component in a system, essentially it may be defined as a piece of equipment with a single function. System design, on the other hand, is formed from a collection of components so arranged that they contribute to the required overall function. The system so formed may be designed as 'closed' if it adjusts by feedback of its output which is compared with its input and then automatically applies correction. If, however, the input is simply transformed into output with no attempt to correct for errors the system is designated as 'open'.

In a sense all products form part of system, for even a domestic appliance has to fit into an existing energy supply system. Hence, the designer has to understand the essential nature of the input to his new creation, and what output he has to obtain, and how it will fit into an existing configuration.

Proper systems engineering is really concerned with large units having a multiplicity of inputs and outputs with many sub-systems.

With all these types of engineering design the nature of the design process remains essentially the same, see Paper No. 1 (Figure No. 2 p.4).

The classification of engineering products required by any developing country will depend upon its basic needs and the support it receives from other countries. If large generating plant is supplied then distribution products may be an essential design area. If an extensive transport system

is to be set up then design for automotive components would possibly be a priority (See Paper No. 3). Mining and petrochemical industries will almost certainly be required and a conglomeration of process control equipment and apparatus will be required. Certain domestic products, such as kitchen utensils and small hand tools may well be essential for all developing countries. These would form a separate category of products and are alluded to in Paper No. 4.

2:3 Need to Establish Sectorial Design Centres

In view of the market studies carried out and the consequent classification of products to be designed, certain design centres or institutes should be established. (Paper No. 3 gives a brief review of some typical established design centres in the USSR, Netherlands, Canada and England). The desirability of such centres stems from the importance of conserving and utilising the inevitably limited number of designers that will be initially available. It would be pointless for designers to be spread thinly and sporadically to various industries, since design is best done by teams of creative individuals. The design centres would allow such teams to be formed and give them an opportunity to develop their capabilities. A design centre for automotive products could cater for many related industries, (bearings, seals, crankshafts, springs, etc.), having factories carefully sited near it.

Similarly, a design centre for agricultural machinery would be an essential requirement. Here the first step would be to get designers to consider the substitution of indigenous materials say, and then to go on to the more difficult design task of producing better suited machines for the local terrain and conditions. (See Expert Group Meeting on Agricultural Machinery Industry in Developing Countries, Vienna 18-22 August, 1969). Likewise, mining and petrochemical industries are likely to be required in any developing country and appropriate design centres for these basic industries will be required. Here design would concentrate on the design of pumps, valves, pressure vessels, mechanical excavators, etc.

2:4 Cost of Design and Point of Finance

The ultimate aim would be for all designs produced to be viable and, wherever possible, to cost in a considerable cost/benefit advantage. However, in the early stages of a developing country's life it will be difficult to achieve this and it will be necessary, very often, to subsidise design centres. Here UNIDO could help - possibly with direct financial grants or loans.

As the design centres gain experience it should be possible for some kind of cost control system to be applied. Here design target costs could be set up and designers would be expected to work to these. If they exceeded their budgeted allowance a special case would need to be made in order to sanction additional monies to complete the design work.

3. DESIGN PROBLEMS

Initially, it would seem desirable to deal with designs which will yield quick benefits to the whole population of the country concerned. Furthermore, it is important to try to use indigenous resources wherever possible. Paper No. 2, Chapter V has suggested that the handcraft industries already existing could be greatly helped by suitable portable tools which would enable production to be increased immediately. Design for these 'cottage type' industries would give fresh impetus and possibly attract additional foreign customers.

In the long term, however, designs will be required for the manufacture of machinery and spare parts for the basic industries of a country, such as mining, cement works, petrochemical industries, electrical generation, and machine tools, etc. In such cases it will be necessary to adapt foreign designs to meet domestic requirements.

3:1 Adaptive Designs for Domestic Needs

It should be possible to adapt existing designs for developed countries by taking out manufacturing licences. Where this is done it is important to recognise that the licence and the

attendant documentation may not supply all the required 'know-how'. Here indigenous designers may need to liaise closely with the licenser by visiting the actual designer's works. Very clear and careful documentation will be required and the organisation and management of design adaptation will need to be 'tight' (See Paper No. 1, Figure No. 4). The testing of the modified design must also be carefully controlled and prototypes must be environmentally tested. (Paper Nos. 3 and 5).

3:2 Creative Designs for Domestic Needs

Here the problems are far greater. The management must be of a different style - a more 'athenian' approach being necessary. Great care must be exercised to ensure that all the factors are taken into consideration, and that the optimum solution to the sum of the true needs of a particular set of circumstances is obtained. The main problem will generally be time. Probably some systematic approaches should be used and designers must be well versed in the latest design methodologies.

3:3 Modernisation of Existing Designs

Here the problems are less arduous since, in general, field operational experience will have been obtained previously. The need for systematic recording of field defect and their analysis becomes of paramount importance. The failures will point the way to where designs can be modernised and improved. (Paper No. 4 cites the case of defect reporting of machine tools). It is essential for developing countries to institute some easy defect reporting system as early as possible in their industrialisation process.

3:4 Standardisation and Technology in Designing

In this age it goes without saying that design standards, when they are created in developing countries, should be in metric. In this connection it should be remembered that a problem may well arise when licensing if the sponsoring country has its design in the inch system, and the receiving country uses

metric, for both systems need handling differently and conversion to metric from inches takes time, and can lead to tolerance difficulties. (See Paper No. 8 - Part II).

A standard may be looked upon as a single solution to a repetitive problem - it is one of the main tools of a designer together with codes of practice and specifications. A code of practice is a 'thou shalt use' document and seeks to give reliable up to date guidance for installation and operation of plant and machinery.

Standardisation can be looked at from three main levels. International (I.S.O.), National (B.S. in England) and Company Standards. In general, Company standards will be developed from National Standards where possible.

Design centres must have complete sets of I.S.O. Standards and seek to start to create their own standards. Standardisation opens the door to interchangeability, a vital factor in design work.

Details of the latest technology can also modify design practice and design institutes or centres will need to be supplied with such information, particularly with regard to new manufacturing processes. (Laser cutting and welding, plasma spraying.).

The problem in both these areas is one of updating the information once a memory bank has been created. Initially considerable help will be need to sift, collate and store documents so that they are readily retrievable. Ideally, some standards organisation should be set up for the developing country concerned and all design centres and prototype centres should become members of such an organisation. (See Paper No. 5).

4. PROTOTYPE PROBLEMS

In order to perfect designs and get them operating satisfactorily

it would be essential to have some centres where prototypes can be manufactured and tested. Moreover, such centres should, where possible, be located near to or adjacent to, design centres, so that designers may see their creations being manufactured and constructed, and learn by positive feedback at first hand, any deficiencies that occur. This is covered in more detail under 'Development Centres, para. 6 of this report.

