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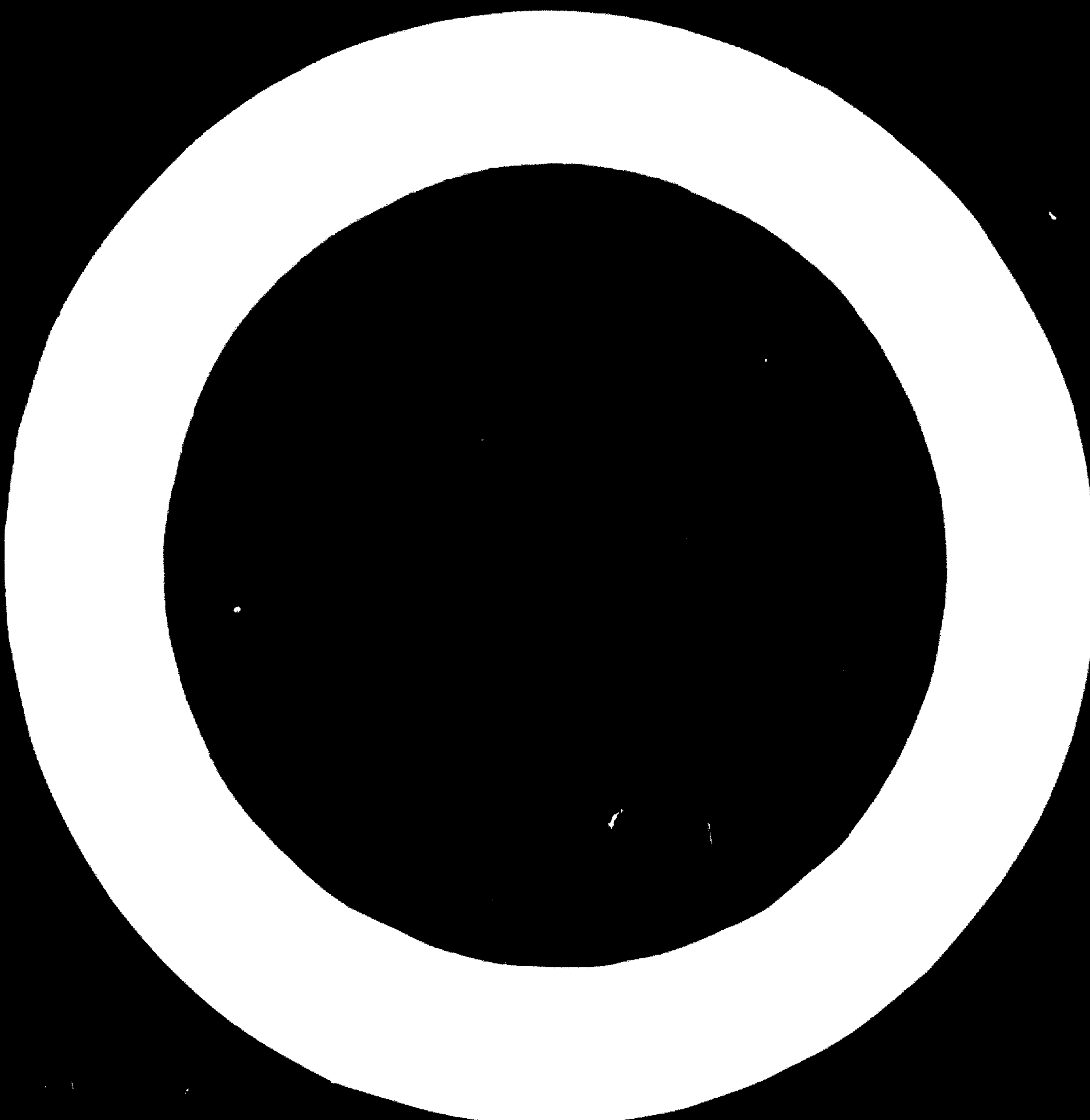

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DEVELOPMENT OF AGGREGATION IN THE PRODUCTION OF METAL-CUTTING MACHINES

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INTRODUCTION

The aggregate principle of designing is one of the ways of achieving standardization in the machine-tool industry. It appeared as a result of recognition of the principle that every repeated application of any result of labour, irrespective of its character (design, technology or even organization), is economically profitable.

Formerly, machine parts were mainly unified and standarized, their previous development having taken into account their optimal fulfilment of their functions under conditions of minimum-cost production to achieve the utmost repetition. In that case, the main factors were the following:

(*a*) The best analogous constructions were used at every enterprise to avoid parallelism in designing. Along with the improvement of the quality of parts, this economized the designers' efforts;

(*b*) The centralized output of the required amount of unified parts made it possible to obtain batches, which permitted the use of far more economic production methods than those used for production at individual plants.

The aggregate principle of designing makes it possible to make one more step forward because the optimized parts are to be optimally combined into units. In this case, the same goal is pursued as in respect of individual parts, namely, the maximum repetition of application on the largest possible scale to ensure the possibility of a more economic projecting and of centralized production.

The accomplishment of this principle of designing is a very difficult and complex task, which may be solved in several stages only because of the great number and variety of machine tools involved. The centrally planned economy creates a good atmosphere for the solution of this problem.

Nevertheless, the following example shows how much time may pass before all these correct conclusions will find a wide and, consequently, a more effective application in practice. In 1949, at the State Conference of a technical department (the voluntary technical society of Eastern Germany), the present writer stated:

"It may turn out to be impossible to fulfil simultaneously all the requirements set before a machine tool and very often contradicting each other. That is why it is necessary to be limited by the most important requirements which promise the utmost success for a larger period of time and on a wider scale. They can be only those machine tools which in their structure are neither the all-purpose ones nor the special ones. They should be the machine tools which on the basis of their common and extremely simple basic structure may be transferred into all-purpose, special, or specialized machine tools by equipping them with widely unified but different units, mechanisms, fixtures, etc. These units should ensure interchangeability and make possible their consequent installation on a machine tool as well."

The process of reconstruction necessary for this task has already made much progress in Eastern Germany, but it is still far from being completed and its potential economic abilities are not exhausted. This type of development will be the basis of all new developments for an unlimited period of time. In this case, the difficulty is in realization and perfection of this designing principle to the degree in which it is possible to prove its economic effectiveness.

I. BASIC STAGES OF AGGREGATE DESIGNING

A. *First stage: Technical specifications and nomenclature*

The first requirement of the aggregate designing principle is the systematic order of the equipment nomenclature. That is why definite technical specifications must be established for each type of equipment. For the turning lathes, it is the largest diameter of the piece for drilling machines the maximum diameter of drilling in steel and for presses, it is the largest permissible effort etc. These parameters are then used to develop for each type of equipment the dimensional designing rows graded according to the geometrical progression, because such grading makes it possible to handle most efficiently a definite scale of work with a minimum number of machine tools. The denominator of the progression is also selected in such a way as to embrace the supposed general scale of work by means of the minimum number of machine tools of the same types and dimensions. This has led to larger intervals for small types and dimensions, and to smaller ones for heavy machinery. The appropriate rows are within the limits ranging from R5 to R20. Both things are done to increase the volume of the batch for the machine tools produced. Through the use of these specifications, it has been possible to collate the efforts of individual designers working in a definite branch of the machine-tool industry and to plan more economically the production of an entire branch.

One of the most successful examples of reduction of a number of designing forms, types and dimensions achieved as a result of the above-mentioned steps and of the better organization in press building is shown in figure 1. The production was simultaneously concentrated at a smaller number of enterprises.

Certain machine tools are united to form the so-called "gammas", which means that they have many common parts. The standard developed for the metal-processing equipment became a firm basis for the sequence of the nomenclature of new designing and the output of machinery in the member countries of the Council of Mutual Economic Assistance and for scientific and technical co-operation in the spirit of a real distribution of labour.

possible number of different but often repeated units, as is done in children's designing sets (see fig. 2). An additional objective is to split the unit to very small ones consisting of a few parts only, as this increases the repetition of application, as well as the number of variants which make it possible to adjust the machine tool to its technological function in operation. The same method may ensure better conditions for economically expedient production, sales and flexibility of the existing machine tool stock of consuming plants.

In general, there are the basic units, general-purpose units and supplementary units. These units are used to build machine-tool lines which are based on a standard

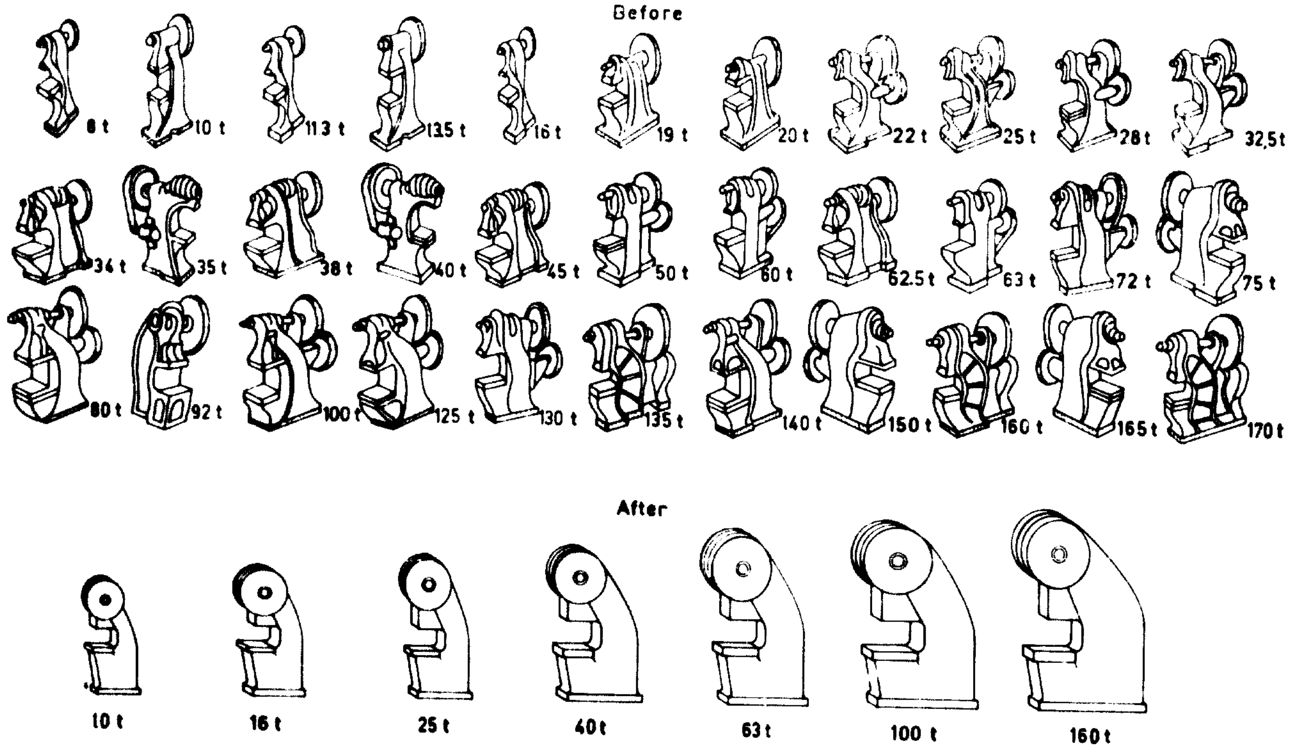


Figure 1

ECCENTRIC PRESS BEFORE AND AFTER UNIFICATION

B. *Second stage: division of machine tools*

The second stage is the division of machine tools into sections, by units which are used repeatedly. This is done either within the limits of one and the same model type or for different modifications of the machine tool (for example, a longitudinal carriage in multiple-spindle automatic lathes); or within the limits of different model types of a single designing row if the model of the machine tool is the same (for example, the main spindle in the centre turning lathes); or within the limits of different designing rows of machine tools of the same type (for example, copying fixture and centre and face turning lathes); or finally, within the limits of different model types of machine tools of various types (for example, the cam type of control mechanism for programmed milling, turning and drilling machines or a loading mechanism for the cylindrical grinding machines and lathes). The problem is to meet all the requirements with the minimum

machine tool by means of the systematic combination of various elements. This machine tool may most efficiently meet various operation requirements of the consuming plant without being a machine tool of individual production, with all the drawbacks of such production from the point of view of the funds and time required.

In this way, an extremely large assortment of variants of machine tools is obtained, which, in case of necessity, may be specialized and partially automated, and even equipped with automatic loading and unloading mechanisms. The existence of such mechanisms makes the cycle of operations completely automatic. The machine tool is supplied with blanks from the inlet hopper, processes them and delivers them to the outlet hopper. Such machine tools are suitable for automatic lines. This system is called the system of free connexion of machine tools into continuous lines. When reconstructing the enterprise, it is possible to separate individual machine

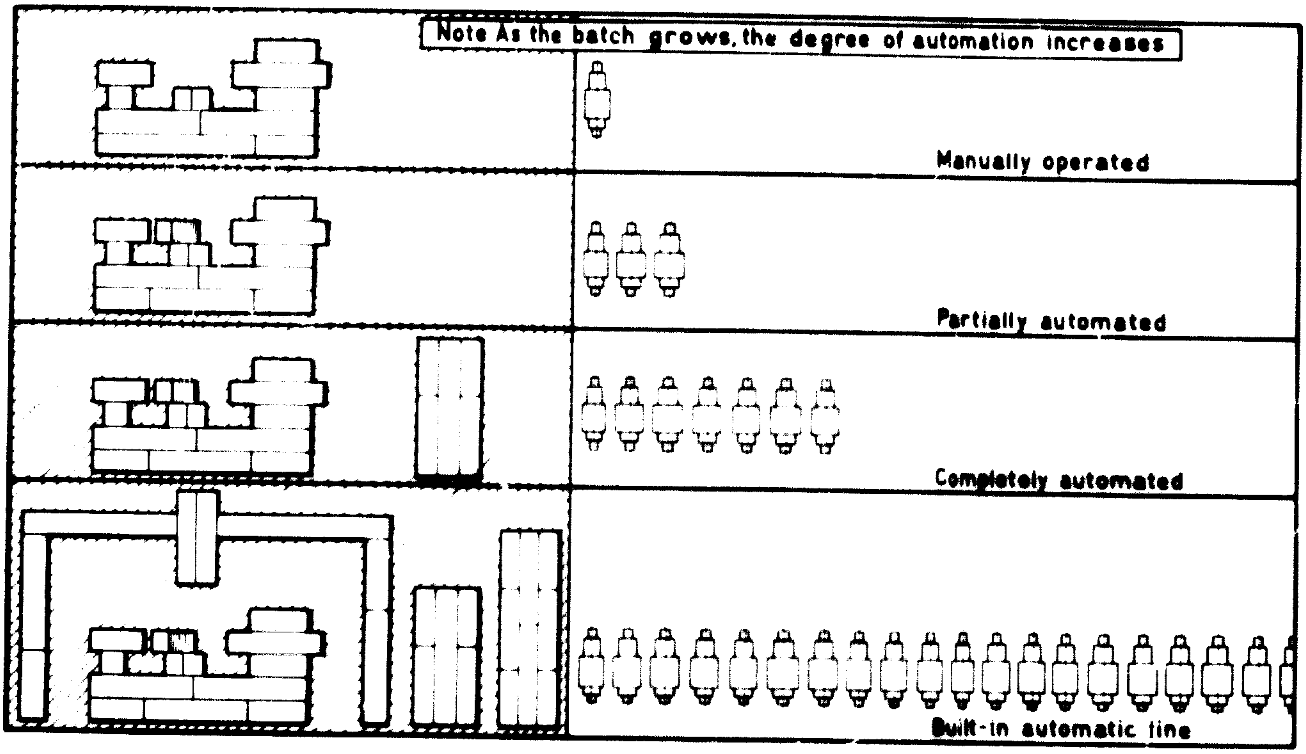


Figure 2

TURNING LATHES FROM CHILDREN'S DESIGNING SET

tools and to assemble them into a new continuous line. That is why such continuous lines have a very great "residual value". In this case, it is also possible to change the units of the machine and to assemble them according to the new functions, as all units are widely unified and have similar fastening dimensions. Means of measuring and control are also included in the system of unification. Thus, the last link in the increasingly more complicated number of variants of one and the same machine tool, especially for the finishing process, could be the machine tool in which the results of processing are measured; the relative positions of the tool and the articles are then adjusted and, in this way, the article, processed with the highest precision, has already been checked when it is delivered to the outlet hopper.

