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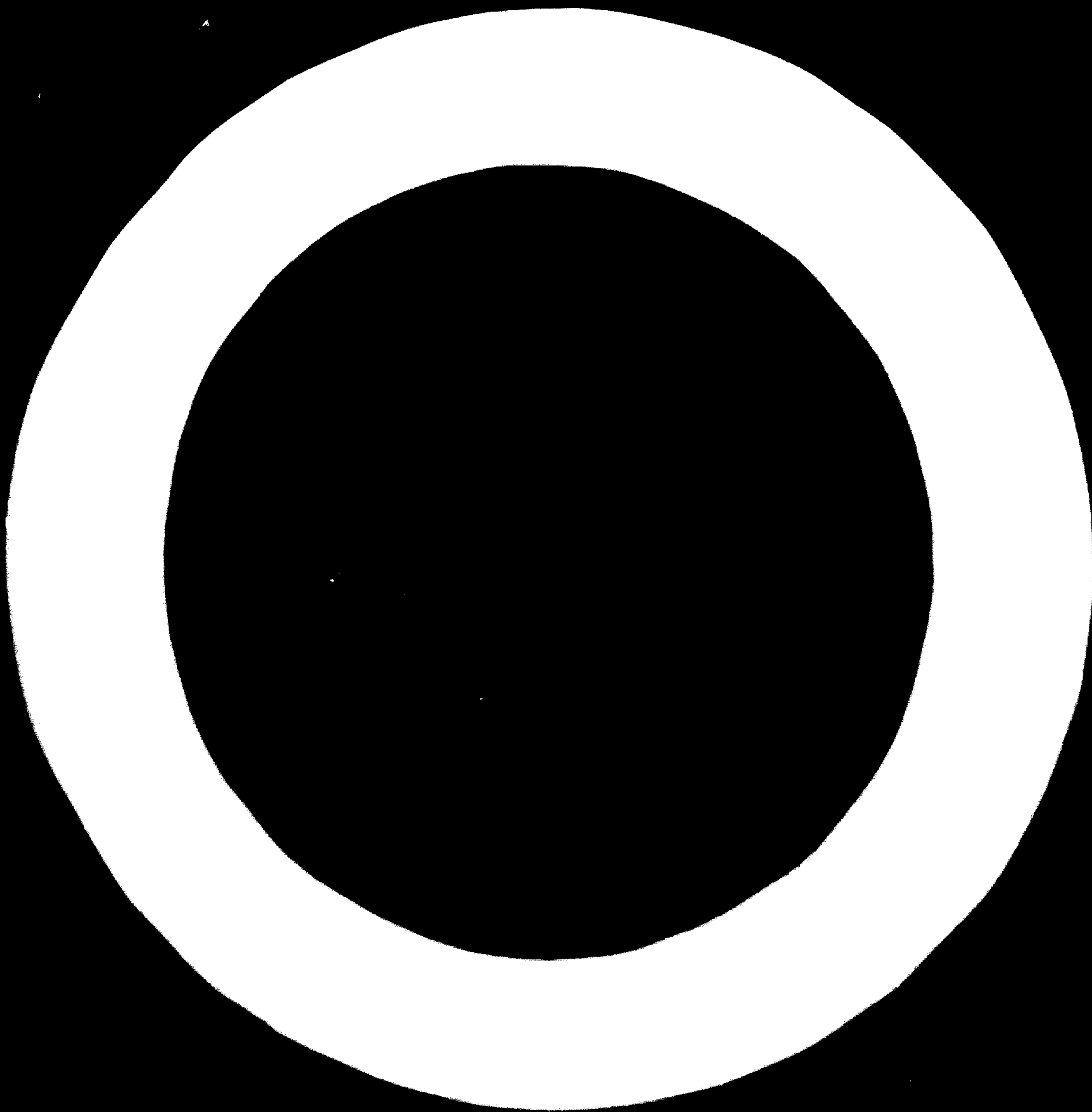

