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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

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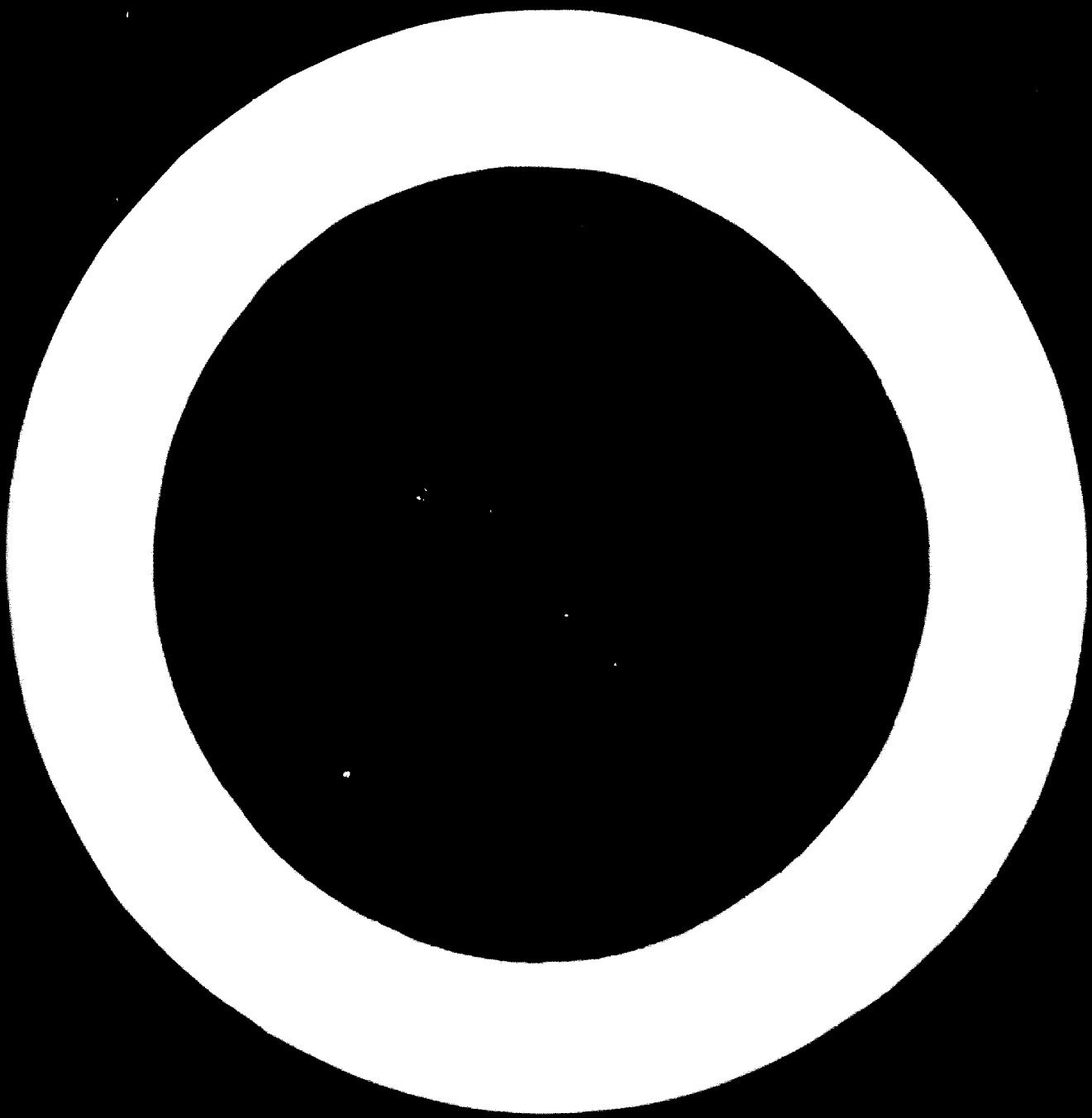