1. *Automatic control*

This ideal of automatic control in the general prospective is the desired goal when designing any machine tool.

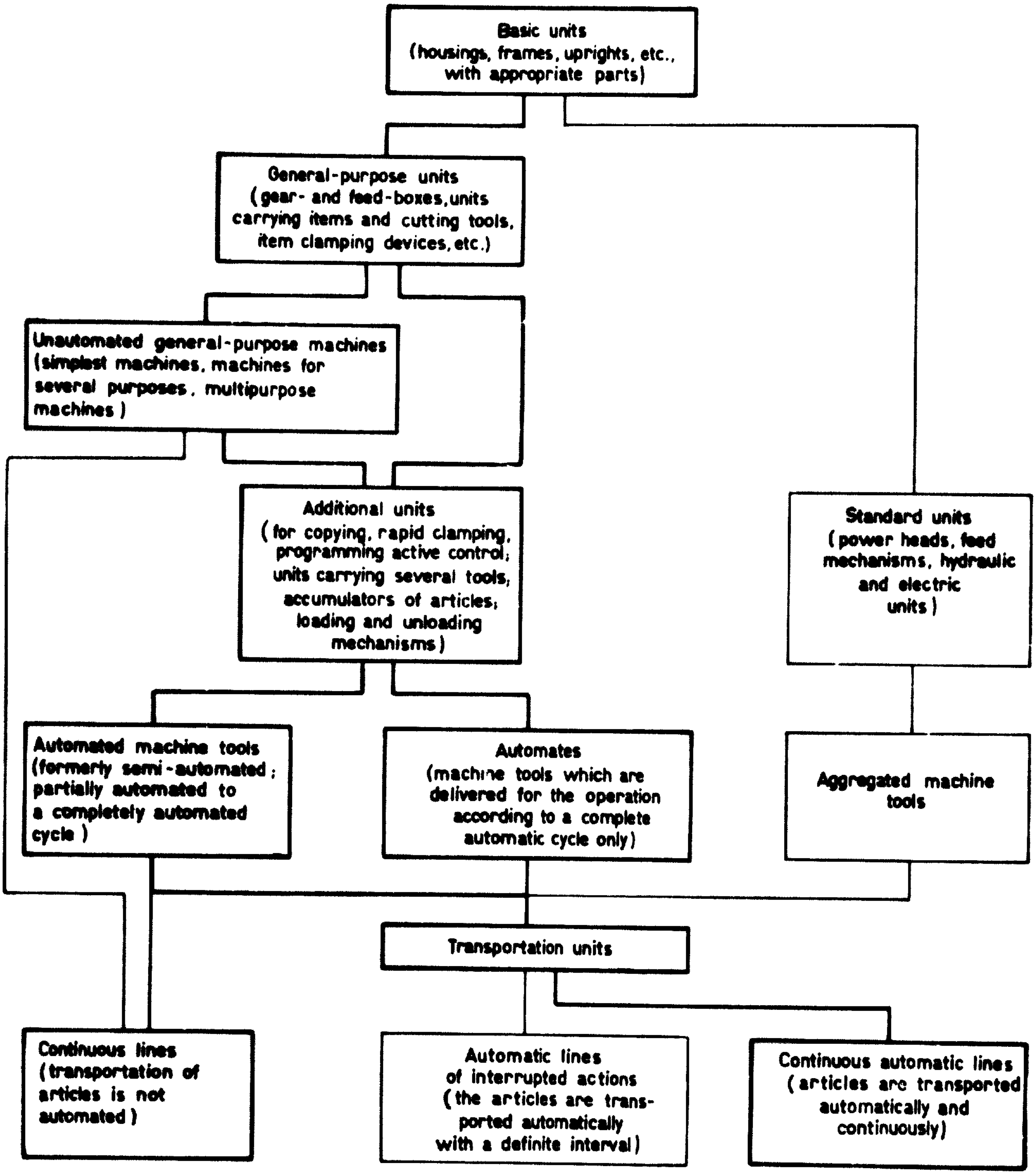
The final link in a number of variants may be a machine tool with programmed control in two or three co-ordinates, whose control system is common for all the machine tools of other models and dimensional types, with the standard eight-channel perforated tape used as a bearer of information, and which contains one of the two measuring systems developed by the Karl Zeiss firm, this system being the same for all co-ordinates.

The diagram of composition of such machine tools is shown in figure 3. The elements shown in heavy lines refer to the above-mentioned second stage of aggregation; the other elements refer to the third stage.

Figure 4 illustrates the principle shown in figure 3 on a planer type of milling machine. The individual groups of units may be clearly seen in this figure.

The designing row of multiple-spindle automatic turning lathes shown in figure 5 is a typical example of the manifold application of identical units in machine tools of the same dimensional type, but of different design. Here, the basic units of four dimensional types (100, 63, 40 and 25) are used to assemble sixteen machine tools of various design. The lathe bed, the driving mechanism and the spindle drum remain unchanged for one dimensional type. The headstock and the carriage, as well as the feeding mechanism, are the same for articles of equal diameter. Thus, for example, if the basic dimensional type is 40, the four-spindle chuck automatic turning lathe, type 4/160, makes use of 861 parts of the four-spindle bar automatic turning lathe, type 4/40. The unified parts constitute approximately 70 per cent of the total since the chuck automatic consists of about 1,200 parts. Furthermore, all the parts securing the items and the tools, as well as the parts of the feeding mechanism, are the same in the four-spindle machine tool of basic dimensional type 40 and the eight-spindle machine tool of basic dimensional type 100 (the through-diameter of the item on both of them is 40 mm). In the eight-spindle machine tool, this is equal to 8 × 65 = 520 parts out of 1,380. It is clear that such unification of construction decreases the designing expenses. The savings obtained through the designing row illustrated in figure 6 amount to almost 2.5 million Deutsche Marks (DM). In the case of serial production, the economic effectiveness exceeds this figure many times.

With each design change made necessary by the pro-



Note. Heavy lines indicate second stage of aggregation; lighter lines refer to the third stage.

Figure 3

DIAGRAM OF COMPOSITION OF AUTOMATED MACHINE TOOLS ACCORDING TO AGGREGATE PRINCIPLE OF DESIGNING

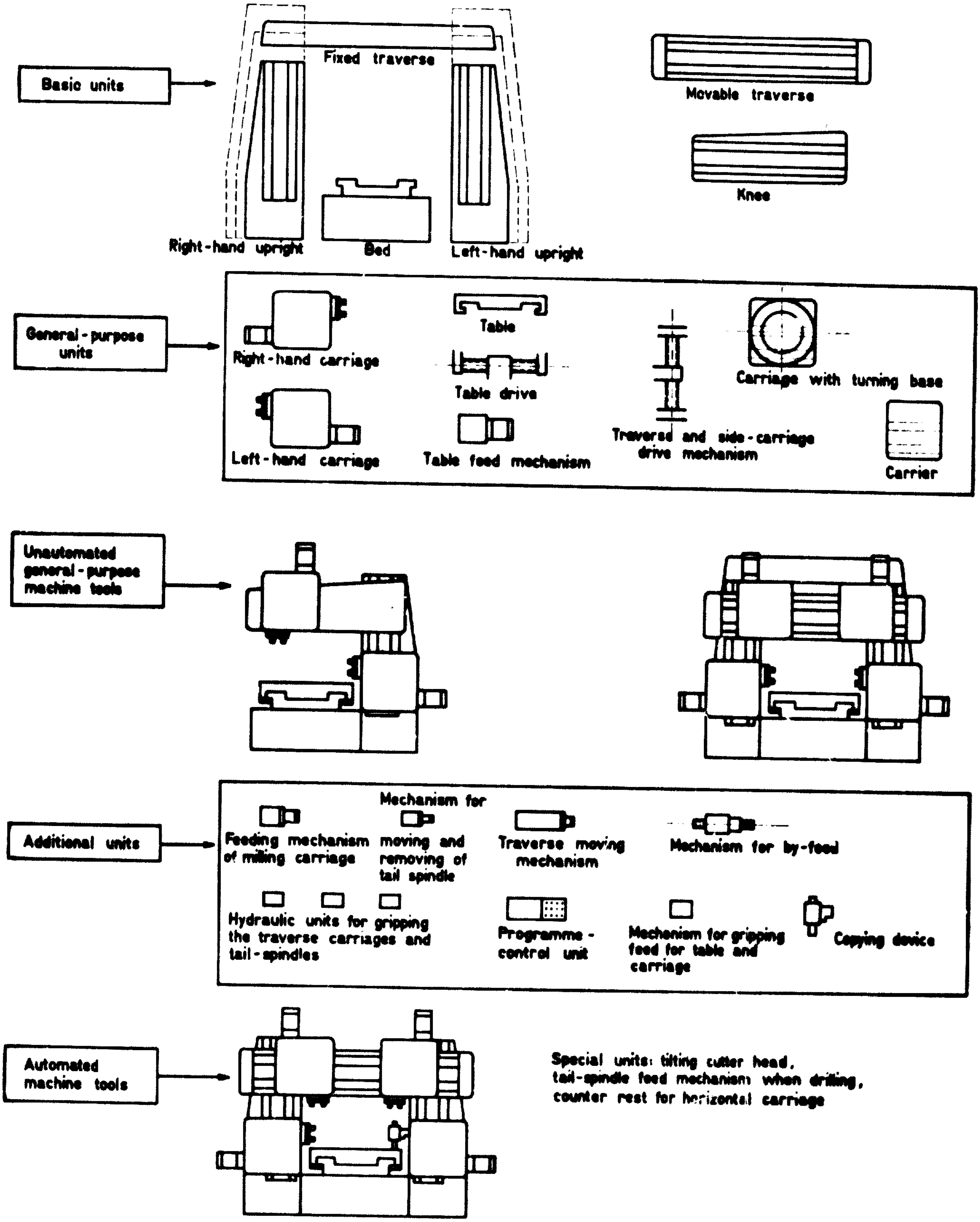


Figure 4

COMPOSITION OF PLANER TYPE OF MILLING MACHINE

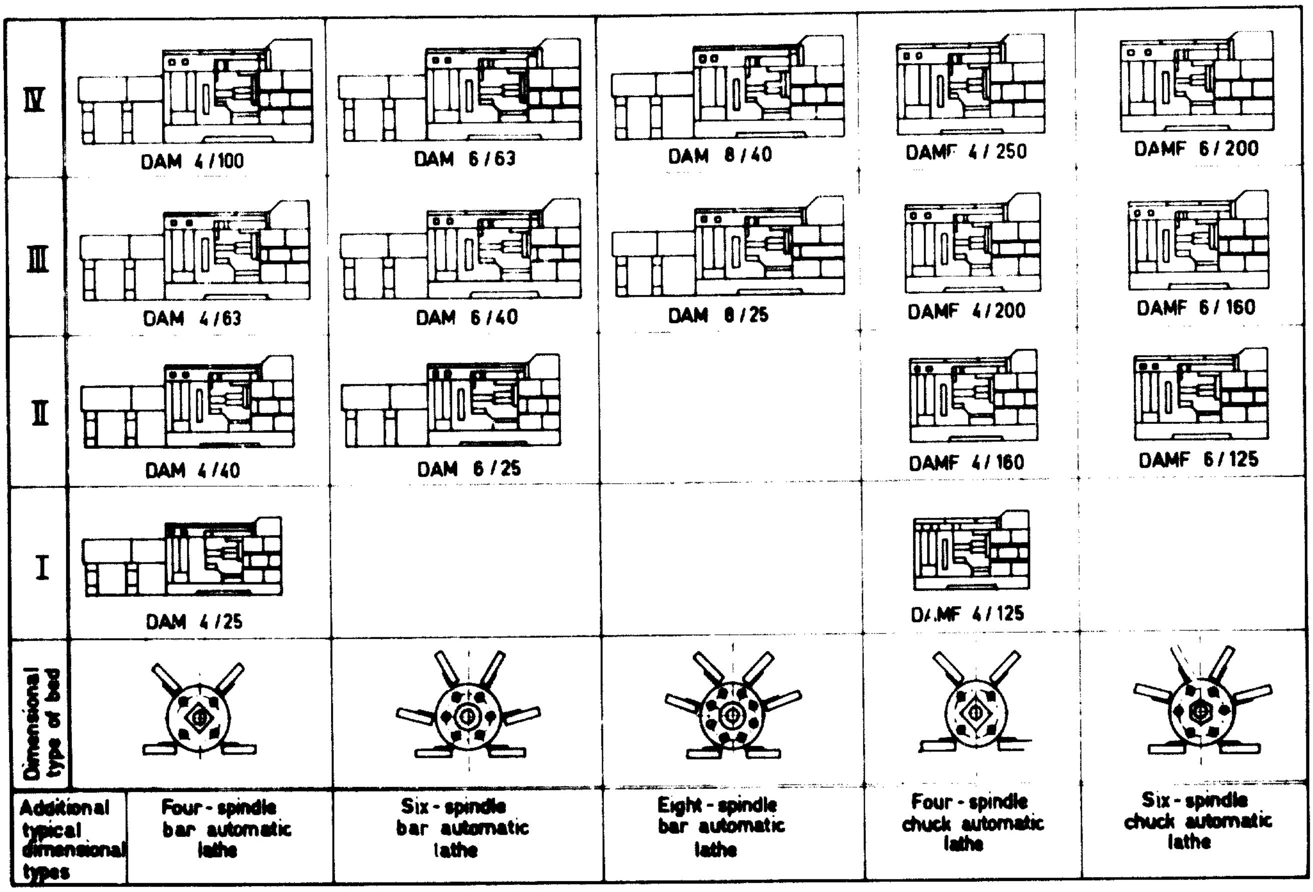


Figure 5

AGGREGATED COMPOSITION OF THE DESIGNING ROW OF MULTIPLE-SPINDLE AUTOMATIC LATHES

gress of the technique, the labour consumption decreases. Furthermore, if the number of designers remains the same, changes can be made more rapidly.