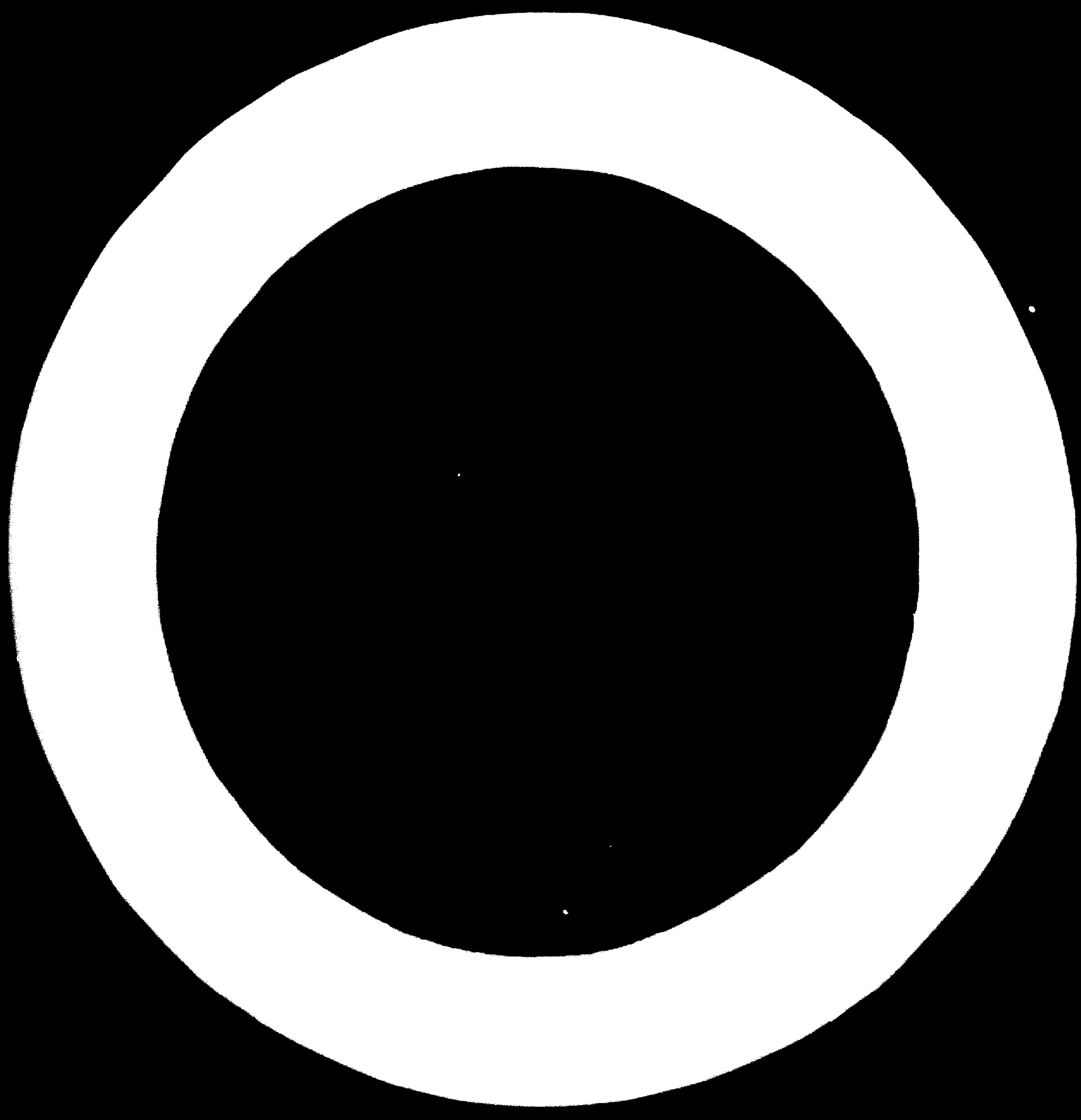

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ORGANIZATION OF FACILITIES FOR REPAIR AND MAINTENANCE OF INDUSTRIAL MACHINERY AND EQUIPMENT

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Introduction

Technical progress in machine building and metalworking can be said to be characterized by a considerable increase in the speeds and temperatures of working processes and an increase in variable loads and complexity of design, in order to ensure added accuracy of manufacture and faultless operation of machines.

The last ten years have brought an increase of from two to two-and-a-half times in the accuracy of mechanical treatment. Turning and grinding of medium-size parts to 10 and 1 microns, respectively, are common, and, in some cases, grinding accuracy of up to a fraction of a micron has also been reached.