4:1 Organisation of Production of Prototypes

The organisation of a prototype centre is really a mixture between a factory of general layout, a co-operative purchase society and a technical training institution. (See Paper No. 5 para. 1:4).

In order that the main functions may be discharged satisfactorily there must be a general administrative unit, production department and some kind of education and training unit. It may also be necessary to have a design department if the designs are not supplied by design centres or from actual factories. In the developing countries, from an organisation point of view, it would seem preferable to concentrate all the design work at design centres at least initially. However, it would certainly be necessary to have the design of tools, jigs and fixtures at the prototype centre, and this should be part of the production department. This can present a problem for good designers in this area are hard to obtain and would need special training.

4:2 Quality Control, Testing and Adjustment

Quality control requires very special consideration throughout the whole process of manufacture. There must be adequate sampling checks taken on incoming materials, components and sub-assemblies. Hence, some form of goods inward inspection is necessary. Then the necessary quality checks must be applied during manufacture and assembly and adequate 'in-process' gauging should be available. Often, this would need to be designed if the best utilisation of men and machines

are to be obtained. Here again, a problem exists since this work often entails instrument design. Final inspection would need to be carefully set up to ensure that no faulty assemblies are passed on to the test bays. Again, the proper recording of defects and proper salvage facilities would need to be set up. Similarly, the adjustment and settings required to equipment would have to be properly documented and kept up to date. Generally speaking, the main problem in this area of work concerns the acquisition of proper measuring instruments, adequate, accurate documentation with careful analysis. This again demands training and considerable experience.

A special case of testing would be with certain items of equipment and capital goods products where type testing would be a mandatory requirement. This would be necessary to ensure safety by proving the reliability of the product over specified times. (See Paper No. 6).

4:3 Co-operation between Manufacturers and Designers

It is important to appreciate that design and production should never be in self-contained departments, but form part of the same continuum, often in the industries of developed countries an unhealthy dichotomy has sprung up so that 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 is a very good communication link between the two activities.

Such communication will ensure that adequate co-operation is achieved for no design can be economical unless it takes cognisance of the manufacturing capabilities of the producing concern.

4:4 Provision of Components

In certain cases it may be desirable for the concern building

a prototype to manufacture its own components according to need. But there will in all probability be a need for obtaining certain items of equipment from manufacturers elsewhere in the country concerned. Purchasing of these requires technical skill as well as business acumen for cost, delivery, quality and reliability has to be correct. This also applies to obtaining parts from other countries which have to be imported.

4:5 Assistance in Future Product Development

This can come from a number of areas, such as private industry, foreign companies, industrial associations, Government and International agencies, including UNIDO. Designers will need to be kept in touch with all these sources by correspondence and possibly visits. In this connection the design centre will need to publicise its work and the information obtained for carrying out design work to the above institutions, so that they are aware of where they might help and vice versa. This could also apply to modernisation of existing products where companies and governments recognise a new need arising, or spot a worthwhile improvement.

4:6 Introduction of Modern Technological Processes in Industrial Production

Here it is vital to the health of the developing country that as new processes become known and may be developed at design/prototype centres that all 'know-how' is immediately made available to industrial enterprises. Special open days with demonstrations must be arranged, so that industrialists can witness, at first hand how any new technological process works, and what application is required to make it operate in an industrial environment satisfactorily. Even in developed countries, very often new processes are developed in Government research establishments and languish for years, due to lack of liaison with industry and poor publicity and little insight by the originators into the real problems of industry.

The introduction of say, plasma coating into an automobile factory which has not used the process before needs careful handling. (See Paper No. 3).

5. Training in Designing

5:1 Selection and Development of Creative People

There is no known formula that will ensure creative thought, although individuals may well develop strategies which leed to plans of action covering certain phases of thought. Mr. E. Matchett has worked on these in his 'Fundamental Design Method' approach. This method has been very helpful to some engineering designers, and it is a tenet of the method that a proper identification of creative people must be made before they come on to the course. Selection here is generally by recommendation from the industrial enterprise concerned.

Creativity is, in general, more easily recognised than defined. One definition says that creativity represents the ability to get out of a mental rut and the ability to look at things in new and different ways. H.G. Conway, Chairman of the C.E.I.* Working Party on Creativity has defined the word in the engineering context 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'.

Creativity does not appear to be linked directly with intelligence, which can be measured to some degree. Paper No.1 suggests some pragmatic ways of possibly ascertaining the most likely creative people. But as yet it does not seem possible to devise meaningful tests, although research work is going on in this sphere.

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* C.E.I. - Council of Engineering Institutions

De Bono has suggested some courses which may prove useful*. More work is essential if proper identification is to be obtained.

As far as development of creative people is concerned in engineering new forms of teaching along the lines of Edward Matchett and Misha Black seem desirable. Matchett's work is discussed in Paper No.1 and Misha Black is Professor of the School of Industrial Design (Engineering) at the Royal College of Art, London, England.

Undoubtedly, much more effort is necessary to understand how the creative person operates and is motivated. Such work could be carried out both in developed and developing countries.

5:2 Project Work in Schools and Institutes

The project method especially if carried out by non homogenous groups, can provide a very useful learning situation. For engineering the design-and-make project exposes the learner to all the problems concerned with turning an idea into hardware. Experiments carried out at the English Electric Management Training Centre at Rugby, England, have demonstrated this on a number of occasions (Paper No.1 Appendix No. VI refers to this).

Schools projects have also been very fruitful and those conducted by English Electric and Esso in England have borne much fruit. As a country develops it should be possible to introduce projects, which are carried out by groups of students, at the top classes in schools. This would have the benefit of widening their horizons and introducing them early in life to the process of design.

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* The five-day course in Thinking, by E. de Bono.

5:3 In-Plant Training and Research

Much would be gained by having on-the-job training carried out effectively for designers, Much here depends on management - will they recognise that it is part and parcel of the manager's job to train and develop his subordinates. They must seek to be good tutors. Much could also be done by formalised training whereby designers from one firm are seconded to other firms for a period of time to study and contribute to their design methods. This is also true of research, but here the secondment would need to be of at least two years duration.

There has been little research into design matters and possibly UNIDO should sponsor some scholarships so that capable students in developing countries could visit and study design work in developed countries. Certain basic design work training could also doubtless, be carried out in design centres of developing countries when they have become established and recognsied as places of excellence.

5:4 Design Methods and Aids

Systematic design methods have grown extensively over the last decade and will doubtless increase even more as creative thinking is analysed and understood. Paper No.1 sets out the advantages of these and how they help designers and design teams. An analogue of some of the most used methods is given in Figure No.9 of that paper.

Generally speaking all of these methods need adapting to the particular product or system design concerned and to suit the particular working environment. A good example of such an adaptation was the development of PABLA* from the Fundamental Design Method by a Government Research Department in the U.K.