The extremely large variety of construction forms of machine tools built according to aggregate principles is illustrated in figures 7 and 8. Figure 7 is related, for example, to a cylindrical grinder and, in addition to the units shown, there are loading and unloading mechanisms. Figure 8 illustrates variants of a centre-turning lathe. Its design is subjected to constant changes brought about by the progress of the technique. Thus, units 25 and 26 are made differently, which is of a special importance for the control system, bearing in mind its dependence upon the magnitude of the batch of items and the possibility of increasing productivity.

The models in figure 9 show how it is possible to make use of the aggregation principle for the design of a honing machine tool. Identical uprights (one or several) are placed around the clamping unit, which is selected according to the technological goal to be achieved. Single- or multiple-spindle honing stocks are assembled on the identical slideway surfaces of the uprights. A simple fixed table, a detachable table, a pendulum or round turntable may be used as such a unit. Various clamping, transporting, measuring and control mechanisms make it possible to create highly automated precision machine tools.

The principle of aggregation is used not only when designing the above-mentioned metal-cutting machine tools, but also for the designing of forging and pressing equipment. The standard eccentric press is typical and was the first machine developed on the principle of systematic unification. The units and the forms of the press assembled from them are shown in figure 10, while figure 11 gives an illustration of the characteristics which are of a decisive importance when designing and operating the presses. The systematic grading of presses is also shown in figure 11.

The design of a three-roller bending machine (see fig. 12) is also of an interest. Eighteen various machines are composed of five dimensions of reducing units and six dimensions of rollers and uprights. The machine is used to bend sheet metal of 6–22 mm thickness and 1,600–3,150 mm width.

Machines for the pressure casting of plastic items with a pressure of 400, 630 and 1,000 kg (see fig. 13) are composed as combinations of driving, injecting and locking units of three dimensional types selected according to the pressure and the volume of plastic material involved. Any of the injecting units can be combined with any of

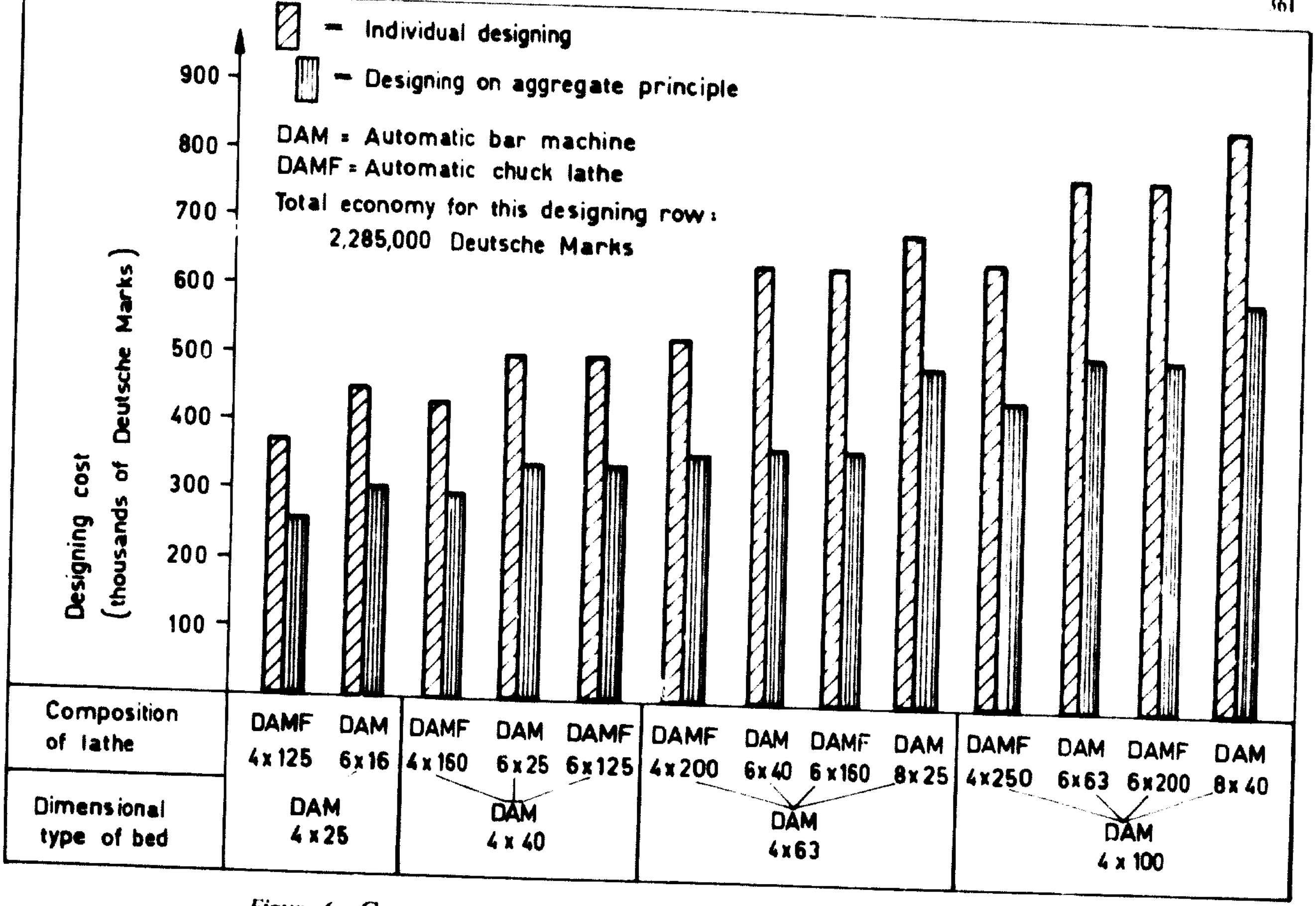


Figure 6—COMPARISON OF COSTS OF MULTIPLE-SPINDLE AUTOMATIC LATHES

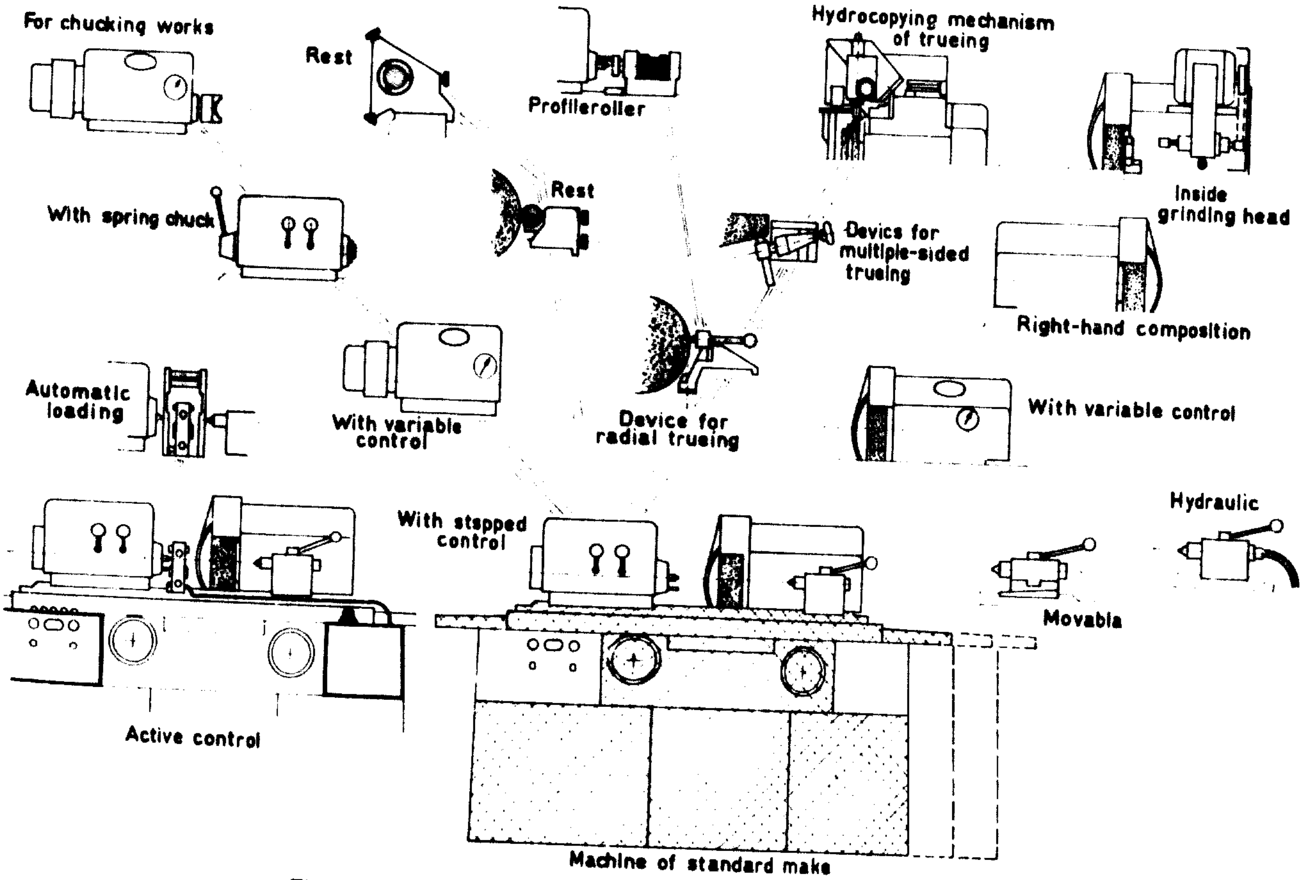
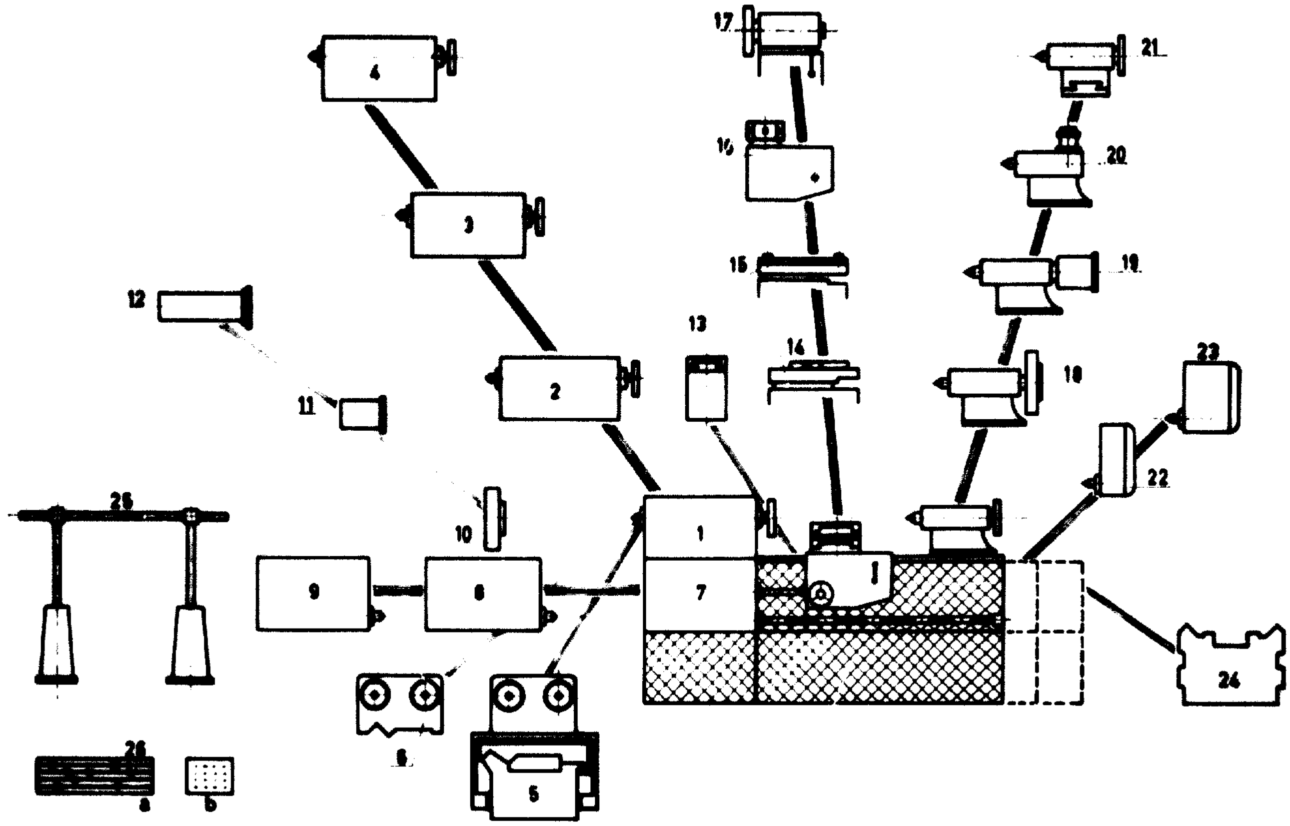