Since the accuracy of manufacture of parts depends, to a great extent, upon the finish of the operating surfaces, increased requirements have been put upon the surface finish of the manufacturing machine. At the current time, an accuracy of up to 2-3 microinches should be ensured in many cases.

Any further development necessarily calls for a further increase of accuracy of mechanical treatment and finishing of parts' surfaces. At the current rate of development, it is expected that in the coming ten years there would be a twofold or threefold reduction in these allowances.

The particular problem is being solved by the perfection of the methods of parts treatment by cutting with tools of new materials and with new precision machines, as well as through the employment of maximum automation and mechanization.

To satisfy the demands made of mechanical engineers, machine building engineers are incessantly improving the designs of metalworking machines along the following lines: an increase of static and dynamic rigidity; accuracy of working and part-adjusting motions; automation, mechanization and control during machining; reliability and service life, parts fitness for repair; and improvement of the technological process.

The second trend is the extension of technological possibilities of the machine.

Deeper drilling, broaching or milling is now being effected by the provision of multiple-position turrets, additional upper carriages and other arrangements on automatic lathes of the single-spindle type. In addition, multiple-spindle turret facilities make it possible to process parts from both sides during the same operation.

At the current time, six- and eight-spindle double-indexing automatic lathes are widely used, the double index giving the advantage of simultaneous machining of two different parts on the same lathe.

While designing, major consideration is given to the reduction of the auxiliary time. This problem is being solved by increasing the speeds of idle displacements; utilizing mechanized means of clamping and fixing of blanks; the introduction of multiple-position tool-holders; and using automatic loading arrangements and resetting facilities, as well as by using other arrangements intended for active control of the parts' dimensions. It is envisaged that the accuracy of the parts' machined surfaces would be checked by various built-in measuring instruments. Besides controlling the process of machining, these instruments would also be used for discarding machined parts as required.

Constant attention is also being paid to design improvements in progressive, high-production, multiple-tool and multiple-position machines. Particular attention is being given to multipurpose, abrasive, broaching, turret and vertical cutting lathes; semi-automatic and fully automatic machines of all the groups and purposes; specialized and unit machines; and heavy-duty and precision machines for new kinds of machining. The share of the machines of the above-mentioned kinds and purposes in machine-building has been significantly increased.

Automation and mechanization of machines are being effected in the following two basic directions. All high-production machines used for mass and large-scale production are so designed and manufactured that they they can be easily installed as "built-in" components of automatic lines. These machines are equipped with arrangements for a pre-selective speed-change system, variable speeds and feed control, and automatic changing of cutting tools.

Automatic lines of resetting automated machines, equipped with normalized transport facilities, loading, control and metering devices, have found a wide application in mass and large-scale production.

On the other hand, in small-scale and piece production, there is a tendency towards the use of machinery equipped with arrangements facilitating dual control, by programme and by automatic cycles.

Programmed control over metalworking machines is becoming one of the most effective means of automation of small-scale and serial production, as it permits the solution of control problems by the position of the tool in relation to the part under processing and to the cycle of the machine operation.

Some of the most important advantages of machines with the programmed control are:

(a) Rapid resetting for processing another part;
(b) Reduction in the cycle of technological preparation;
(c) Simplification of technological rigging and reduction in operational costs;
(d) Increase in machining productivity at the expense of reduction of auxiliary and main time for machining;
(e) Reduction in the number of rejects as a result of possible mistakes of operators.

Since machines with programmed control have a higher degree of automation, as compared with multi-purpose machines, it stands to reason that a higher degree of accuracy and rigidity be given to these machines.

The sphere of application of machines with programmed control is rather extensive. The particular type of equipment makes the machine universal and flexible, when mastering new production units under conditions of small-scale and serial production. Processing of parts on machines with a programme control is characterized by a high degree of concentration of operations, and automatic lines consisting of machines with a programmed control will find wide application in the near future.

The up-to-date technological equipment of the mechanical-engineering and metalworking enterprises requires a more qualified maintenance. Both the operation and repair of such equipment have become highly complicated.