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* PABLA stands for Problem Analysis by Logical Approach

All designers need to be made aware of the latest aids to help in the design process. It is sometimes from quite simple aids that the greatest benefit may be derived - e.g. models made out of cardboard or balsa wood, stickers and tapes for doing quick drawings, perspective grids, etc. Specialist engineering designers must also become familiar with both digital and analogue computer operations. This would, in most cases, require designers in developing countries using machines in developed countries. In these days of increasing use of data links this will not be so formidable as it might at first seem. But software awareness will be a problem unless adequate dissemination of programs is made available. Information centres as mentioned earlier in Paper No. 2 will be required for this purpose. (See also para. 5:[illegible] below)

5:5 Education and Training of Future Designers

Much care and thought will need to go into developing the education and training pattern of developing countries. Doubtless initially, the identified best designers should be sent for training to the developed countries' design centres and industries, so that they can absorb what is already known and understand design in the light of modern technology.

However, eventually there must be a proper recognised educational pattern for designers in the developing countries; the sooner this is established the better. If possible the country concerned should seek to make this career pattern widely known and attach status to those who achieve success in this field. Too often in developed countries designers are looked upon as inferior engineers and most glory is attached to research and development engineering work. Developing countries will have a good opportunity to reverse this trend or at least make for parity of status.

So much engineering teaching in developed countries tends to iron out design ability (creativity). Curiosity, finding out for

oneself and using imagination are often stifled , as 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'.

5:6 Training and Sources of Knowledge

All designers live on information, they have an insatiable appetite for new technical data and facts. Any developing country will need to set up a library and technical information centre to cope with the enormous amount of present day published data. It may be desirable to put these information bases at the design centres, initially. But later, when development has taken place, regional information bases will be required for local industries. Probably it would be best for particular regions to specialise in certain types of information.

Some form of regular publication listing current accessions and standards, etc. would need to be published by all information centres. It would be particularly important to have, wherever possible, a unified classification system so that collation and retrieval of information would be made easier and could, in the years ahead, be computerised if necessary.

6. ORGANISATION OF DEVELOPMENT CENTRES

Development in engineering design may take place before or after or during the design process depending upon the circumstances.

There is, however, also advanced development which is generally only undertaken in those areas where engineering problems can be clearly recognised a long way off. The purpose of such development work is usually to add to design information in the early creative stages or to provide feedback earlier in the process.

The need for development work may arise because of error in design, lack of method or data, or worst of all, lack of an adequate specification.

The characteristic activity of development is to reveal any discrepancy between performance and specification and suggest ways of reducing it. In other words development is design carried out by other means.

6:1 Aims and Objectives of Design Development Centres

For the reasons given above it would seem desirable to introduce design development centres as complementary to sectorial design centres (See para. 2:3). From an organisational point of view they should be sited adjacent to each other so that frequent face to face communication can take place and hence ensure rapid feedback of information. For developing countries specific areas where development centres will be of particular use are:

6:1:1 Design Adaptation

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

terrain topography of the developing country.

6:1:2 Design Creation

Where large complex design projects are undertaken, such as a new transport system or atomic power station, they are usually initiated because some existing system of goods, services or information no longer answers the customer's need. Furthermore, it may be so remote from what is now possible that very deliberate means are required to force the new system into existance. Here design creation is required and development tends to become the epic phase in the process.

Here development work will be necessary when parts of a system are being designed. The specification to which the part is being designed has generally been derived from a larger, more comprehensive, description. Although there may be doubts as to how well this deduction has been made, the total number of uncertainties involved can be kept to a minimum if the performance of the part meets the specification. Hardware made to the design must be tested and, if necessary, changes made. (See Report Nos. 3 & 4). Initially, in developing countries such large projects will not be undertaken but it must be borne in mind when setting up development centres that ultimately such work may have to be undertaken. Also, when parts are actually being made to new designs the results are often poor. Typical reasons are: inadequate instructions, lack of skill, inappropriate tools, wrong materials, or merely that the method of manufacture simply does not work.

Obviously not all these shortcomings can be put right by changes in design, but whatever action is taken generally needs the support of development.

Finally, when the system is put together for the first time there is need of development work. Interfaces which were

imagined by the designer now exist in reality as mating plugs and sockets, etc. The system performance will have been deduced from separate tests on several co-operating parts previously tested on their own. The input to these parts were, in all probability provided by signal generators. (i.e. sources of electrical or mechanical power), the outputs were given to measuring instruments. Now the parts are flanked by other parts which give and take.

6:1:3 Construction of Experimental Models or Prototypes

This has already been alluded to para. 4:1 of this report. Prototypes will be needed for experiemntal tests but even more important may be the models which may be made-up for strength, vibration and deflection testing during the process of design. For this purpose experimental production workshops will be necessary. They must in all ways be comparable with the best known manufacturing practice. The equipment selected should be such that all jobs of the centre's activity could be carried out within them, including jigs, fixtures, press tools and control gauges, etc. Special considerqtion will need to be given to toolmaking in this connection.

6:1:4 Testing and Adjustment of Models and Prototypes

Testing will require special consideration in developing countries and the right kind of measuring equipment and environmental test equipment must be available. Aesthetic and ergonomic factors will also need to be considered in the final testing phase of prototypes. For consumer products potential customers should be asked fo try the products and comment on how they handle and what, if any, eye appeal they have.

6:1:5 Introduction of Prototypes into Industry

If maximum contribution to the economic development of any industry is to be achieved the selection and production of prototypes to be produced is very important. The main danger lies in developing 'attractive prototypes' without guarantees that the industry is really in a position to

manufacture them, and perhaps without there being any real demand for them, in the country concerned. (See paper No.7).

A warning is necessary here for too often in developed countries products have been rushed into production which have successfully passed prototype testing; but the end result has been a failure and very costly to put right. This is because the prototypes were built up by very skilled fitters, craftsmen and technicians who adjusted the parts without feeding back what they did to design. Furthermore, the plant capabilities in the factory were vastly different from the machines in experiemntal workshops making the prototypes.

6:1:6 Organisation of a Repair and Maintenance Service

The manufacturing unit of the development centre should offer service and repair facilities to all the country's institutions - hospitals, government industries, private industry, research centres, etc. This would have considerable benefits for training future designers, as experience of failures and defects would reveal design weaknesses.

Likewise, spare parts might well be produced in the prototype workshop thus helping to even out the shop loading and again afford valuable experience. Also designers might start on their careers by applying value engineering to spare parts to evolve cheaper and better parts manufactured from indigenous materials.

6:2 Structure of Design Development Centres

Paper No.7 suggests that there are two possibilities for setting up design development centres:

a) Have a completely self-contained separate organisation containing all the necessary divisions, such as design, marketing, documentation, laboratories, packaging, and manufacturing.

b) Have an organisation which is closely connected with a training

centre which has the necessary facilities to produce prototypes.