Figure 7—VARIANTS OF COMPOSITION OF CYLINDRICAL GRINDER



1 With standard range of species; 2 With reduced range of speeds; 3 With larger range of speeds; 4 Variable control; 5 Bridge for diamond boring; 6 Headstock with two spindles; 7 Mechanism for feed and thread cutting; 8 Feed mechanism only; 9 Feed mechanism only for one speed, 10 Pneumatic clamp; 11 Hydraulic clamp; 12 Electromagnetic clamp; 13 Cutting-off carriage; 14 Copying device; 15 Turning carriage; 16 Turret with vertical axle; 17 Turret with horizontal axle; 18 Pneumatic tailstock; 19 Hydraulic tailstock; 20 Tailstock for drilling operations; 21 Double-spindle tailstock; 22 Mechanism for high speed; 23 High speed for two carriages; 24 Bed for doubled carriage; 25 Automatic charging of article; 26 Programme control (*a*, command instrument; *b*, punch card)

Figure 8—VARIANTS OF COMPOSITION OF CENTRE TURNING LATHE

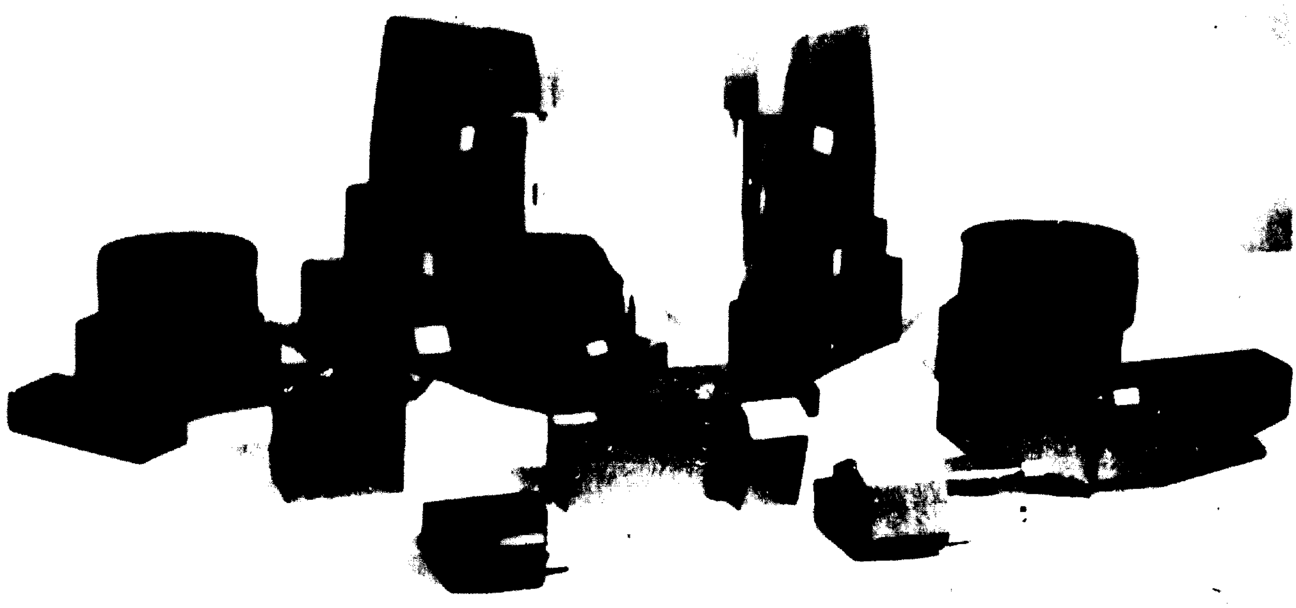


Figure 9 MODEL SET FOR HONING MACHINE

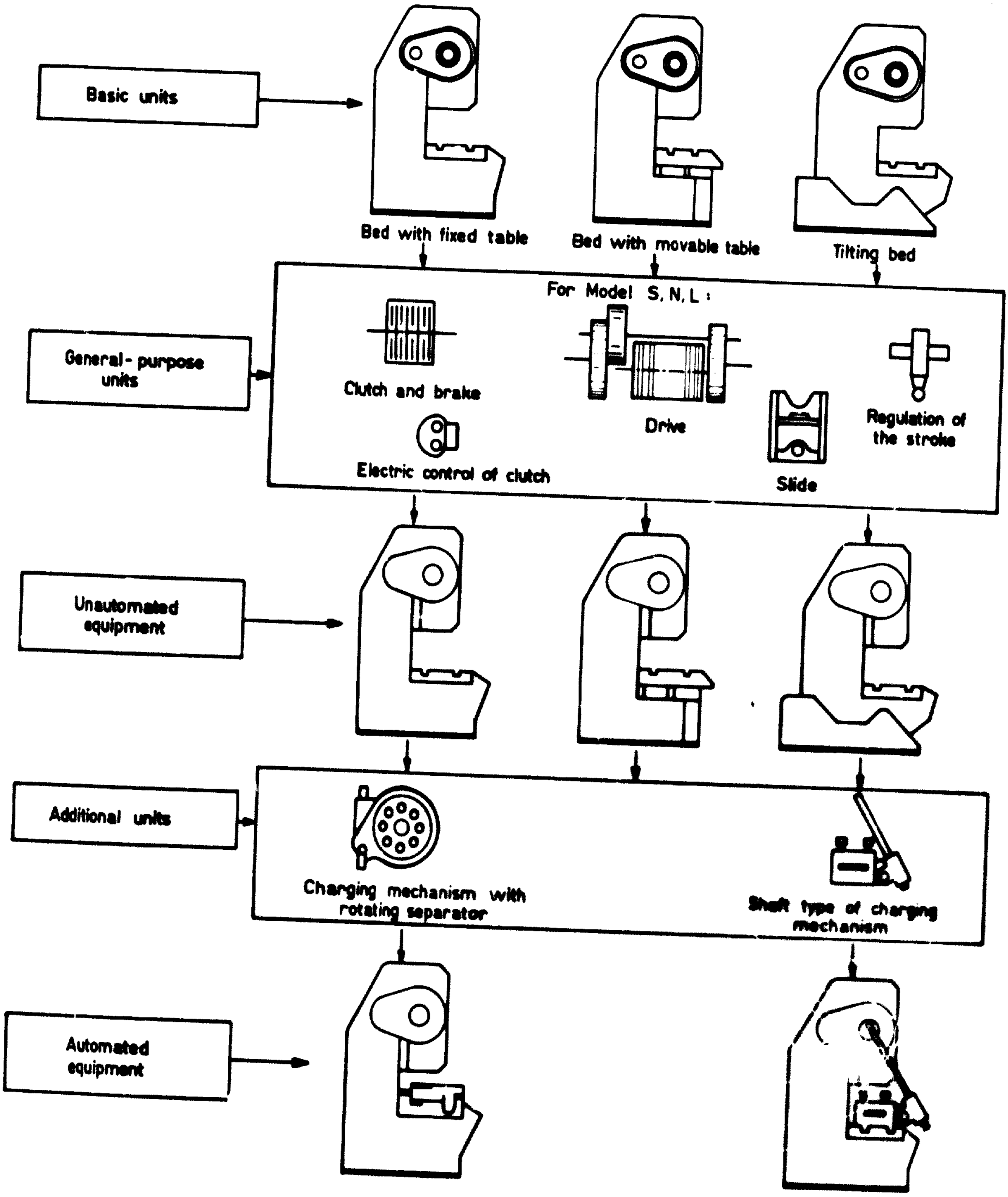


Figure 10

COMPOSITION OF ECCENTRIC PRESSES

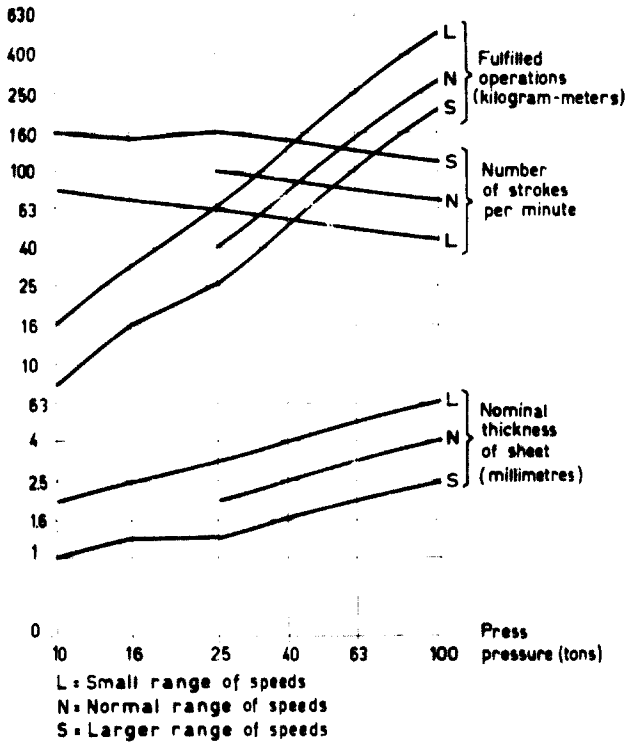


Figure 11

GRADING OF PARAMETERS OF ECCENTRIC PRESSES

the locking units. Thus, the presses for processing duroplastics may be adjusted for the pressure casting of thermoplastics.

The machines of the above-mentioned designing rows are used for the same method of processing. The machine tools for cutting bevel gears, described below, refer to the other group of equipment used for processing by four various methods on a common design basis. Milling and drawing are done according to the Arkoid method, and milling is performed according to the Kurwex and Konvoid methods (see figs. 14 and 15). The degree of unification of units in the machine tools of various design is shown in figure 15. The entire design row of machine tools requires a total of approximately 5,100 parts, including only 1,600 original parts. This means that by making use of these 1 600 parts it is possible to assemble any individual machine tool. Thus, each part is used, on the average, three times. It has been established that the expenditure for designing and producing an experimental sample of any of these machine tools is many times lower, as compared with that of individual designing. The reduction of expenses is expressed bv the following figures: designing, 45 per cent; assembly of models, 40 per cent; development of technological process, 50 per cent; production of fixtures, tools and gauges, 45 per cent. This amounts to about DM 1 million for one dimensional type in all designs. Production may be in increased batches; it may be better equipped with