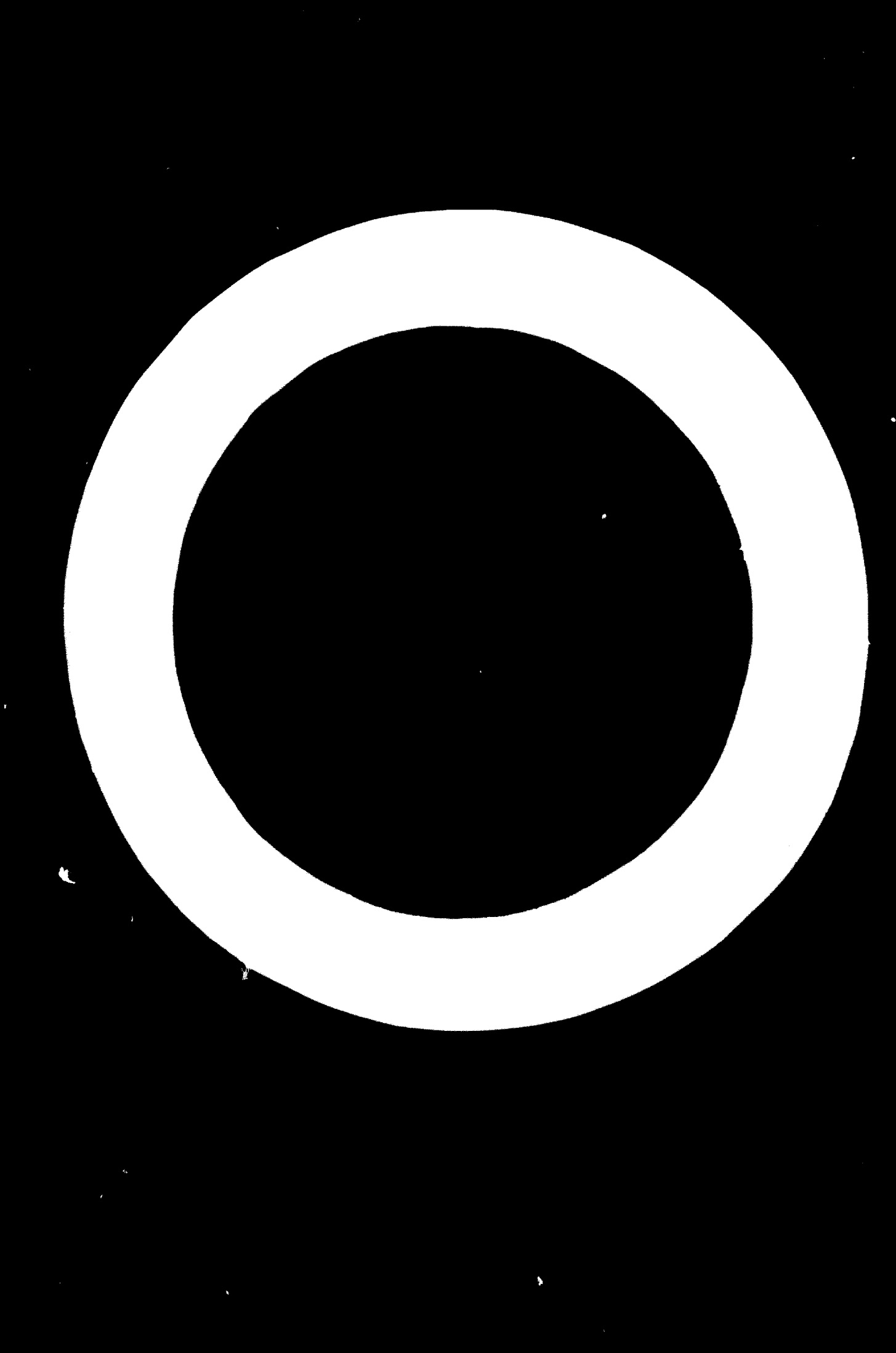

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SOME MAJOR PROBLEMS IN THE INTRODUCTION AND MASTERING OF DIGITAL CONTROL AT MACHINE-BUILDING PLANTS

L. Champetier, Chief Engineer, Centre d'Etudes et de Recherches des Machines-outils, France

Since the appearance of machine tools with digital control, those who are interested in machine building, in general, and in machine-tool building, in particular, have continuously encountered difficulties in connexion with the introduction and mastering of such tools in mechanical workshops. But it would not be expedient merely to accept the existing situation; it is necessary to take measures which, in the majority of cases, do not depend entirely upon the designers of machine tools. The purpose of the present paper is to draw attention to those means which could help to improve the current situation.