The a) alternative means that the design centres would be on the same site as the development centres and that all relevant information would be on hand. There seems to be no reason why a training centre should not also be placed alongside so that the development centre becomes the teaching laboratory for students. The whole complex would then be responsible for new designs and their development as well as training experts in industrial design, engineering design and development and the whole gamut of industrial production. The logistics of the placement of individual industries and the relationship with one another is important to developing countries. The lessons slowly being learned by developed countries through takeovers and mergers leading to concentration and specialisation where complex, sophisticated technology is being developed should be noticed. The relationship of basic industries to design and prototype centres is also important and Paper No. 8 Parts I and II give some guidelines on these important aspects.

For developing countries the setting up of such centres of excellence would seem to be highly desirable, rather than having separate teaching/training centres. There seems little doubt that one of the major educational and training failures of the developed countries for engineering design is the divorcing of academic, theoretical training from live practical work. If this could be avoided by developing countries seeking to establish all embracing engineering centres great benefits should accrue in the future.

Initially, it would be desirable for such centres to be set up with UNIDO expert help to get them established and get some training going for the nationals. In this connection it is imperative that the right kind of work is chosen to start off the centres. As Paper No. 7 states, it is no good trying to produce the most advanced engineering items, but rather the simple yet very useful articles for day to day and domestic use. Items such as electric switches, door locks, latches, handtools, etc. would have a wide application and make a better contribution and technical assistance than some sophisticated equipment.

6:3 Technical Staffs

The most important asset of any organisation is the staff and it is essential to select good technical people. They must have adequate qualifications, but also the necessary human abilities. It is recommended that candidates should be given certain psychological tests conducted by experienced specialists so that their human qualities can be gauged. It will be the responsibility of the director of the centre to select a well balanced team of technologists and technicians. A teaching aptitude would also be desirable although not absolutely essential, but good all round industrial experience must have been obtained by the prospective candidates.

In all probability there will be insufficient candidates whose qualifications and abilities in design and production are adequate and, therefore, initially it is recommeded that chosen UN experts would be needed to fill key positions. At some future date these positions could be taken over by nationals when they had gained sufficient experience.

It is vital to the wellbeing of a centre of excellence that good salaries are paid and these should be above the equivalent offered by industry to avoid poaching and luring away well qualified staff. For if such centres are to really get going they must at all costs preserve their qualified manpower.

Again, for the good of the centre it is highly desirable that staff are allowed time off to do consultancy work from time to time, so that they can keep in touch with the industrial practice and situations in their own country.

6:4 Buildings

Good quality functional building should be provided with adequate lighting. No embellishments in the form of luxurious industrial palaces are required.

The layout should be carefully arranged with a logical flow from feasibility study offices to design to delineation and finally, production/test and despatch.

The positioning of the office complex should be central with laboratories, workshops and environmental test bays, etc. positioned around them. This makes for easy access and therefore good communication. All services should be run in ducts with loose covers placed on the side walks for ease of access. Adequate capacity for growth in terms of cable and pipe sizes must be considered. Proper air conditioning may well need to be provided depending upon the climatic conditions of the site. Paper No.6 details essential requirements for designing and locating such buildings.

6:5 Equipment

6:5:1 Workshops

This will depend upon the nature of the work to be undertaken but certain standard equipment will be required at all such development centres. Caution is necessary, however, to avoid choosing all the latest automatic machine tools, since maintenance could be troublesome without expert assistance. Far better to have conventional machine tools of high quality with all the necessary additional equipment to make possible maximum utilisation. Cutting tools of standard type will also be necessary and their attendant grinding machines to maintain them. Para. 6.10 of Paper No. 7 lists the type of overall equipment which might be required for a precision manufacturing centre. While Paper No. 6 sets out in detail the type of equipment for electrical equipment.

6:5:2 Laboratories

All centres will need standard measuring equipment and special laboratories will need additional equipment such as heat treatment furnaces, fatigue testing apparatus and general rigs for testing mock-up and prototypes.

6:5:3 Design Offices

Here a proper layout is essential so that competent designers have adequate work stations. These will include draughting machines, layout tables, work benches for modelling (Paper, balsa wood, etc). and cameras. (polaroid type).

Adequate reprographic equipment will also be needed and it is recommended that microfilm facilities be provided for both reading and producing prints which can then be easily stored. This would avoid future trouble which is now emerging in developed countries where storage and adequate retrieval has become a problem.

In addition to each senior designer's own work bench there may, in certain instances, be a need for a separate mock-up and model shop. This should be located adjacent to the main drawing office.

Drawing offices need to be spacious and of open plan style with designer's offices placed round the periphery. It is important to form the latter with moveable partitions to give added flexibility.

7. RECOMMENDATIONS

7:1 For Developing Countries

If the developing countries are to foster and encourage engineering design creativity then it is considered that the following action should be taken by them:

7:1:1 Establish some form of design centre(s) or institutes strategically placed with respect to local industries. Here selected designers could be trained and effectively used. They would form the élité and the country would need to build up its design work by using this team of designers. The selection of creative designers is difficult and will require some research.

7:1:2 Select creative nationals and have them properly trained in engineering design. Such training might take two forms:

i) Attending university post graduate courses in design in a well developed country. (Such as Loughborough, Aston, Royal College of Art, in the U.K. or Manioba Design Institute in Canada).

ii) Undergoing industrial training overseas in small to medium size industrial firms in a developed country.

7:1:3 From 7:1:2 obtain a group who would be able to teach others how to carry out engineering design. Some consideration might be given to teaching engineering design by a 'back-to-front' method, relevant material for this would have to be collected, collated and put into teaching form, possibly using automatic group learning techniques.

7:1:4 Development centres where prototypes are produced should be established near or adjacent to design centres, so that the designers can validate their creations and gain confidence in their work.

7:1:5 Design work initially should be confined to simple applications (righthand side of Figure No.4 of Paper no. 1), so that know-how and confidence is built up. The applications should be appropriate to the country's requirements and their resources. Value engineering/analysis could be used as a working tool for replacements parts, etc. In the first instance, some licences of useful equipment should be taken out so that designers and production engineers may gain some experience.

7:1:6 Particular attention should be paid to the management of design at the design institute so that the correct working environment is established, and it must be realised that senior designers need to be supported with technician designers. Provision for the education of technicians in the design sphere will need to be considered.

7:1:7 Good designers take time to develop and some of the best ones should be seconded for a year or two to do design research in a developed country. Such research work, however, must be directly related to problems encountered in the developing country concerned. (e.g. use of indigenous resources). (This would avoid falling into the present trap of providing good designers to the developed countries and hence, contributing to the brain drain).

7:1:8 Any design centre will need to create its own information system, and data banks. This will take time and require planning. (Such information banks should contain case studies of recorded systematic design work, as well as design data - standards, quality, guides, properties of materials, particularly any indigenous material, etc.).

7:1:9 Identify and classify the required engineering design work to be carried out and plan accordingly. Initially help will be required to do this.