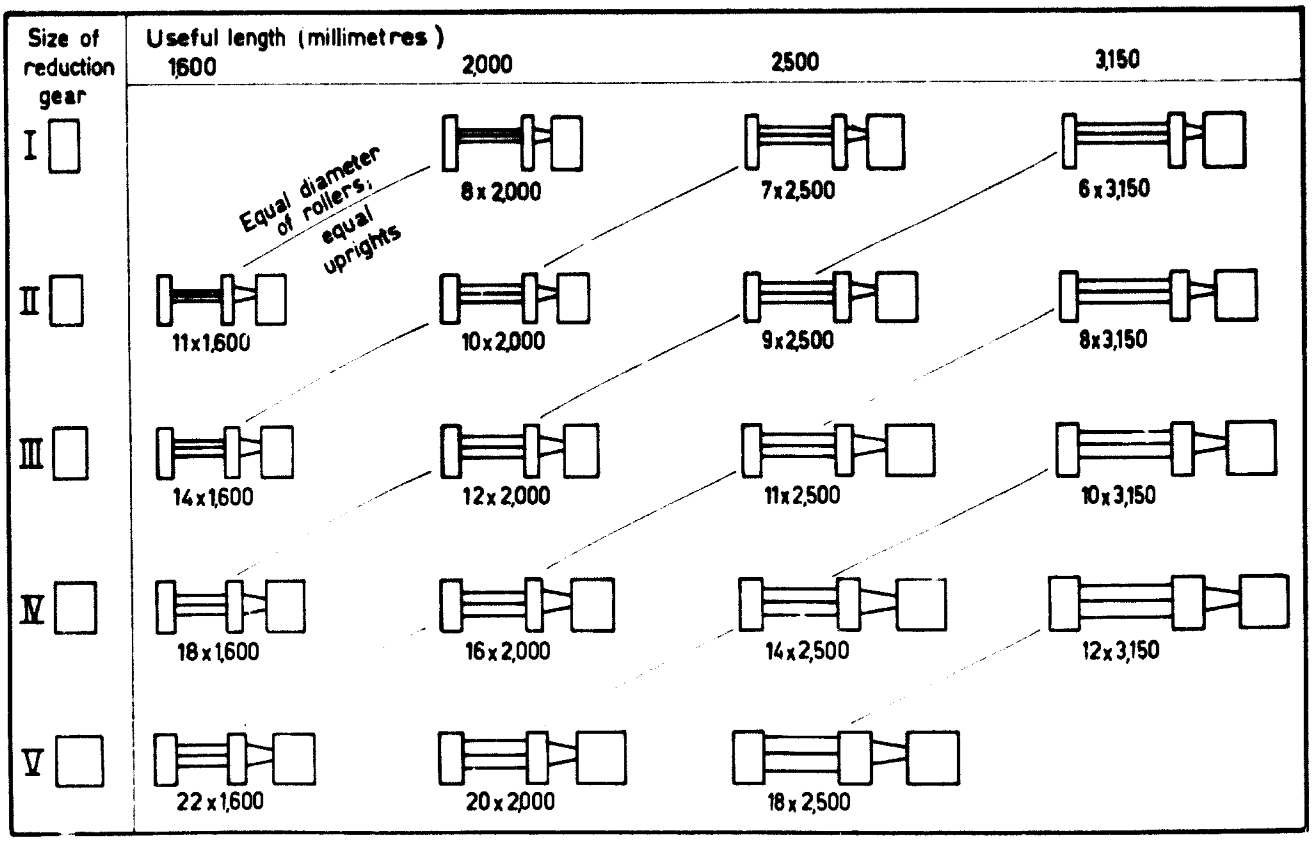


Figure 12

COMPOSITION DIAGRAM OF A ROLLER BENDING MACHINE

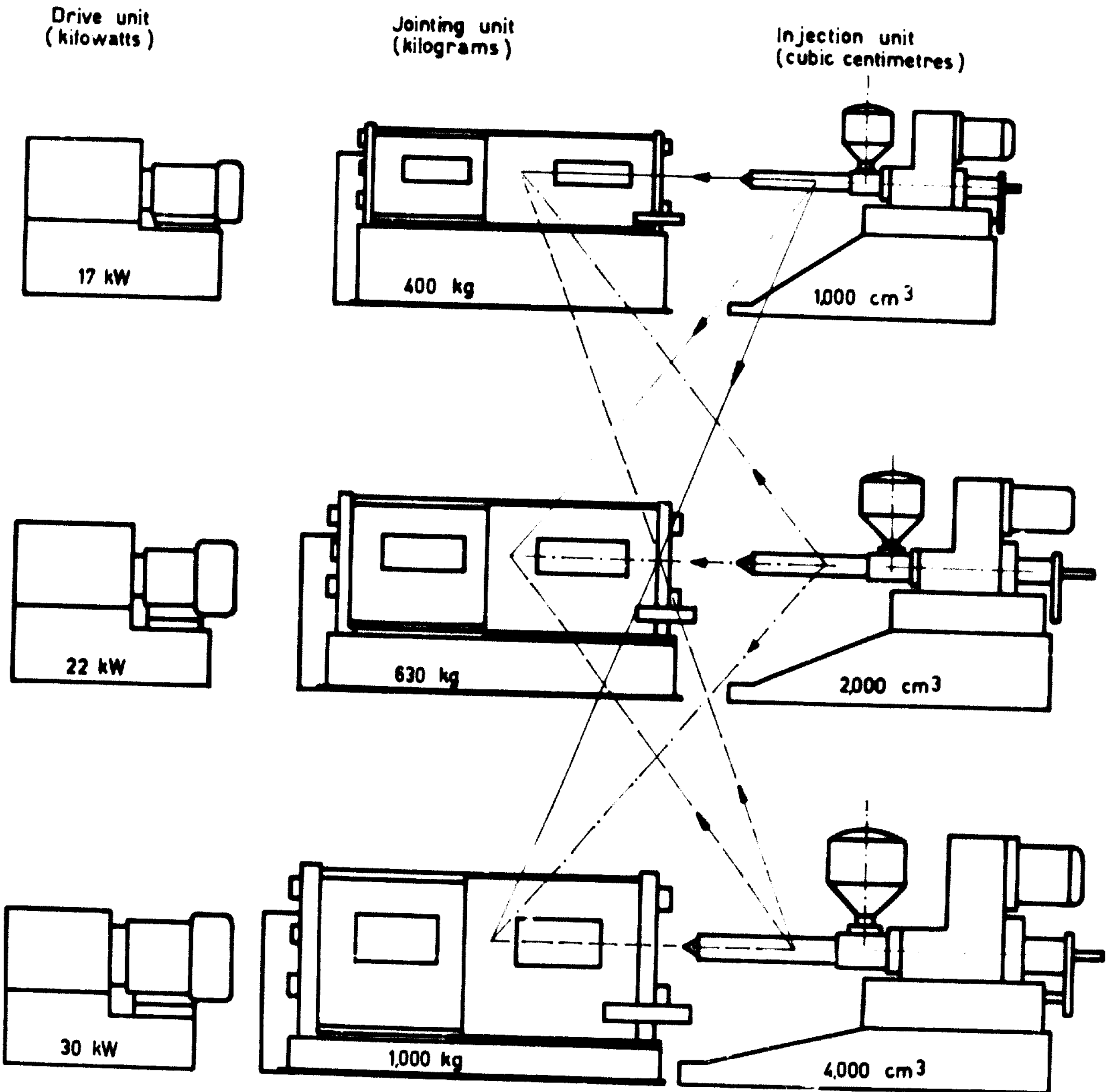


Figure 13

COMPOSITION DIAGRAM OF PRESSURE CASTING MACHINES

fixtures and gauges; and it may be carried out on better automatic machine tools due to the high degree of unification. This is why 80 per cent of the parts are processed with higher economic indexes when individual machine tools are made. If one is to assume that this economy constitutes only 10 per cent of the cost production of a machine tool, then the production of 100 machine tools will yield an economy of DM 1.5 million.

The optimal degree of unification becomes the criterion of the technological features of a machine tool while it is still being designed, for which purpose the indexes are used, which are the proportion of a number of standard or unified parts and units, and the total number of parts and units. The designer should determine the following indexes:

(*a*) The degree of unification of machine-tool units of the same designing row:

$$K_B = \frac{Gr_{uni}}{Gr} \cdot 100 \text{ per cent}$$

where Gr_{uni} = the number of units taken from other machine tools of the same designing row; Gr = the total number of units in a machine tool;

(*b*) The degree of unification of units taken from machine tools of other types:

$$K_T = \frac{Gr_u}{Gr} \cdot 100 \text{ per cent}$$

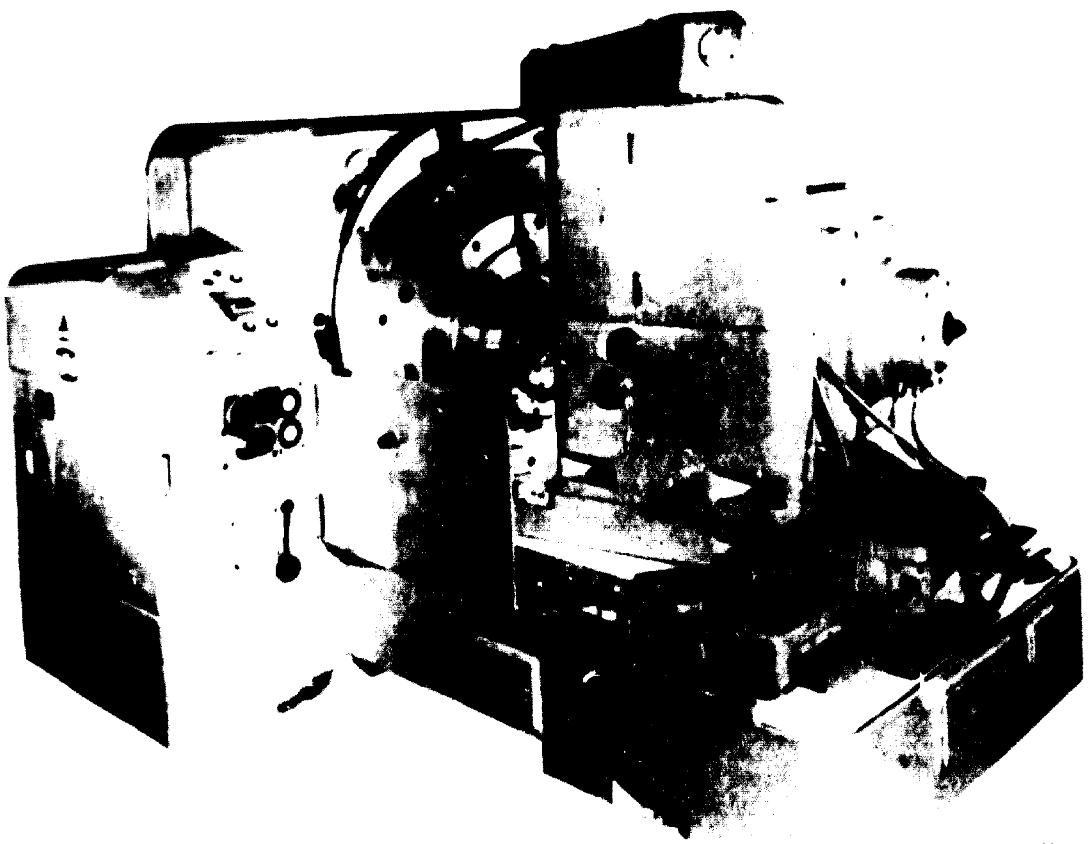


Figure 14 MACHINE FOR MILLING BEVEL GEARS WITH DIAMETER OF 500 MILLIMETRES BY THE KURWEX METHOD

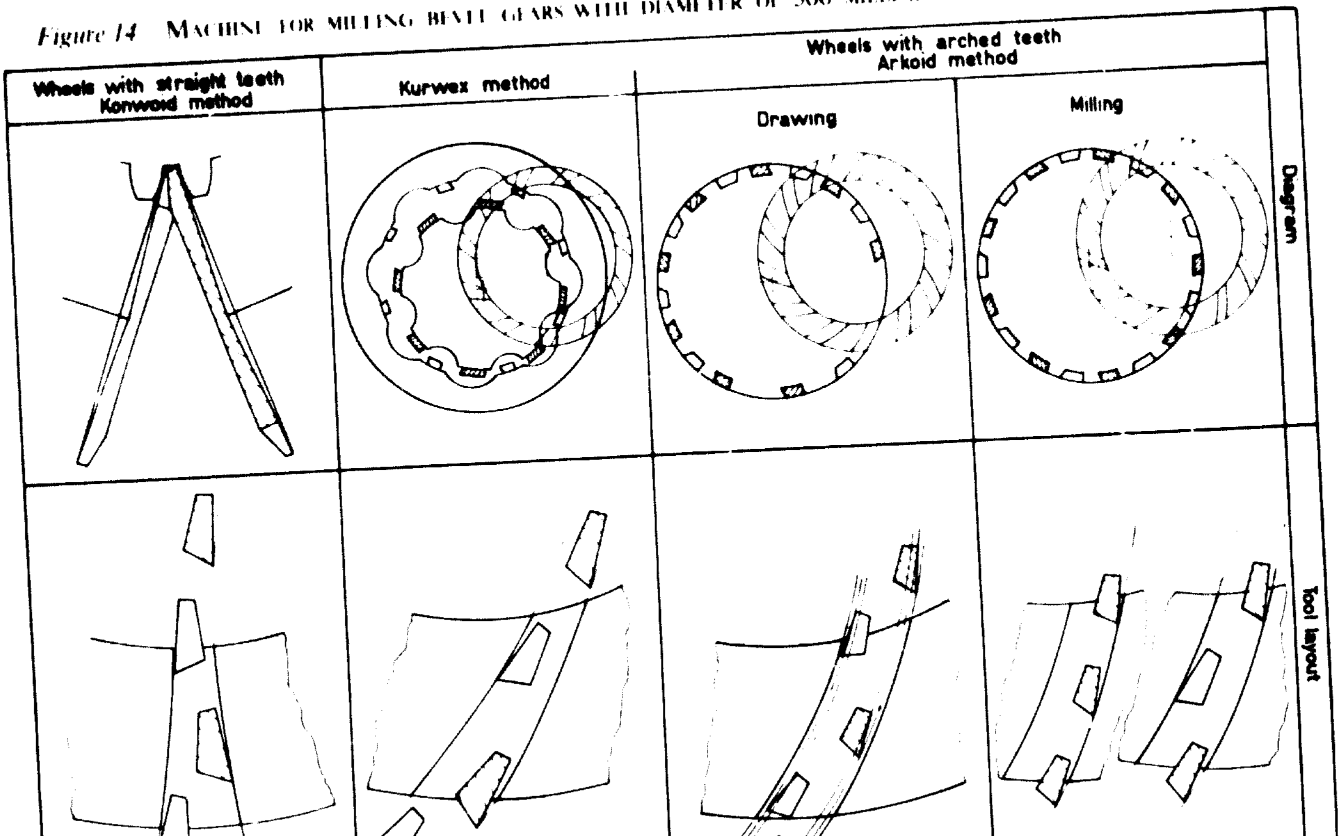


Figure 15 —METHODS OF PROCESSING USED BY VARIOUS MACHINE TOOLS FOR CUTTING BEVEL GEARS

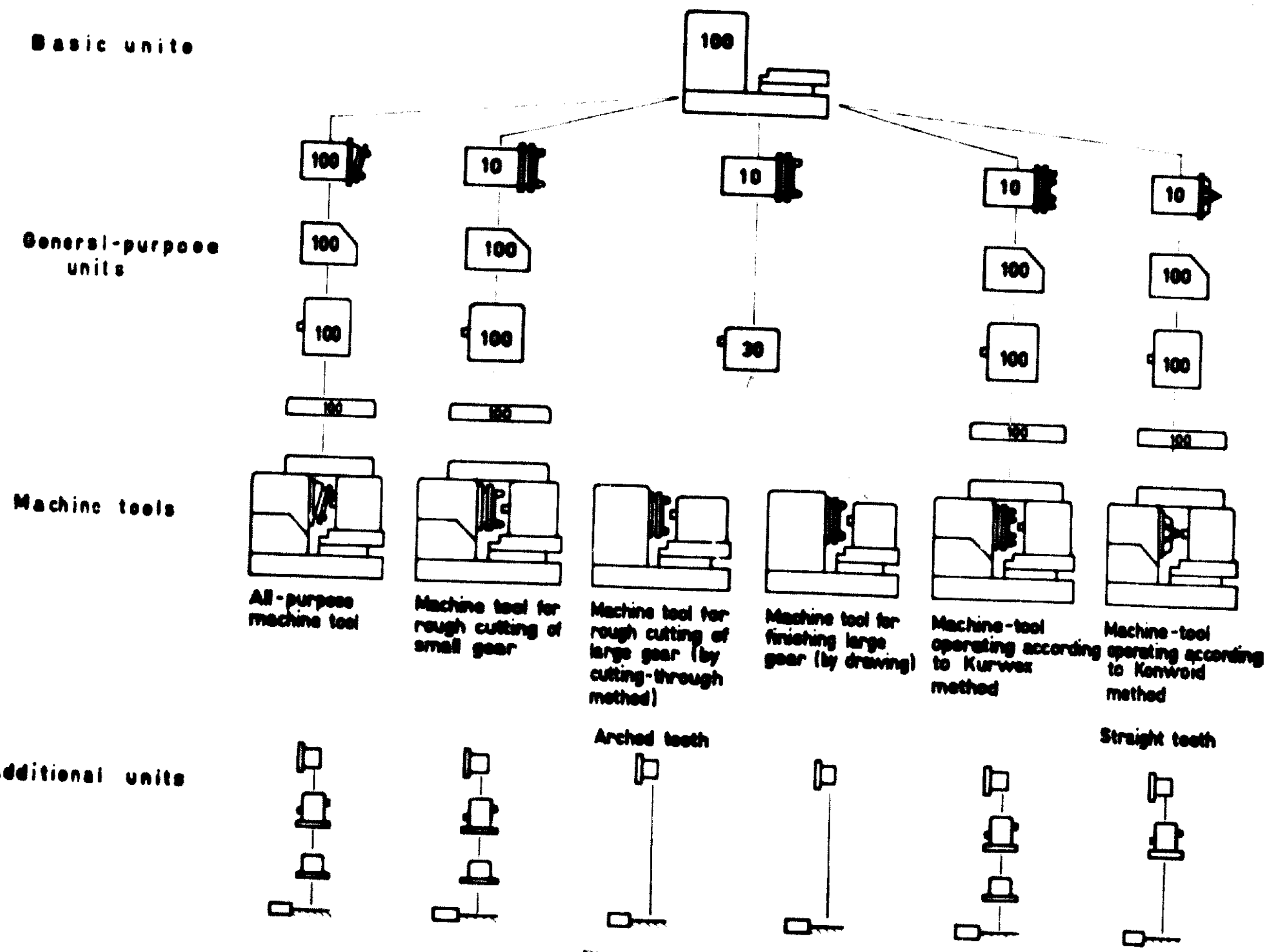


Figure 16

UNIFICATION OF VARIOUS MACHINES FOR CUTTING BEVEL GEARS: PERCENTAGE OF REPEATED PARTS OF INDIVIDUAL UNITS OF THE UNIVERSAL MACHINE TOOL

where Gr_u = the number of parts taken from units and machine tools of other parts; Gr = the total number of units in a machine tool;

(*c*) The coefficient of use of formerly designed parts in the new design:

$$K_K = \frac{E_{rorh}}{E_{gk}} \cdot 100 \text{ per cent}$$

where E_{rorh} = the number of parts of a unit or a machine tool taken from the already existing constructions; E_{gk} = the total number of designed parts of a unit or a machine tool;

(*d*) The degree of repeatedness of normalized parts:

$$K_{NB} = \frac{E_{no}}{E_n} \cdot 100 \text{ per cent}$$

where E_{no} = the number of standardized parts of a unit or a machine which already exist in the lists of a factory specifications; E_n = the number of standard parts in a unit or a machine;

(*e*) The degree of applicability of standard parts:

$$K_N = \frac{E_n}{E_g} \cdot 100 \text{ per cent}$$

where E_n = the number of standard parts in a unit or a machine; E_g = the total number of all parts in a unit or a machine.