In the twentieth century—the century of atoms and rockets—it would not be proper to leave the modernization of mechanical enterprises engaged in small- and average-batch production in the hands of blind mechanisms which are more or less efficient. The policy of waiting and neutrality expressed by the formula "wait and see", which had some success in the past, is now out of place. It is necessary not only to force the development of events at any cost, but also to control the extremely slow evolution without waiting for its completion, through the study and introduction of "national plans" which will facilitate the co-operation of allied branches of engineering (mechanical production, machine-tool building and electronics).

The era of individual initiative and scattered efforts is already far behind. When modernizing mechanical workshops in order to increase efficiency and to improve working conditions, it is important to mobilize, coordinate and concentrate these efforts.

I. Field of application of digital control: its significance for small- and average-batch production

With a few special exceptions, digital control is not used at enterprises engaged in large-batch production. Such enterprises are equipped with special machine tools and equipment designed for high productivity—machine tools for combination processing, automated production lines etc.

As regards enterprises producing small and average batches, digital control is capable of sharply increasing their productivity through the use of universal equipment and instruments. There are reasons to hope that it will not take long for digital programme control to affect most deeply the mechanical enterprises in this category, and, first of all, the machine-tool industry, which is primarily a sphere of small-batch production.

Digital control ensures the automation of machine operations, which eliminates the necessity of manually adjusting machine tools and the costly fixtures used for the purpose. It makes it possible to accomplish a quick re-setting of the machine tool by a simple change of the programme-bearing tape, and the coefficient of machine-tool loading rises from 20 to 70 per cent.

In spite of the high cost of machine tools with digital programme control and the necessity to envisage an individual programme for each type, to say nothing of the reorganization of entire plants and firms caused by the introduction of the above-mentioned machine tools, the advantages obtained in the production cost are such that programme-controlled machine tools will be employed in ever-increasing quantities.

There is no doubt that mechanical enterprises will be forced to refer to such machine tools more and more often, and especially to those machine tools with a co-ordinate control system, which are comparatively simple and are much less expensive than the machine tools with loop control.

This inevitable and desirable progress will lead to the fact that small-batch production will cease to be an insurmountable barrier in the reduction of production cost and terms of delivery.

One may expect that machine tools with digital control will gradually be substituted for the conventional machine tools in 80 per cent of the operations which are currently being undertaken in workshops producing small batches and in those producing tools.

It suffices to say that large-batch production enterprises constitute only 25 per cent of the firms representing machining enterprises to make clear the extent of the revolution which will be accomplished by machine tools with digital control. And if one takes into account the fact that the machining enterprises produce one-third of the entire output of all the branches of the industry in general, it then becomes clear that any change in this sphere will be of great importance for the production level of the country concerned.

Current application of machine tools with digital control

Up to the current time, the main purchasers of digitally controlled machine tools have been the large firms which are specializing in the provision of equipment for aeronautical and space purposes. In addition, these firms have been buying expensive machine tools—those with loop control and those for machining centres.

If one does not consider the above-mentioned firms, for which the introduction of progressive equipment is obligatory, it will be correct to assume that unless measures are taken, there is a risk of witnessing a relatively slow progress in the expansion of machine tools with digital control, either because the majority of manufacturers are not yet willing to part with the setting system and classical machine tools which are in good condition, or because they have insufficient amortization to buy programme controlled machine tools, irrespective of their price. The introduction of the new equipment is very slow, as a result of the following circumstance. It is possible to understand manufacturers when they produce small batches of machine tools with digital control before organizing their large-scale production. On the other hand, the consumer refrains from introducing a costly novelty until the advertised machine tool receives good recommendations in operation. One sees, therefore, two approaches, which counteract each other and which present a serious obstacle to the increased application of machine tools with digital control.

There is no doubt that digital control will win recognition, for progress does no stop. But the question is how many years will be required if no measures are taken to urge manufacturers to modernize their existing equipment.

It should be mentioned that many industrially developed countries have taken a number of measures to the benefit of new equipment. Data on this subject have been collected and are given below. These data, which, it should be noted, are incomplete, refer to Belgium, France, the United Kingdom of Great Britain and Northern Ireland, and the United States of America. The information was supplied by both official organs and persons connected with such organs.