The perspectives of the development of metalworking and expansion of the spheres of application of new processes and new equipment require that paramount attention be given to the improvement of the equipment utilization rate and, consequently, to the problem of organization of equipment operation and its repair.

Technical progress in mechanical engineering is constantly presenting new problems of the personnel of various repair agencies, the said problems having a final goal of maintaining, with minimum expenditure, the equipment in a serviceable state.

Thus, the exceptional role of repair agencies in modern mechanical engineering is explained by the introduction of extremely complicated equipment, the intensification of machining modes and the increased level of mechanization and automation of production processes, as well as by the considerable expenditure allocated for maintaining the equipment in a serviceable condition.

I. Concept of reliability, service life and repairability of equipment

Much attention is given to repairability of parts in the mechanical engineering and metalworking industries.

The problems of reliability, service life and repairability may be equally related to the designing, technological, operational and economic aspects.

The reliability, service life and repairability of machines are taken into consideration while working out the designs, are ensured in the course of equipment manufacture and are maintained during operation.

1. *Reliability*

Reliability is a property of the machine and it has a probable character. Reliability is probability of the fact that under certain conditions of operation the machine will function satisfactorily for a sufficiently long period of time for its use to become effective. Reliability is characterized by regularly appearing faults and is considered to be one of the most important quantitative characteristics of machine quality.

Faultless operation of the machine within the prescribed period of time may be regarded as a quantitative estimate of reliability of a general-purpose metal-cutting machine. In the above-stated case, the numerical value of reliability is determined from the time interval during which the machine is likely to function satisfactorily, tp, and from the total time of machine idling, tnp, owing to preventive maintenances, emergency repairs and additional setting-up of the machine. Besides, the numerical value is also characterized by the coefficient of readiness:

$$\eta = \frac{tp}{tp + tnp} \qquad \text{(Equation 1)}$$

It is also important to optimize the degree of machines' reliability. The higher the technical standard of the equipment designing and manufacture, the higher will be the degree of its reliability and, accordingly, the greater will be the expenditure of means and the labour consumption, which will, after all, determine its high production cost.

Since the increase of reliability will require certain material expenses, it cannot be obtained for nothing. At the same time, the increase of the degree of machine reliability will, evidently, bring down the repair and operational expenditures.

The minimum of curve x (see fig. 1) summing up total expenses, including purchase of the machine, and its repairs and operation, C_2, determines the degree of reliability which is likely to be the optimum from the point of view of the customer.

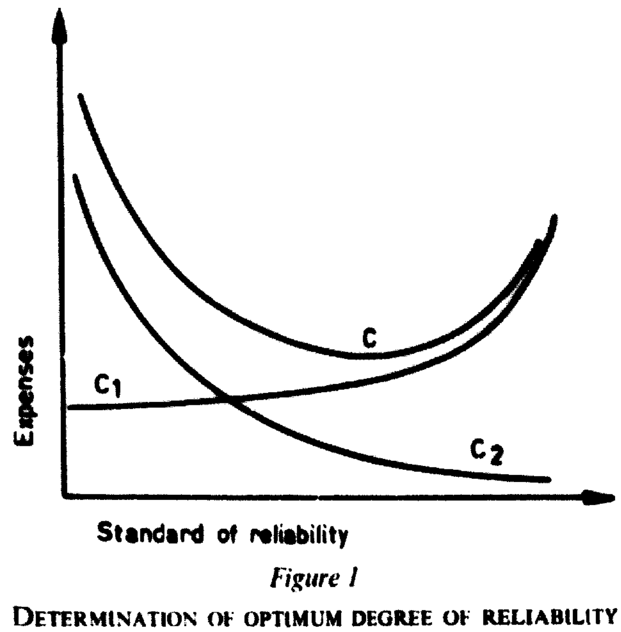

Figure 1

DETERMINATION OF OPTIMUM DEGREE OF RELIABILITY

Equipment reliability is assuming an ever-greater importance in automatic lines where synchronously operating machines are combined by means of a transport facility. The probability of faultless operation for automatic lines and complicated equipment is of paramount importance. In this case, the service life of the equipment is pushed to the background.

B. *Service life*

Service life is characterized by the duration of a machine's operation under certain operating conditions until the serviceability of the machine is completely exhausted and the machine is ready to be sent for overhaul or to be scrapped.