The above-mentioned system of aggregation has served as an example for many other branches of industry because of its economic advantages. Not only has the system been acknowledged by experts, but it is also being more and more widely introduced throughout the world.

C. *Third stage: universal unified standard units*

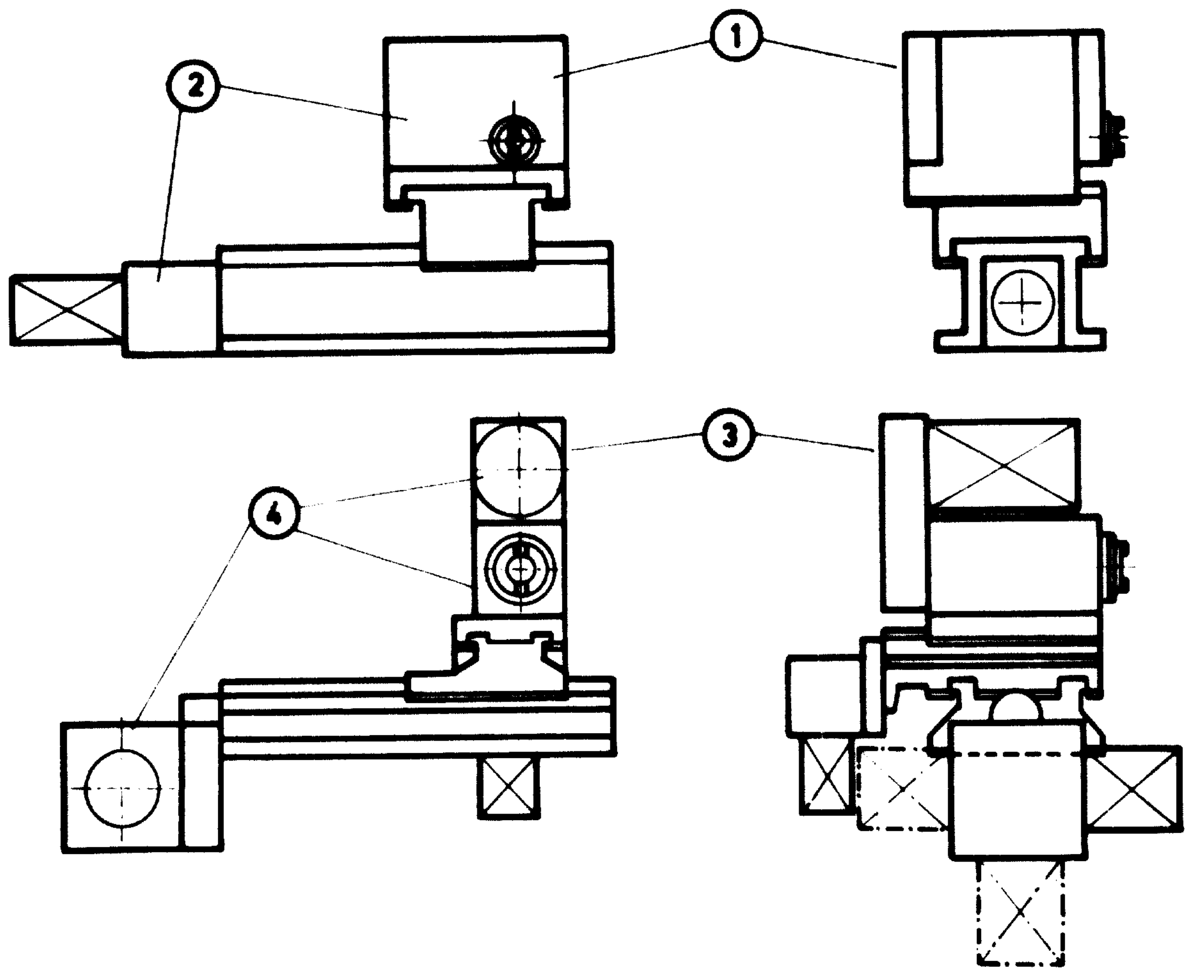
The third stage of designing on the principle of aggregation consists in the fact that along with the above-described units, other units with a higher degree of unification, namely, the so-called "universal unified standard units" are being developed. From the very beginning, these units are not related to any definite kind of machine or processing method, but are developed irrespective of them so that in any combination with each other they could be used to compose various machine tools for processing any actual item. These machine tools are called aggregated machine tools (see the composition diagram in figure 4). They are also often called special machine tools, but at the current time, it is difficult to give a definition of this name. All trends in the development of the machine tool industry are aimed at making all the machine tools according to a standard, that is, to design them in accordance with actual conditions which exist at the place of their operation. In other words, the trend is, to some degree, towards the designing of special machine tools.

As distinct from the units described above when considering the second stage of aggregated designing, the universal unified units are standardized within a country at least, as the former are rarely used outside the enterprises producing machines of a definite type. That is why it became possible to establish a uniform design, or at least identical fastening dimensions, for many standard units, by an agreement between the centrally planned economies. There is no doubt that it will be possible in the nearest future to achieve the level of the International Organization for Standardization (ISO) and thus, the highest existing degree of standardization.

Fixtures for setting tools or items, the driving and the actuating mechanisms for them, auxiliary units for loading the blanks, controls and means of automation, measuring etc. are chiefly used as the universal standard unified units. Of course, these units are also subdivided by dimensional types, with the maximum degree of unification.

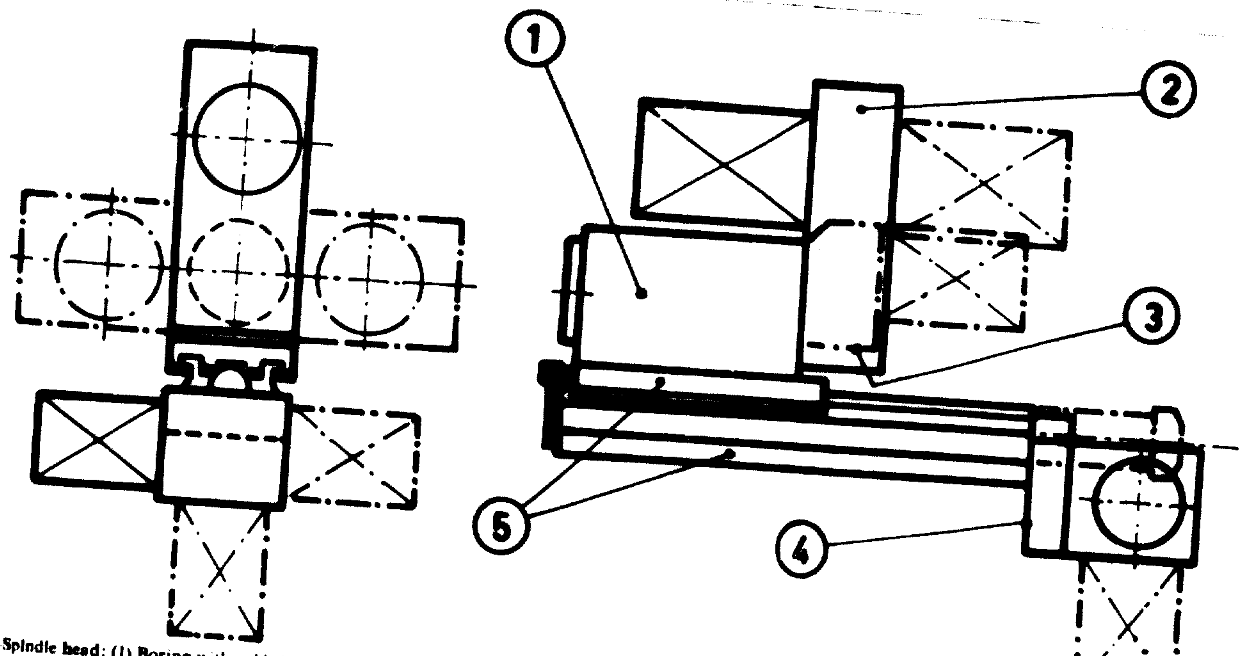
In future, only the principal diagrams of some of the most widely used standard units, which make it possible to understand both the nature of their development and the variety of their application, will be considered. As time goes by, their nomenclature increases because people manage to expand the use of those units which were formerly designed for some definite types of machine tools only. The units are gradually transformed from factory standards to branch and then to state standards, thus turning them into universal standard unified units. At the current time, this transformation chiefly occurs in the sphere of mechanical, pneumatic, hydraulic, electrical and electronic types of control and management.

The production of universal unified units should be carried out in a centralized way and the ready-made products should be kept in warehouses, from which they should be delivered to the enterprises which assemble machine tools.



1—Old power head; 2—In one casing, spindle, gear-box, withdrawing mechanism, two motors and one mechanism for feed and rapid travel; 3—New power head 4—Individual standard units for spindle, gear-box with motor and withdrawing mechanism with motor, and for feed and rapid-travel mechanism with motor.

Figure 17—OLD AND NEW TYPES OF MILLING POWER HEADS



1—Spindle head: (1) Boring with guided tools; (2) Rough and finishing boring; (3) Deep drilling; (4) Thread cutting. 2—Drive unit (single-spindle only): (1) Single-purpose transmission (1 speed, 4 gears); (2) Transmission with change gears (2 speeds, 8 gears); (3) Transmission with gear shifting (9 speeds, 11 gears); (4) Transmission with electromagnetic clutch (2 speeds, 4 gears). 3—Other modifications (for single- and multiple-spindle heads): (1) Single-purpose transmission (1 speed, 4 gears); (2) Transmission with gear shifting (9 speeds, 11 gears); (3) Transmission with electromagnetic clutch (2 speeds, 4 gears). 4—Unit of feed and rapid travel (mechanical drive): (1) Transmission with change gears (1 feed); (2) Transmission with gear shifting (2 feeds); (3) Transmission with electromagnetic clutch (2) feeds or other modification (hydraulic drive with variable control). 5—Carriage unit (length of lower part may vary, depending upon length of stroke and carriage)

Figure 18

MULTIPURPOSE HEAD FOR BORING WITH GUIDED TOOLS, FOR ROUGH AND FINISHING BORING, AND FOR THREAD CUTTING

use them in a complex, and that now merely five units are required to fulfil the same task. It is possible to make various designs and combinations using these units. Thus, greater freedom of combinations is achieved with a considerably smaller number of different parts. There are many individual units similar to the case of a children's designing set, shown in figure 2. The old milling unit (see fig. 17, top) is used as a whole; the common case houses the spindle, the gear-box, the withdrawing mechanism, two electric motors and the gear-box for feeding and rapid traverse. The case travels over the guides of the base. The new milling unit (see fig. 17, bottom) consists of the following parts: spindle head, gear-box with electric motor, withdrawing mechanism with an electric motor and the base with a carrier for feeding and rapid travel. It is possible to compose all these units individually in various ways and to choose a different design and dimensions. The surface of the carrier is a plane on which it is possible to assemble a spindle unit of appropriate dimensions parallel to the feed for boring or at right [angles] to this direction for milling. Both the gear-box [and] the feeding mechanisms are placed so that they can [be tu]rned with respect to the spindle axis; the motors [coul]d be installed on either side, as shown in figure 18. [Figur]e 19 illustrates a spindle unit with a gear-box and [motor.] The dimensions of the case and the fastening [dimen]sions are the same for all the units of the same [dimensi]onal type designed for various types of [machin]ing. Some of the principal possibilities of com-

Figure 17, using an example of standard milling units, illustrates that formerly such units usually consisted of a larger number of parts, so that it was only possible to

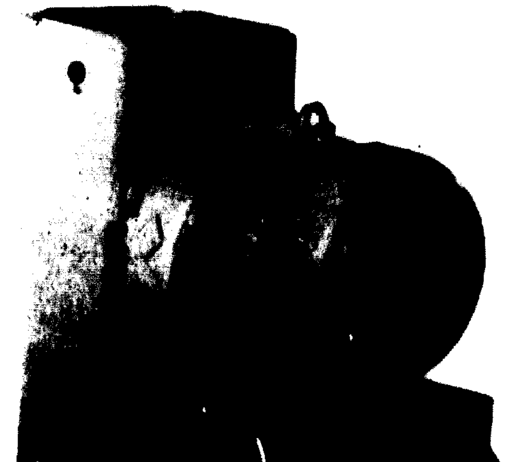


Figure 19—POWER HEAD WITH DRIVEN UNIT AND MOTOR

posing such standard units to make machine tools fulfilling various processing operations are illustrated in figure 20. The power heads on single-, double- and triple-direction machine tools are placed around the fixed table, which is also a standard unit. One or two heads may be installed in the vertical position for processing from the top. If the machine tool is equipped with a round indexing table, the power heads are placed around the table with a vertical axis of turning (round turn-table). On a drum type of machine tool, the items which may be turned around the horizontal axis (the standard unit of a drum) are processed on both sides. In automatic lines of interrupted action, the items move linearly along the power heads. From those few sketches it is possible to understand the extremely large number of composition variations which are possible, beginning with the simple one-sided aggregate machine tool and ending with an automatic line of interrupted actions, which serves here only as one of the possible applications of the principle of aggregation.