Belgium

In Belgium, which currently does not have any designers of machine tools with digital control, a series of lectures on the subject (given by Professor Peters) was organized at the Institute of Mechanics of Louvain University. The lectures were sponsored by the Centre de Recherches Scientifiques et Techniques de l'Industrie des Fabrications Métalliques (CRIF).

These lectures on digital control were read during the "Louvain days of February 1966" and were accompanied by an exhibition of the equipment and demonstrations of its operation. The purpose of the "Louvain days" was to acquaint Belgian machine-tool builders with the equipment designed for digital control, through demonstration of its operation. As a result, it was recognized that it was necessary to develop propaganda about digital control to prepare for its acceptance.

The "Louvain days" demonstrated the good co-operation between CRIF, Louvain University and the manufacturers or persons supplying digitally controlled equipment (machine tools and fixtures). Machine tools with co-ordinate digital control and machine tools for longitudinal machining were the only ones exhibited.

Finally, an experimental workshop of digital control was established at Louvain University, which planned to commission, by the end of this summer, a drilling machine with an Xlo-Burgmaster turret equipped with a three-spindle digital-control system of the Hugues type.

One of the tasks of the above-mentioned experimental workshop was to render actual assistance to Belgian machine builders by demonstrating the advantages of the new equipment where small-batch production is involved. The Belgian manufacturers will join the ranks of digital-control supporters when the facts have convinced them of its advantages.

France

In France, the Délégation générale á la Recherche scientifique et technique (DGRST) joins in the efforts of some groups who are interested in the digital-control firms, for example, the efforts of the Centre d'Etudes et de Recherches des Machines-outils (CERMO).

The Laboratoire Central de l'Armement (LCA) has organized, in its department of applied mechanics, an experimental workshop for studies of digital control and for inspection of machine tools purchased by the technical department of ground weapons for the equipment of their objects.

The Groupement pour l'Advancement de la Mécanique Industrielle (GAMI) has recently established, together with the Association Française de Règulation et d'Automatisme (AFRA), a working group called "digital control", whose task is to facilitate the development of methods of digital control of machine tools and the allied branches of technique (programming, computers).

The above-mentioned group intends to make use of every possible measure which will ensure the development of numerical control, namely, the following:

(*a*) To assist in establishing contacts between representatives of those branches of engineering which are participating in the development of digital control, e.g., mechanics, electronics, automation, programming, automatic methods of calculation, mechanical treatment etc.;

(*b*) To provide information to the designers and the users of digital-control systems by means of publications, seminars, demonstration, lecture courses etc.;

(*c*) To contribute to standardization in the field of digital control and to help the official institutions working in this trend;

(*d*) To establish contacts between national and international organizations associated with digital-control problems;

(*e*) To promote the inclusion of digital-control problems in official educational programmes;

(*f*) To develop interest in programmed control among leading industrial figures and among people of industry in general.

United Kingdom

An exhibition completely devoted to machine tools with digital control was organized by the Machine Tools Trade Association (MTTA) in London in May 1966. The purpose of the sponsors of the exhibition was to advertise digital control to attract representatives of interested branches of industry.

In addition to this exhibition—the first attempt in the

world in the field under consideration—it was decided to organize regular "open weeks" to enable the manufacturers of the machine-building branch to visit machine-tool works and to become convinced that these enterprises give an example of the profitable use of equipment with digital control when manufacturing their products.

A periodical, *Metalworking Production*, reported that a British Numerical (digital) Control Society was established in London in July 1966. The Society's purpose is to inform its members on economical, technical an pother aspects of digital control for the popularization and expansion of the new technology and its application.

On the other hand, the Government, taking into account the difficulties encountered at the introduction of digital control (costly equipment and unwillingness of the consumers to take the risk of introducing new equipment, which is associated with the solution of a number of problems), intends to adopt the following measures, which were disclosed by the Minister of Technology at the opening ceremony of the above-mentioned exhibition:

(*a*) To sign a contract for the purchase of pilot batches of new machine tools to support the manufacturers and to publish the test results of those machine tools obtained by individual consumers. The first four orders, totalling £500,000, were distributed between the Churchill, Ferranti and Molyns firms;

(*b*) To envisage a sale with a test period, which will give the consumer a possibility of returning the machine tool to the manufacturer within six to twenty-four months after its installation if its operation turns out to be unprofitable. In such cases, the consumer will pay only a definite fee, depending upon the time the machine tool has been in operation and a definite compensation—a sort of compulsory, although reduced, fee—to avoid possible misuse on behalf of the consumer, who, in normal conditions, purchases the equipment "for eternal use". Any machine tool returned to the manufacturer is to be repaired at the expense of the National Research Development Corporation, a State institution, whose budget for these purposes is £1 million.