7:1:10 Important consideration must be given to the supply of adequate jigs, fixtures and tools, as well as basic manufacturing machines. Design of fixtures, etc. must be considered in parallel with product design.

7:2 For Developed Countries

Considerable help could be made available to all developing countries if the developed countries were to give access to their higher educational facilities as well as their industrial activities, in particular:

7:2:1 Certain scholarships might be made available to designers in developing countries to allow them to study design methodologies, etc. They should also allow them to become familiar with the latest design aids (Digital and Analogue computers). An introduction to computer graphics may also be useful.

7:2:2 A limited number of travelling scholarships should be established to enable designers from the developing countries to travel abroad to inspect at first hand, the work of other design teams. This would apply to both the industrial designers and the engineering designers.

7:2:3 When licence agreements are entered into it would be advantageous if experts from the developed country concerned were sent to the developing country concerned for a period until adequate know-how had been built up.

7:2:4 Developed countries should supply all information required about design work such as standards, codes of practice, quality guides, etc.

7:2:5 Make available training places in certain medium and small industries specialising in basic products.

7:2:6 Consider placing manufacture of simple designs into developing countries to get them started. (viz. English Electric factory in Madras, India, producing switchgear and relays, etc.).

7:3 FOR UNIDO

While all developing countries require technological help it is essential that the correct aid is provided and this may require expert advice from UNIDO to ensure that valuable resources and time are not wasted. In particular UNIDO should offer specific aid as:

7:3:1 Expert assistance should be made available to the developing countries to enable proper market surveys to be conducted. From these surveys a priority list or lists of engineering products or systems could be established. (Certain basic industries would require immediate work to be carried out, e.g. mining and petrochemical).

7:3:2 From 7:3:1 above plans could be drawn up with the developing country concerned and UNIDO should then be able to ensure that a all relevant information about such products and systems is made available.

7:3:3 From the information supplied lists of equipment required could be drawn up and submitted to UNIDO who should assist in securing the capital required.

7:3:4 Steps should be taken to assist with translation work on standards, textbooks and other information supplied by developed countries.

7:3:5 For certain products type testing recommendations should be formulated and agreed with the assistance of UNIDO.

7:3:6 **Sponsor research** work on selection methods for identifying creative designers. Also help by providing experts to carry out psychological tests to choose suitable people for design work.

7:3:7 **Arrange** for a relevant knowledge of production techniques to be made available to design centres in developing countries. The designers must know what the manufacturing capabilities of their country's facilities are and are likely to be in the future, in order to ensure that realistic viable designs are produced. UNIDO should ensure that this information is available for each developing country and ensure that such information is communicated between all these nations.

7:3:8 **Assist** in securing low tariffs for the export of engineering products from developing countries.

7:3:9 **Developing** countries will require assistance in setting up patent systems and UNIDO could assist in this, and foster the use of patents on an international scale.

7:3:10 **Ensure** that adequate information is supplied to design centres on computer programs available in developed countries.