Any of these machine tools may be designed for processing definite items, but in contrast to the all-purpose

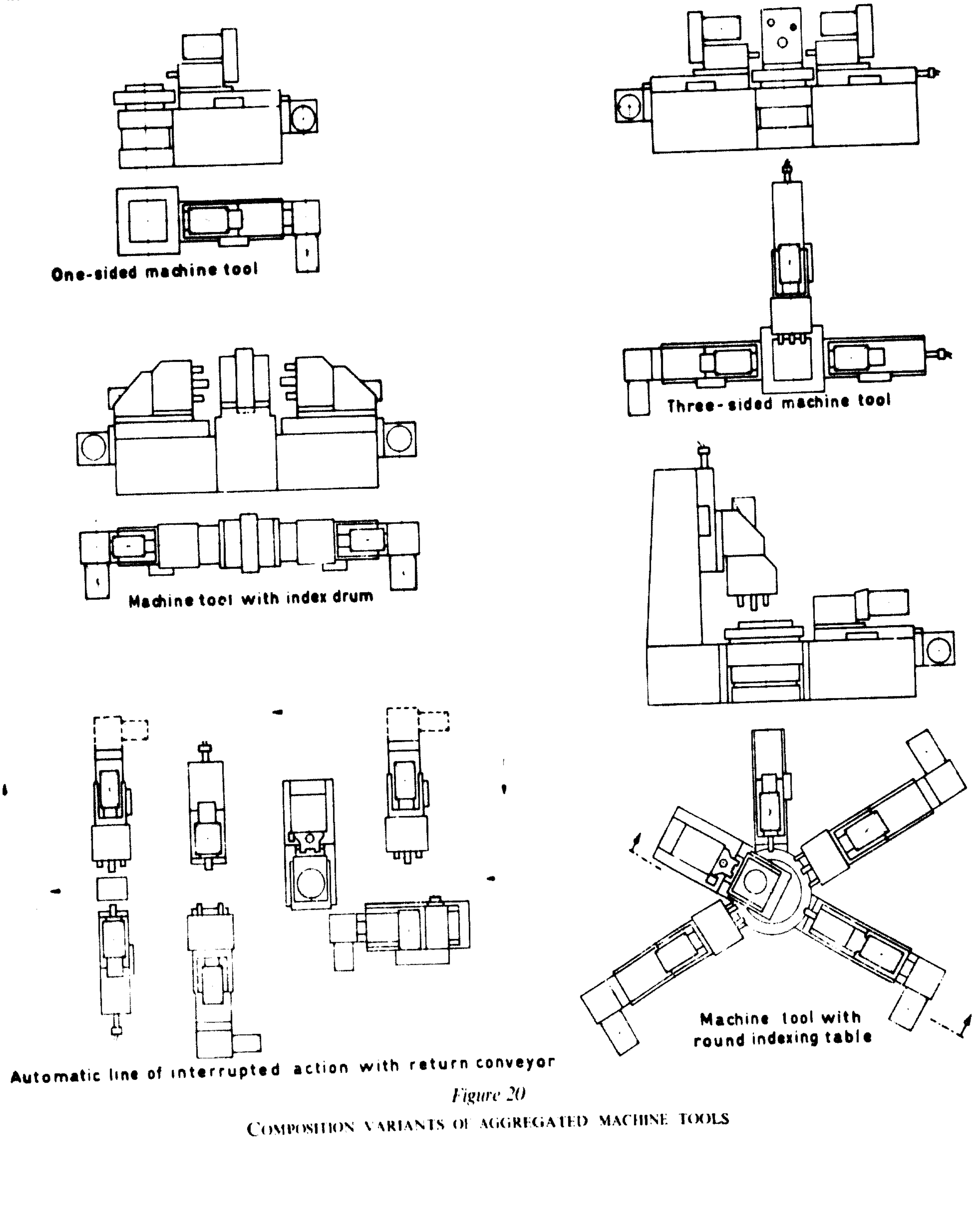


Figure 20

COMPOSITION VARIANTS OF AGGREGATED MACHINE TOOLS

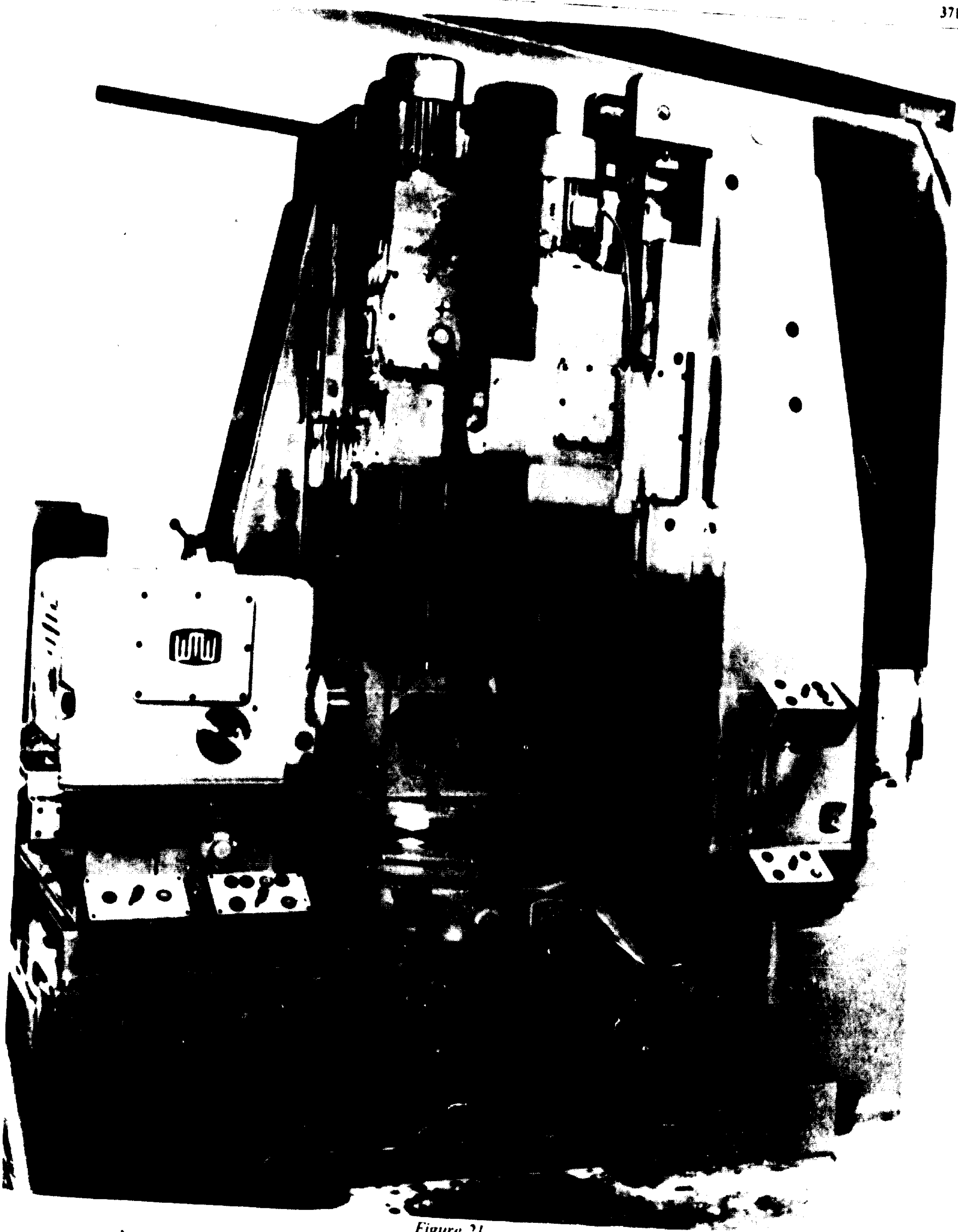


Figure 21

AGGREGATED MACHINE TOOL WITH ROUND INDEXING TABLE FOR MACHINING PUMP BODIES machine tools, the power heads are grouped around the item. The fact that a comparatively larger batch of machined articles, i.e., mass production, was considered necessary for the economic use of the equipment is the result of the definite specialization on one item. In a short time, however, the growth of productivity achieved on such aggregated machine tools led to their introduction for the processing of smaller batches. For this purpose, they tried to reduce the time of readjustment. In this case, it even became economically feasible to use complex automatic lines of interrupted action for processing several similar items produced in respectively smaller batches. For example, a machine tool with a round indexing table (see fig. 21) is intended for processing bodies of forty-five different geared pumps, of which the smallest has a maximum length of 90 mm and the largest, a maximum length of 260 mm. It takes about two hours for readjustment. The complex automatic line of interrupted action (see fig. 22) is used for processing five valve housings.

The further development of machine tools designed at the second and third stages of aggregate designing will take place in the direction of increasing the mutual changeability of the units obtained at those stages; in this case, the degree of their standardization will increase. In other words, a larger number of machine tools will become aggregated. It will be possible to compose the unit carrying the item with the power heads in any way desired on both the aggregated and the universal machine tools. Standard units are already in use on many all-purpose machine tools; an example of this is the drilling machine tool on an upright of box sections (see fig. 23), where the standard unit of spindle socket is used and, as a result, 80 per cent of its parts are taken from a set of standard units. On the other hand, the above-mentioned planer type of milling machine is converted into aggregated machine tools through the use of standard units, beginning at least with the unification of its power head (see fig. 24). A modern technologist who has obtained new equipment will demand that the binding surfaces correspond as precisely as possible to the items of those dimensions and forms which he is planning to process and that the power head or the heads with their drives are of exactly the same power and are located, in respect to the item, in the most expedient way for processing and tending those items precisely.

It may be seen, therefore, that metal-cutting equipment is more and more frequently produced by means of composing rather than by means of designing so that skilled designers are liberated for the very thorough development of the remaining small number of new constructions which are necessary.

D. *Fourth stage: optimal use of aggregation principle in designing*

The systematic implementation of this process throughout the entire industrial nomenclature of the metal-cut-