It is also necessary to note that research in the field of digital control has been subsidized for a number of years by the Government and has been entrusted with the Industrial Research and Development Authority (IRDA) and with the following universities and official technical centres: Nel, Glasgow University, the College of Aeronautics at Cranfield and Birmingham University.

Among the most important works are the following:

(*a*) Exploration of possibilities of machine tools with digital control;

(*b*) Testing of an experimental sheet-bending press with digital control for bending sheets used for sheathing ships, including studies of the spring-back of sheets after their stamping and studies of residual stresses occurring in cold stamping;

(*c*) Studies of static and dynamic rigidity of hydraulic follow-up systems;

(*d*) Testing of a highly sensitive mechanism of high rigidity for hydraulic feed; an analogue computing device for prognosticating dynamic characteristics of mechanisms was built in the course of testing;

(*e*) Comparative testing for accuracy of various setting devices for pre-set co-ordinates (the weight of the travelling table, persistence and rigidity of the feeding mechanism and the friction and free play of the moving parts were taken into account).

Some interesting results were published in technical literature and were read as public lectures at the annual September Conferences of International Machine-Tool Design and Research, which are held alternately in Manchester and in Birmingham.

United States of America

The initiative of the first theoretical research in the new control system, which was undertaken at the Massachusetts Institute of Technology, belongs to the Government of the United States of America, the country in which digital control was first devised (1948–1953). The Government's order for the manufacture by 1956 of new machine tools, which made it possible for the designers working on this problem to carry out the necessary tasks in creating prototypes without concern for monetary questions, was of major significance. These facts were of great interest to the members of the French delegation of digital-control specialists upon the occasion of their visit to the United States of America in 1964, on behalf of the French syndicate of machine-tool industry designers.

Another outstanding fact is that when the Seneca Vocational High School in Buffalo (New York) foresaw the demands of the industry, it installed in April 1966 with the Government's support and in addition to the School's existing equipment with simple digital controls a three-spindle milling machine of the Gorton type (valued at $50,000) for contour treatment, so that specialists might be trained in the sphere of programmed control.

Still another important detail to be mentioned is that only those enterprises which are equipped with machine tools with digital control are given government orders to fulfil.

II. Suggested Measures

No matter how necessary and useful the above-mentioned expressions of initiative are for speeding up the introduction of digital control into industry, they may turn out to be insufficient if no measures are taken to ensure their simultaneous effect.

It would have been in the interests of the mechanical-production enterprises, whose higher efficiency is of essential significance, to have provisions for "national plans" directed towards the widest application of machine tools with digital control.

It is necessary to draw a clear line between contour and co-ordinate digital controls, and linear control, where all the machining is accomplished along the trajectories, which are parallel to the guides of the machine tool.

The contour digital-control system is very complex and expensive, and it is used by firms who are interested in the newest equipment, which, in the majority of cases, needs no advertising. Furthermore, the problems of the

contour control system differ from those of the co-ordinate system. Thus, the continuing development of contour control depends greatly upon the progress in an important and wide field of computing techniques.

Digital control according to pre-set co-ordinates, which is simpler and much less expensive, corresponds (and this is the advantage) to 90 per cent of the demands of the industry. Thus, it is clear that this control system should receive concentrated efforts at the very beginning.

The application of digital control raises economic, financial and technical problems, whose scale exceeds the framework of machine-tool building.

Considered below are those measures which, it seems, should be given priority and which appear to be the most effective.

As a first measure, it is recommended to popularize digital control and to prepare people for its introduction. Good results could be achieved by presenting films of demonstrations of machines with such controls, in order to attract the largest possible number of consumers.