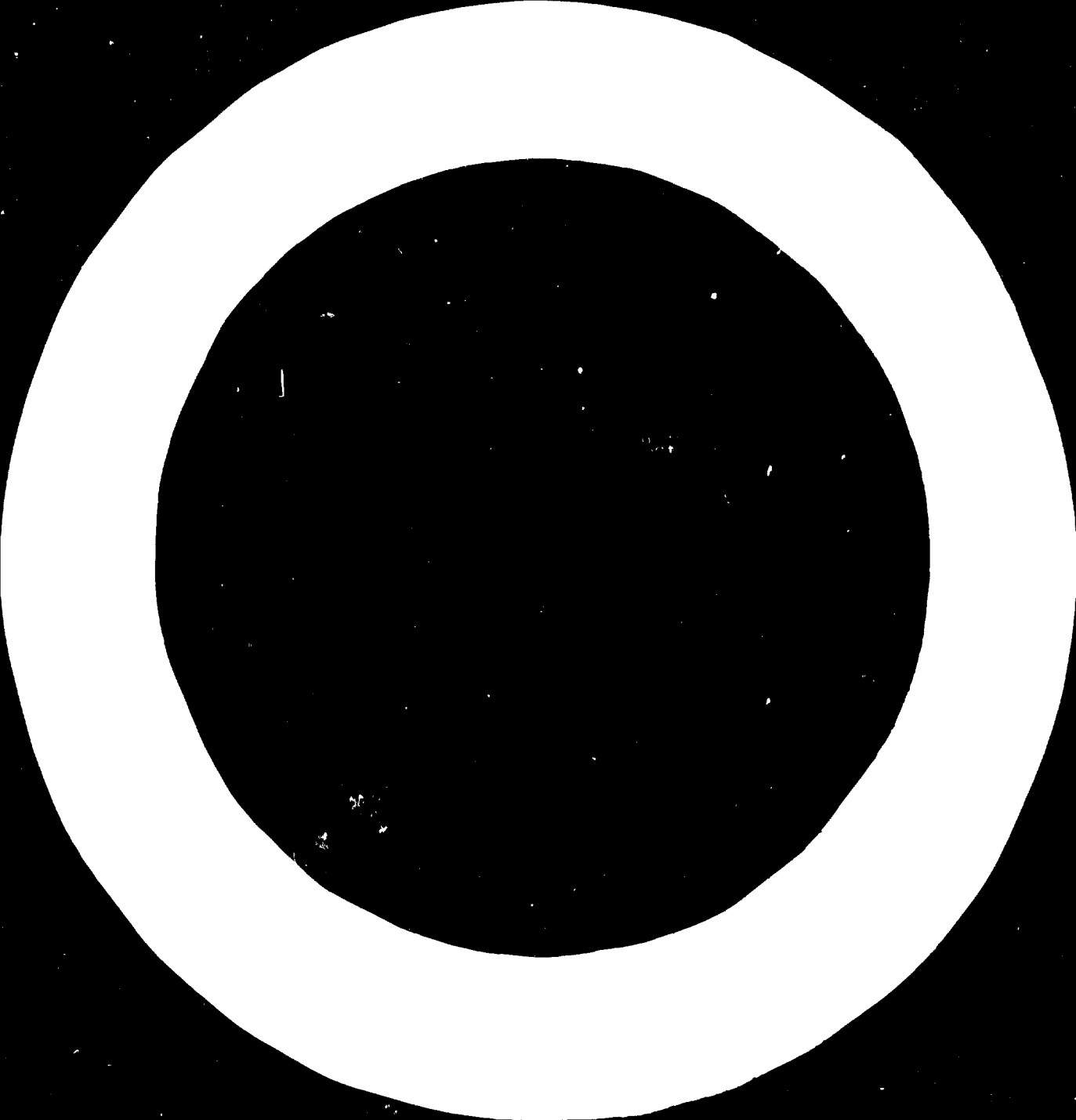
APPENDIX NO. I

LIST OF PAPERS PREPARED FOR

EXPERT GROUP MEETING ON ENGINEERING DESIGN CAPABILITIES IN

DEVELOPING COUNTRIES

Paper No.	Title	Author(s)
1.	Some Thoughts on the Creative Aspects of Engineering Design	B.T. Turner
2.	Development of the Engineering Design Capabilities in the Developing Countries	M. Fouad Hussein
3.	Improvement of Engineering Capabilities of the Developing Countries	Emil P. Ghian
4.	Production of Prototypes by Centres and Introduction of them in Various Branches of Industry in the Developing Countries	H.-W. Meir
5.	Modern Practice in Engineering Product Design of Various Products, such as Industrial Machinery, Equipment and Consumer Goods.	M. Kronenberg
6.	Establishment of Facilities for Electrical Equipment, Development, Design, and Prototypes in Developing Countries.	R.E. Rowell
7.	Production of Prototypes by Centres	A. Sennhauser F. Claus
8. Part I.	Complexity, Specialisation and Concentration of Technology in Machine Industry	Lajos Bálint
8. Part II	The Problems of Adapting Constructions and their Production.	Lajos Bálint
9.	Organization and Structure of Scientific Engineering Centres in the Developing Countries and the Role of Technical Laboratories and Experimental Shops	V.S. Belov



POSTSCRIPT

1. Industrial/Engineering Design

Reference has been made to the work of the C.E.I. (Council of Engineering Institutions) in this report. Attached is a copy of their recommendations for an Engineering Design Council to be established. As will be noted the final recommendation has clearly stated that the present activity of the Council of Industrial Design should incorporate engineering design.

The importance of a combined attack on any design problem from both industrial and engineering aspects is thus now formally recognised in the UK. (See p.3 of this report).

2. Layout of Design/Development/Centres

Paras 2:3, 2:4 in the report speak about design centres and development centres and suggest that these should be located close together. Obviously careful layout of such centres will need to be considered in some depth. There must be adequate room for expansion, they must be flexible in arrangement and, where possible, located near to the industries they seek to serve. By using a circular layout a logical flow of work may be obtained together with the required flexibility. A suggested embryonic form of such a layout can be seen in the attached diagram.

1. Introduction

A country such as Britain which can continue to exist only by its manufacturing and industrial activity, much of it in the engineering field, must acknowledge that design is highly important. The better the design of a manufactured article, other things being equal, the more readily will it sell. It is clear therefore that any steps which could be taken to improve the quality of British design, particularly of engineering products, would be beneficial to the country as a whole.

The word design has many shades of meaning. We are in this report primarily concerned with engineering design as opposed to those aspects of design commonly called "Industrial Design". Even in the case of engineering design there are different meanings ranging from the broad system design of a complex product to detailed design on the drawing board. The Appendix defines the two broad areas of design activity which can readily be identified by engineers, and as understood by those who have prepared this report.

The report proposes that a national Design Council should be set up to stimulate engineering design activity and to match the successful work done on industrial design by the Council of Industrial Design. Indeed it makes proposals for integrating the two activities.

2. Background

The report has been prepared by a Committee set up under the aegis of the Council of Engineering Institutions and serviced on their behalf by the Institution of Mechanical Engineers. Its membership is given on the inside front cover.

It grew out of proposals put forward by the Mechanical Engineering Economic Development Committee which sponsored jointly with the Institution of Mechanical Engineers a Conference on Improvement of Design Performance in 1967. This conference concluded that there was a need for a high level national body to stimulate work on engineering design.

The Committee had the following terms of reference :—

1 To take note of the proposal made by the Conference on Improvement of Design Performance that there should be a high level national body to exert continuing pressure to improve design and design performance, and to determine if there is a need for such a high-level body ;

2 If the need for the proposed body is established, to state its objectives, to consider the form it should take and how it might be staffed and financed, having regard to existing organisations, especially the Council of Industrial Design ;

3 To advise on relationships if any with such other existing organisations ; and

4 To make appropriate recommendations to the Council of Engineering Institutions.

3. The Case for a Design Council

The committee concluded that a case existed for the creation of a Design Council, based on the following points :—

1 That improved design of engineering products was a vital factor in the country's efforts to improve its balance of payments by promoting exports.

2 That engineering and aesthetic aspects of design could not be separated and must be integrated to a degree which depended on the type of product.

3 That there was a need to create a better management climate in which good design could flourish and could be properly appreciated.

4 That there was much to do in promoting improved training of designers and assisting educational and Government sponsored training organisations to this end.

5 That there was much to do to encourage market orientation in the outlook and activity

of designers notwithstanding the wide range of engineering products and the highly specialised nature of many of the markets

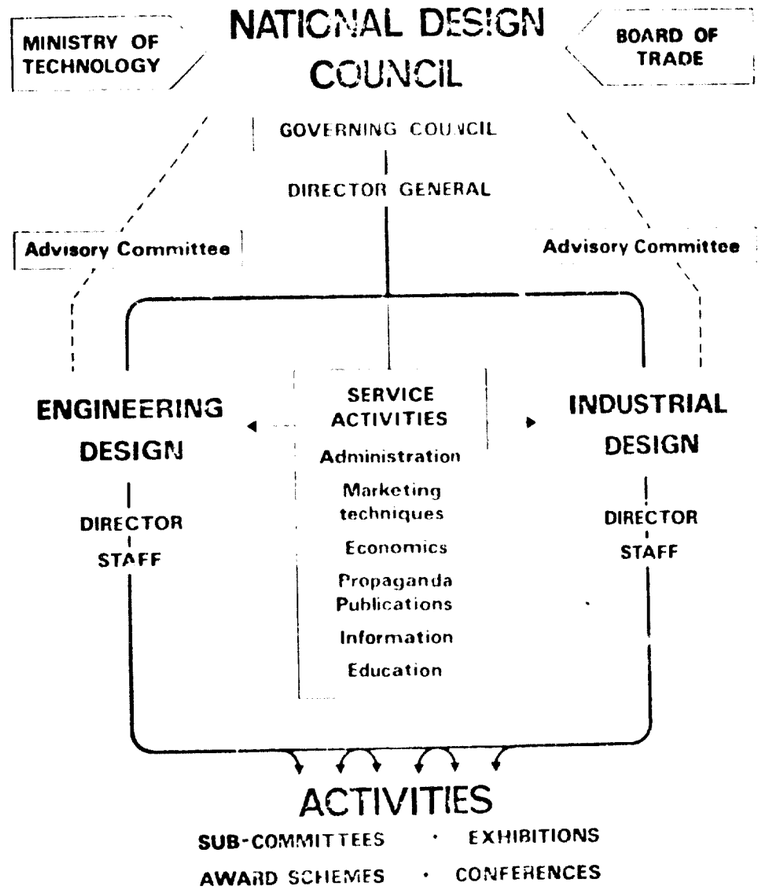
6 That there is a complementary need for the further education of designers to keep them up to date with new techniques by various means including refresher courses

7 That a Design Council could, by acknowledging and stimulating good work and, by granting awards and prizes, do much to raise the status of the design engineer and to stimulate public awareness of his activities

8 That the Design Council might act as a stimulant to innovation replacing in some degree the benefits of technological fall-out from ambitious space and similar programmes carried out in the U.S.A. and the U.S.S.R. which have no direct counterpart in Britain.