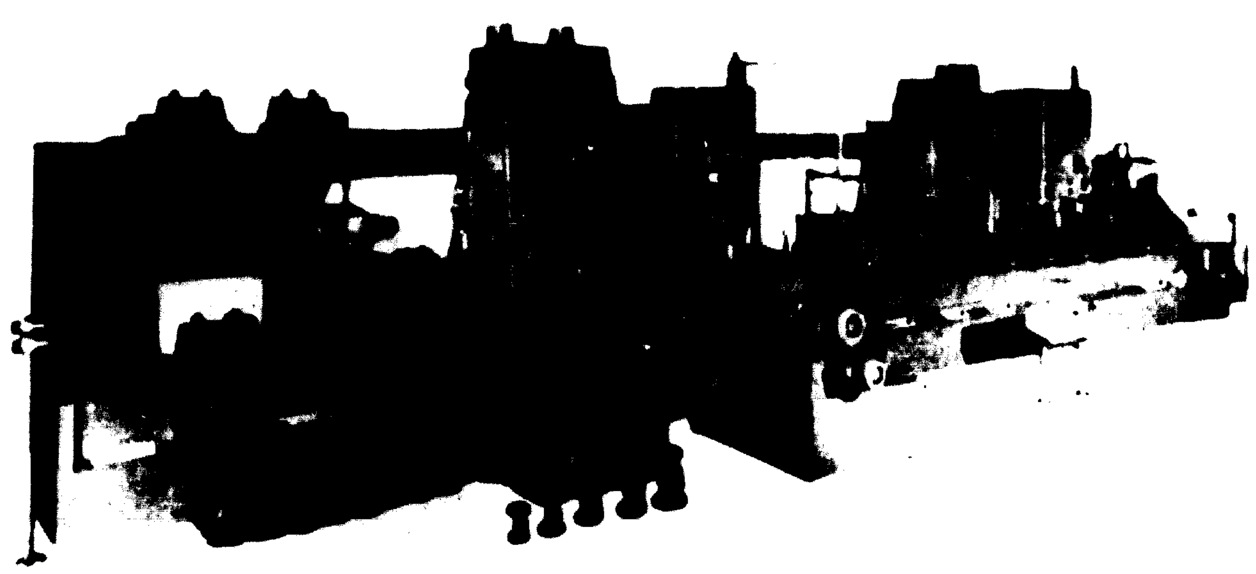


Figure 22

AUTOMATIC LINE OF INTERRUPTED ACTION FOR VALVE PROCESSING

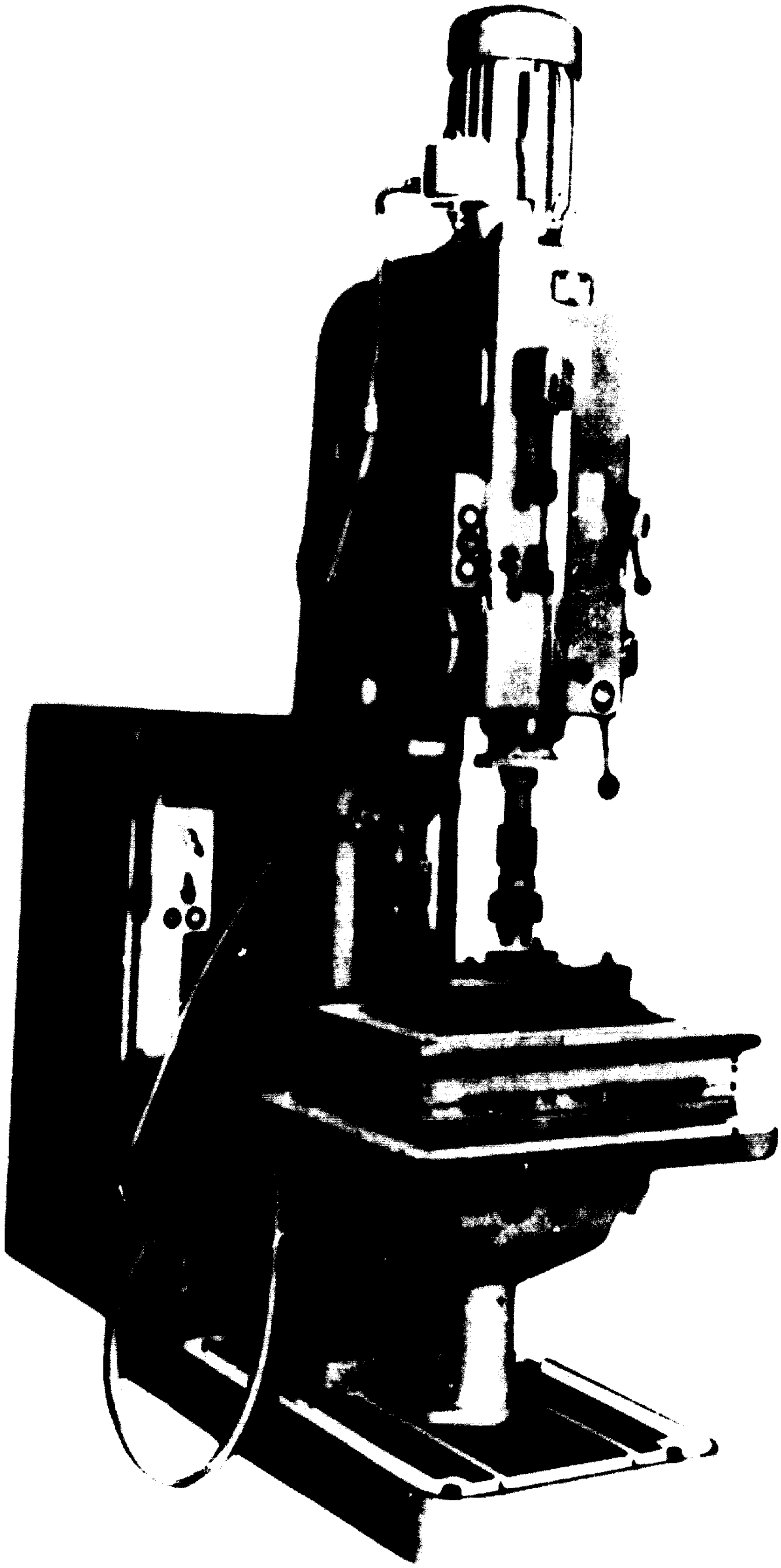


Figure 23

DRILLING MACHINE ON AN UPRIGHT OF BOX SECTION

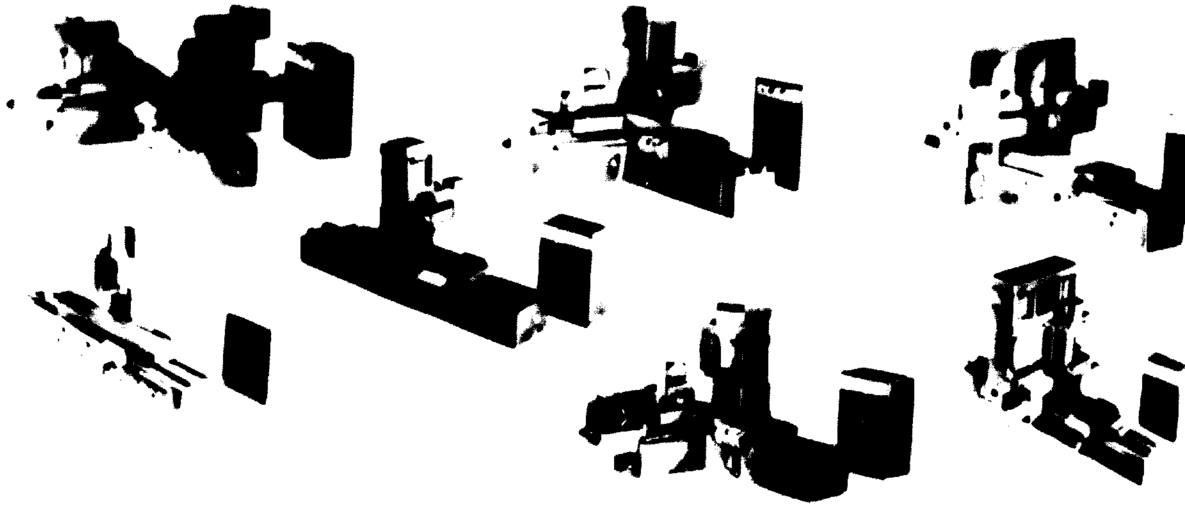


Figure 24

AGGREGATED PLANING MACHINES

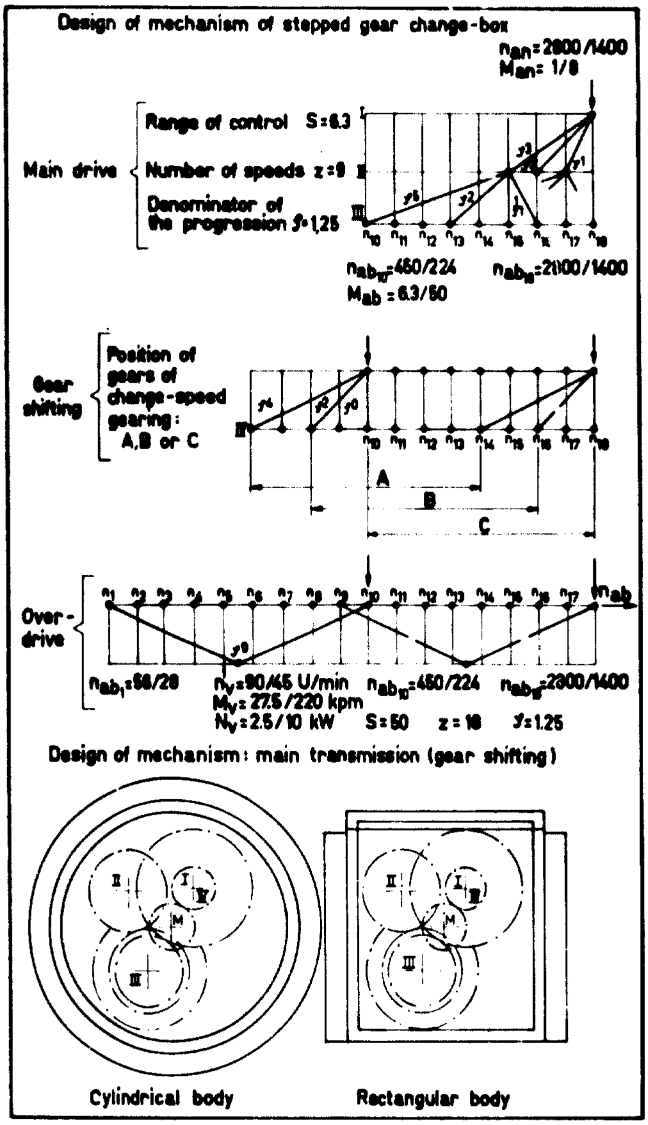
ting equipment produced, i.e., the optimal and complete use of the advantages of the aggregation principle of designing, may be indicated as the fourth and final stage. In this stage, it is necessary to move forward step by step, persistently studying every unit used in this branch of industry from the point of view of the possibility of using it universally for various purposes. It is then necessary to find the best design solution based scientifically, economically and technically, to check it in laboratories and in practice, and then to make it a standard. In each individual case, this should give the maximum economic effect and should be concluded with the centralized production of those units which have become standard.

The group of beds and uprights is one of the groups of units to be subjected to standardization. Scientific research yielded information on the most favourable proportions of size, heights and cross sections of the beds and uprights which should be employed in turning lathes, milling and planing machines, machine tools for grinding guideways and combined machine tools of various types. A designing row of beds and uprights, in which the proportion of sides, cross-section and height are in a geometrical gradation which would ensure the maximum rigidity with the minimum consumption of materials and the minimum labour expenditures in processing, is currently being developed.

Stepped reduction gears (see fig. 25) for use in the speed and feed-gear change-boxes of turning lathes, milling, boring and drilling machines, as well as in other machine tools of similar purpose, are included in another group of units. These reduction gears are developed according to the geometrical grading in power, speed and level of the speed range. The minimum number of modules of gears, various clutches etc. is established. The reduction gears may be used either as a unit with a housing or in the form of a kinematic chain consisting of gears, shafts and clutches assembled, in the case of an appropriate machine tool, in the most expedient way.

The next group of units are those carrying items and tools. Here, the base-rests, with and without a turning basis, are being developed. These are equally efficient for composing the central zones of aggregated machine tools and for horizontal boring, turret lathes and milling machines. It is especially clear from the example of this group that the all-purpose machine tools which have been considered individually until now have many things in common with the aggregated machine tools.

Although it is true that the instrument-carrying units must be of various forms, depending upon the peculiarities of the tools and the methods of placing them in the working position, a deeper analysis of the wide spheres of application in the entire branch will make it possible to discover many common requirements. This will lead to the creation of the designing rows, which promise great advantages from the point of view of improving the quality of design and the reduction of the cost of production, in case they are used repeatedly.



Note: n_{an} – speed of the driving shaft; n_{ab} – speed of the driven shaft; n_v – speed a full power capacity; M – torque; N – power.

Figure 25

DIAGRAM OF SPEEDS FOR A STEPPED STANDARD GEAR CHANGE-BOX

In the course of such a radical reconsideration of the production programme, all the results of prospective and even prognosed designing are used with success. In the sphere of units of carrying tools, the development takes place from the cylindrical spindle sleeve (tail spindles) on the guideway or roller guides through unified turrets to the automated magazines of tools.

The units of the measuring, control and adjustment group are most widely used because they are easily subdivided into small complexes of elements with simple fastening surfaces.

The foregoing examples of the wide assortment of optimized and standardized units are sufficient to explain the essence of the important process of wide aggregation for both the construction of equipment subdivided into unified or standard units and the application for production where the central or the standard units are produced by specialized enterprises, while the chief supplying plant deals mainly with assembly.

II. Advantages of aggregation system

In conclusion, it is necessary to comment on the economic significance of the aggregation system from the point of view of both production of the means of production of all types and their operation. In the process of production, especially of metal-cutting equipment, the significance lies in the numerous advantages in designing and production:

(*a*) When developing the first machine tool of a designing row, the labour required for designing is larger when developing multipurpose units for use in a system which is being permanently improved than that required when designing a unit to be used for one purpose only. This labour consumption decreases sharply, however, if one considers the establishment of designing rows and dimensional types using identical units repeatedly and on different enterprises. It becomes even smaller after a definite fund of unified and standard units is created. Aside from the units which have to be designed individually for some of the machine tools, this fund includes a large number of small or large unified groups of elements delivered by the centralized enterprise and the ever-increasing number of standard units. The quality of production increases simultaneously with the wide application of constructions which are optimal from the scientific and technical points of view;

(*b*) The creation of constructions meeting world standards and their continuous perfection becomes easier, the number of designers being the same because of the repeated use of identical units;

(*c*) The time required for designing special models and special machine tools is considerably reduced;

(*d*) The maximum repetition (of large batches) of parts and units makes it profitable to use a higher form of technology (i.e., fixtures, special devices, automated machine tools, special cutting and measuring instruments); the productivity as well as the quality and the homogeneity of the product, increases;

(*e*) The specialization of producing enterprises in a particular branch of industry and the centralized production of the parts and units used by different plants of this branch to complete different kinds of equipment, in turn, facilitate the production of increased batches of manufactured items, thus improving process conditions. Centralized production facilitates the planning and material supply and results in a more efficient consumption of materials and, hence, their saving;

(*f*) It is possible to achieve short terms of delivery for even very complex machine tools and automatic lines adjusted for the required technological process and the form and dimensions of the items;

(*g*) In the majority of cases, those machine tools can be brought into operation in an extremely short period of time;

(*h*) The commitments of the producer on an urgent delivery of spares and rapidly worn parts can be fulfilled more easily;

(*i*) Unification of fastening dimensions and the fastening apertures on the machine tool for additional units makes it possible to modernize machine tools which are already in operation by installing additional units or exchanging them for the old one. That is why the machine tools produced earlier can be used if they are developed further.

It is possible to understand fully the extremely large economic significance of the aggregation principle for the consumer if one imagines that the stock of equipment of an entire country, or even of a group of countries, consists of such machine tools. This stock of equipment based on aggregation would have created extremely wide possibilities to increase productivity. As this is currently the most important problem of industrial production, the economic significance of the aggregation principle cannot be over-estimated, and it should lead to a more intensive and, consequently, a more rapid introduction of this principle into all the branches under consideration.

A number of the advantages obtained by the producer from equipment according to the aggregation principle have a direct effect on the consumer:

(*a*) Reduction of labour consumption in designing and production of machine tools, including tools which are specially made from units delivered in batches to the warehouse, cut down the terms of delivery. The new technique is introduced more rapidly, which is accompanied by an appropriate economic effect;

(*b*) The delivery of interchangeable units from the plant-producer (warehouse) makes it possible to cut down the idle time caused by repair, to make the storage cheaper, to develop the equipment in operation and to modernize it without large adjusting operations;

(*c*) When buying new equipment and when modernizing the existing equipment, the repeated use of identical units guarantees the immediate reliable operation of the equipment as these units have already been repeatedly checked and, consequently, have been subjected to a continuous test. There is no risk in buying a new machine and no period is required to master it, which, as a rule, must be taken into account when calculating;

(*d*) It is possible to buy for immediate use the least expensive and most reliable machines, as it is possible to readjust them at any time to fulfil new functions by adding the appropriate units. The residual value of such equipment is always maximum;

(*e*) The possibility of obtaining equipment for special purposes and with the required degree of automation is ensured, and it is possible to use the identical standard units in various ways, depending upon the necessity. Thus, the price of a special three-sided drilling machine tool is about one-half of the price of the machine tool if it is developed individually for the same purpose without use of the aggregation principle;

(*f*) It is possible to solve complex technological problems by means of a free joining of universal machine tools to form automatic lines or by means of assembly of standard power heads along the flow of item on aggregated machine tools or a continuous line. This ensures the shortest ways and smallest losses of time in transportation;

(*g*) The consumer himself could make special machine tools intended for the actual individual needs of his branch of industry by using whatever is possible from the continuously growing nomenclature of unified and standardized units of the machine tool industry. This is inevitable, as only the consumer possesses the actual experience and necessary means to develop and test the remaining special units required;

(*h*) Identical fastening surfaces of the items and of tool-clamping units and their cutting parts in all machines of the same type and of the same make, as well as those at other enterprises of the country, make possible the increasingly wide application of the tools and the clamping units within one enterprise and in interplant co-operation. When some individual machine tools are out of operation and during the major overhaul, the clamping units and tools may be used on other machine tools;

(*i*) This is also valid for various additional units, for example, copying devices and units of automation, loading, measuring etc., which can be installed in the places envisaged for the purpose on a machine tool which has been constructed according to the aggregation principle;

(*j*) Equal grading of the speeds and number of double strokes, transverse and other feeds creates the condition for a uniform technological processing, thus facilitating the economically profitable application of a new technology, i.e., one needs less information to calculate the time for processing one item and also a smaller number of normals for instruments and fixtures, etc.;

(*k*) The same maintenance of the equipment and its attachments with electric, electronic, hydraulic, pneumatic, lubricating and other devices makes it easier for the people attending the equipment, as well as for the technologists to study better the technical peculiarities of equipment and the possibilities of its use.

It goes without saying that for each individual application of equipment built on the aggregation principle, the economic effect will be different. Furthermore, this principle could be more profitable if the consumers also understood all the advantages.

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