Propaganda by the machine-tool designers themselves would be very effective also. In fact, the designers present a business-like example by studying in their laboratories the possibilities of the maximum use of machine tools with digital control, informing others of the results obtained using various means and, above all, demonstrating their achievements. In the United States of America, where about 7,000 machine tools with programmed control are in operation, the machine-tool industry is using a comparatively large share of them, if one takes into account the proportion of machine-tool building in relation to other branches of machine building. With the exception of one firm which manufactures aircraft engines, a machine-tool manufacturer has the largest number (sixty-two) of machine tools with digital control. Furthermore, many important enterprises in the United States of America have commissioned works in which the majority of machine-tool parts are produced on machine tools with digital control.

According to the statistics in the United Kingdom, the machine-tool plants have concentrated from 18 to 20 per cent of all machine tools with digital control operating in that country, while the output of those plants is only 3 per cent of the entire output of mechanical enterprises.

During the exhibition in May 1966, the firm of Kearney Trecker willingly demonstrated, upon request of interested persons, the operation of its plant near London. Kearney Trecker is now machining the beds for milling machines in seventeen hours (sixty-five hours were formerly required) by using Milwaukee-Matic machine tools with digital control; the above-mentioned part is machined in two operations.

It would have also been very useful to publish the most interesting results obtained by those industrial firms which use or test digitally controlled machine tools.

There is no doubt that the suggested measures will help to promote in the near future the widest scale of use of the new types of machine tools and will build up the demand, thus justifying a larger production of the above-mentioned machine tools than the level which is now contemplated by the designers.

The second measure suggested is to render assistance in research and designing, and in the purchase of machine tools with digital control and appropriate equipment.

Assistance on behalf of the Government when buying digitally controlled machine tools should take place at the stage of adjustment and commissioning of new enterprises to have the maximum effect. If such assistance is not yet being rendered, it should be made available in the very near future.

Thus, it would be useful to supply machine tools with digital control to the system of technical education and to the largest possible number of vocational schools. For the beginning, it would be possible to limit these to simple machine tools, for example, drilling machines with manual programming.

Thirdly, it is recommended to render assistance in the commissioning and further equipment of experimental laboratories, one of the tasks of which would be to provide technical assistance to manufacturers in the period of commissioning the digitally controlled equipment, for example, consultations on the expediency of the planned capital investment.

Designing bureaus which are projecting machine tools are ready-made experimental laboratories for consumers, provided they are well equipped.

In addition, it is important that some official institution, such as the machine-tool building scientific research centre in France (CERMO), should render technical assistance to consumers (programming, commissioning of new enterprises etc.) at the stage of adjusting and commissioning.

III. Conclusions

The magnitude and the urgency of the problems raise the question of governmental support for the interested mechanical enterprises in order to promote the success of the new technique of digital control and for rendering assistance to machine-tool designers. It is very important to ensure co-ordination of the efforts of State institutions and private firms which are interested in developing this technique and in the perspectives of development of mechanical production of the country in question.

In conclusion, it should be remembered that the sphere of application of digital control is not limited by those enterprises where machining is obligatory. As soon as there is a possibility of interpreting mathematically any mechanical process, there is a possibility of controlling it by a computer. As an example, one may refer to the device for balancing, pairing or sorting, paper-making machines etc. Digital control is also used in other non-mechanical branches of industry—e.g., metallurgy (control over blast-furnaces and rolling mills) and the oil industry (refinery of oil products).

In the near future, the all-sided automation ensured by digital control may pose a number of problems which differ from the problems of today, as follows:

(*a*) Training of necessary skilled staff;

(*b*) Introduction of new requirements into the programmes of technical education;

(*c*) Retraining of the personnel who fell in reserve. This is a cardinal problem, whose solution will require the help of the Government and which was not considered in the present paper as it was beyond the scope of the topic.

The spheres of machine-tool building and mechanical production have considerably expanded, which is another reason for the necessity of co-ordinating, at the highest possible level, any activity. Recently, much has been said about the new successes achieved in mechanical production:

(*a*) Equipping machine tools with interpolators;

(*b*) Application of digital computers for optimization of machining conditions;

(*c*) Application of self-adjusting systems for automatic control of machine tools in the process of machining;

(*d*) Direct transfer from the designer's idea to the command for fulfilment without making conventional drawings and compiling an operation plan (probably the day is not far ahead when the man would learn to introduce a written information into the machine and then he would be satisfied to give the information in an oral form).

But these perspectives should not hide the problem of today, i.e. the maximum profitable application of every possibility of using digital control for machine tools.

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