4. What a National Design Council would do

The Council of Industrial Design already operates in its own field with considerable success. Its Industrial Division maintains contact with and keeps up the pressure on industry, visits factories to give design advice, organises courses and conferences for industry, provides lectures and articles, offers a Designer Selection Service for firms requiring industrial designers and administers the C.o.I.D. Capital Goods Awards. Its Information Division publicises successful design achievements of industry to general and specialist audiences, produces *Design* magazine, provides the technical and general press and producers of television and radio programmes with current information on Industrial Design, and co-operates with the education authorities on the introduction of design appreciation into the curricula of schools and colleges. Its Exhibitions Division, through The Design Centre and other exhibitions at home and abroad demonstrates the progress made by industry in industrial design



Having regard to this excellent work done by the Council of Industrial Design, the Committee concluded that a national Design Council with an appropriate specialist staff would operate in the engineering field as follows :—

1 It would seek to influence social attitudes, in industry, especially in management, and indeed throughout the country, towards engineering design and designers.

2 It would sponsor special activity relating to training of engineering designers in conjunction with Government training boards and professional Institutions

3 It would arrange a permanent display of new and meritorious designs along the lines of that already carried out by the Council of Industrial Design at The Design Centre for consumer goods

4 It would hold exhibitions and conferences in London and throughout the country relating to good engineering design practice

5 It would encourage manufacturers to run for designers exhibitions or presentations of new materials or processes to stimulate interest in and adoption of, new and improved techniques.

6 It would act as a centre or operate a consultancy service related to modern design techniques, and aids, the use of advanced computer techniques and the like, and to modern techniques of design office management, within the limits of available finance, or as might be arranged, for example, under contract from the Ministry of Technology. And it could publish Data Sheets or leaflets related to design matters

7 It could take over the existing Award for Capital Goods, administered by the Council of Industrial Design, broadening its base as may be appropriate as a means of encouraging better design throughout Industry.

8 It would seek to give prominence to the work and achievements of designers, and award prizes to design teams and possibly individuals for outstanding design contributions.

And as the Council's activities developed no doubt many other matters requiring attention would present themselves.

5. The Proposal

The Committee gave much thought to the advisability of setting up a separate engineering Design Council in parallel with the existing Council of Industrial Design. It noted that while the latter was sponsored by the Board of Trade the engineering industry is the responsibility of the Ministry of Technology. Having regard to the need to treat design as a total process the Committee concluded that it would be unwise to attempt to set up a separate and new organisation and it thus recommends that a new body be created which will not only develop a new Engineering Design activity but also take over the functions of the C.o.I.D. within it. The Committee is confident that from the point of view of economy, speed and efficiency it would be better to build on this existing foundation by recruiting the necessary additional staff rather than to set up a separate organisation. In making this recommendation it is aware that this may require some adjustment in the mechanism of Government sponsorship but does not consider that the difficulties here are insuperable.
The proposal it makes is therefore as follows :—

1 A national Design Council shall be set up to include the present activity of the Council of Industrial Design

2 The Council would have two main industrial streams : one stream concerned with Engineering Design and the other concerned with Industrial Design. It would have a third area of activity providing a service to both of the main streams (see Diagram).

3 The Industrial Design stream would comprise much of the present activity of the Council of Industrial Design. That part of the present organisation concerned with capital goods would be transferred to the Engineering Design group.

4 The third group would comprise the present service activity of the Council of Industrial Design amplified as appropriate to serve the expanded activity of the enlarged Council. This service group would include such activities as market study, publications, economics, and sales and administration. A new section dealing with education should also be set up.

5 The present Council of the Council of Industrial Design would be re-constituted as a Council dealing with the total activities of the enlarged national Design Council, with two of its Advisory Committees being responsible for the activity of the Industrial Design and Engineering Design Groups.

6 The staff of the engineering group would consist of an engineering director assisted by a suitable qualified staff. The engineering director would be a top level qualified engineer of national standing.

6. Finance

The Committee took note of a number of estimates of the cost of operating an Engineering Design activity along the lines proposed. It concluded that the necessary budget was relatively modest in relation to the benefit to the country as a whole. A budget of the order of £250,000 p.a. would appear to be adequate for some time; initially this would need to be wholly covered by a grant. This is to be compared with the present budget of the C.o.I.D. of £800,000 (of which rather more than £500,000 is by Government grant) or of the Arts Council of £7.2M.

7. Recommendation

The Committee recommend that a national Design Council be set up, taking over the present activity of the Council of Industrial Design, and building on its organisation; that it be given an adequate budget; that the new Council include a strong Engineering Design activity led by an engineer of national standing; and that early action be taken to implement these recommendations.

APPENDIX

Definition of Design

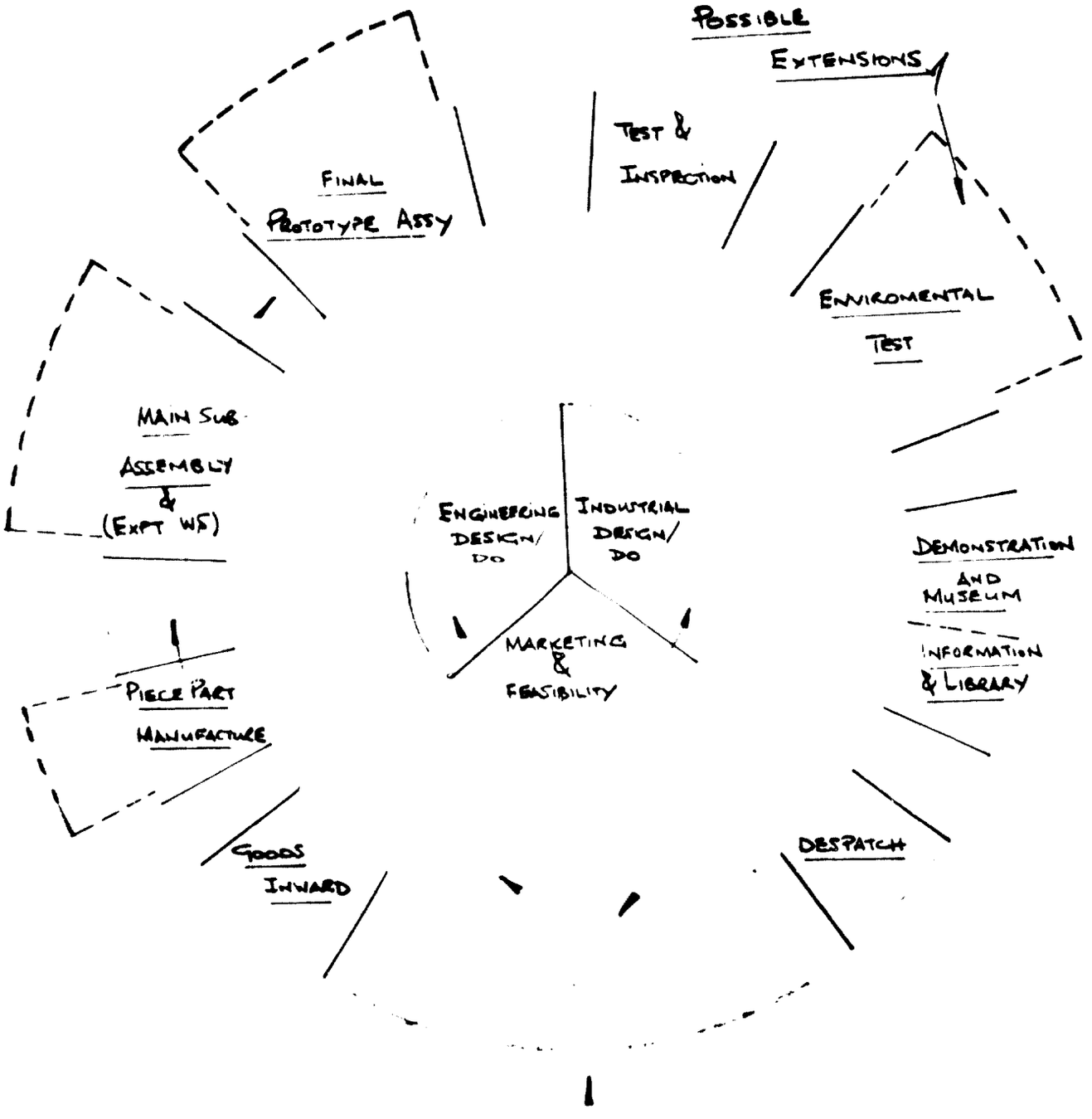
In an engineering context, two broad areas of design activity can be identified (among many).

1 Design in the sense of system design: optimisation of a broad scheme or plant (e.g. a computer or turbine), using new or improved scientific principles (this needs much theory and less actual drawing).

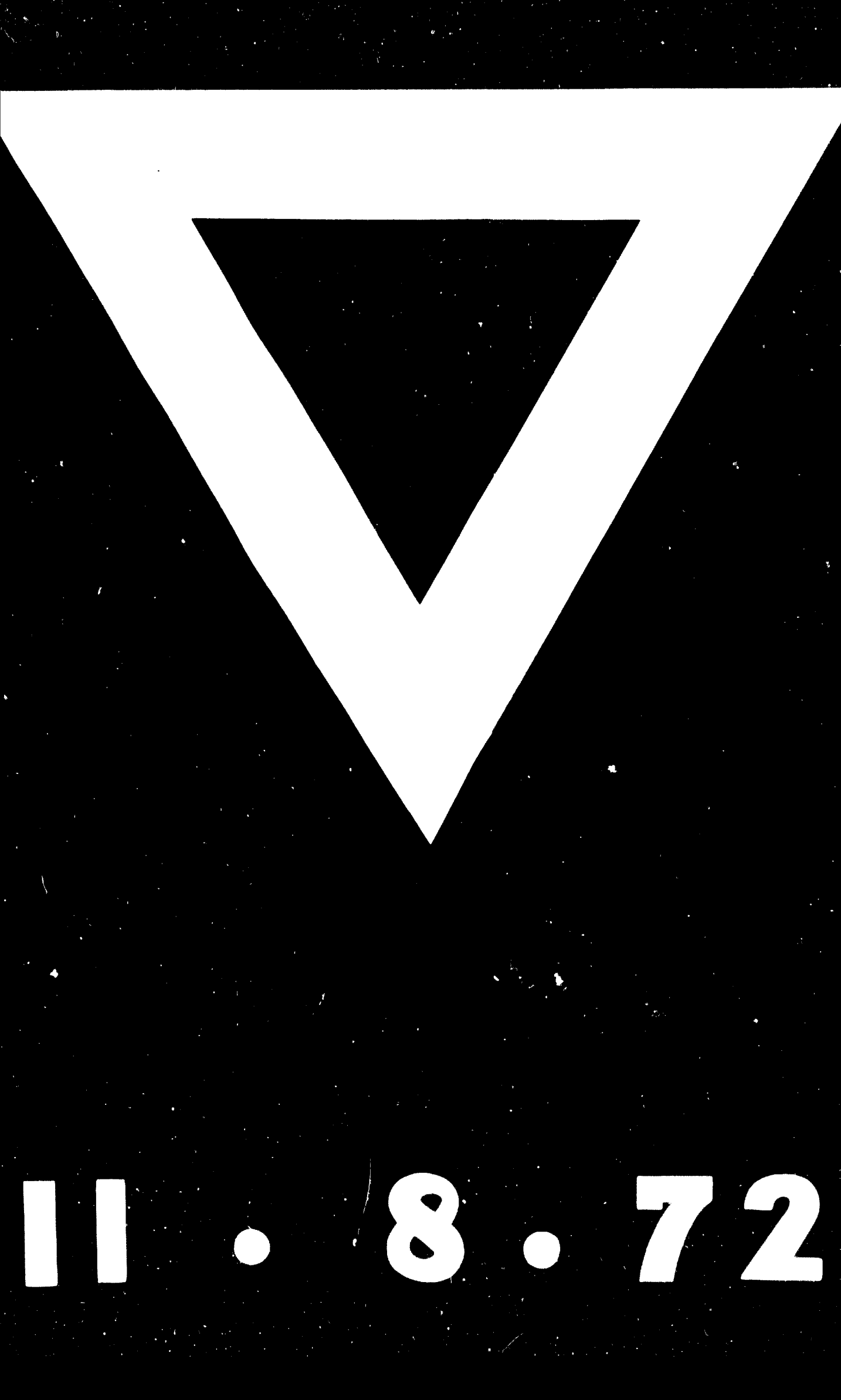
2 Design in the sense of scheming or detailing of a broad concept (this needs less theory and a great deal of drawing).

Successful engineering products involve both to a greater or lesser degree. A guided missile may involve some new and highly sophisticated radar control system, its wing operating servo may demand the highest skill of drawing board design. A motor car may involve a great deal of practical design work and the minimum of mathematical or theoretical skills. An aero gas turbine demands great skill of both types.

Published by the Council of Engineering Institutions
2 Little Smith Street, London, S.W.1
Printed by Southern Press (Printers) Ltd., Purley, Surrey



POSSIBLE LAYOUT for DESIGN/DEVELOPMENT CENTRE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