Total operation of the equipment throughout its operational period (until it is damaged or requires an overhaul) is considered to be a quantitative characteristic of the equipment's service life.

Metal-cutting machines should be related to the category of multiple-action and recoverable systems which are periodically repaired in order to restore their operational characteristics. After repair, the systems become serviceable again. However, no machine can be reconditioned perpetually. The time will come when further operation of the machine will turn out to be uneconomic and its replacement will be urgently necessitated.

For determination of the optimum service life of the equipment until the approximate date of its replacement, in addition to the expenses on the equiment purchase, and its repair and maintenance, there should necessarily be taken into account the factor of technological obsolescence of the equipment, that is to say, when the operated equipment can no longer be compared to other equipment which is similar in purpose, but which has far better working indexes, namely, in its efficiency, reliability and service life.

Prior to replacement of the equipment, it is necessary to compare the specific production cost per unit during the period under review, of both the equipment which is to be replaced and that equipment which is to replace it.

Here, the original cost of the machine should be taken into account along with the current operating expenses (monthly wages of workers, repairs, electric-power consumed and the tools used).

The following equation can be used for the particular comparison:

$$3e = \frac{3ct + \sum_{i=1} 3pi + \sum_{i=1} 3\epsilon i}{\sum_{i=1}^{n} Qi} \qquad \text{(Equation 2)}$$

where: $3e$ = specific expenses per unit of production;
$3ct$ = purchase price of the machine and cost of its mounting;
$\Sigma 3pi$ = repair and maintenance expenses;
$\Sigma 3\epsilon i$ = wages of workers and cost of electric-power consumed and the tool used;
ΣQi = total quantity of articles manufactured during the period under consideration.

The solution of the problem is a matter of some difficulty, since the values included in the above equation vary in time. Thus, figure 2 shows the variation of specific time wastes relating to one repair unit required for repair and interrepair maintenance of the universal machine, depending upon its service life.

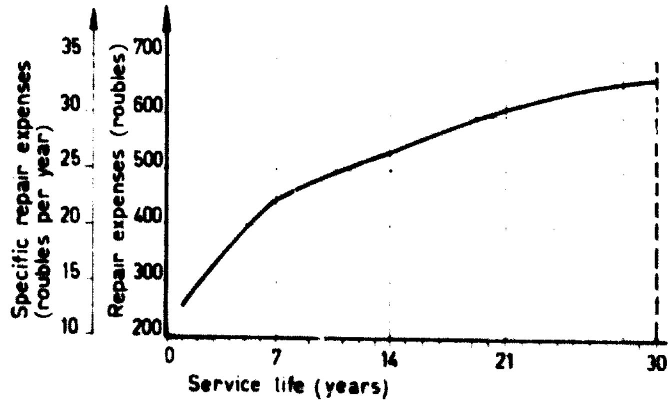

Figure 2

DEPENDENCE OF REPAIR EXPENSES UPON SERVICE LIFE OF THE MACHINE

C. *Repairability*

Repairability characterizes fitness of the machine for any repair and technical maintenance. Time required for reconditioning of the machine is considered to be the basic criterion of repairability.

The estimate of repairability may be carried out by the following characteristics: convenience in mounting and dismounting of units; convenient access for technical inspection with the objective of preventing, detecting and correcting the malfunctions; and possibility of rapid replacement of the parts which are most subjected to wear.

Reliability, service life and repairability are considered to be the main criteria for determination of the technical state of the machine.

II. FUNDAMENTALS OF PLANNED PREVENTIVE MAINTENANCE OF EQUIPMENT

In the course of operation, machines lose their working capacity mainly because of wearing and destruction of separate parts or of their surface layers, as a result of which the equipment becomes less accurate, in addition to the decrease in the machines' power and efficiency. Restoration of these most important operational characteristics of the equipment can be achieved by repairing the machine. The replacement and repair of worn-out parts, as well as the adjustment of mechanisms, should also be carried out in the course of the machine repair.

The experience of the Union of Soviet Socialist Republics over the years, which has been transferred to other countries, has proved that it is preferable to carry out the maintenance of equipment on a planning and preventive basis. Planned and preventive maintenance is carried out in accordance with a definite system adopted by industry in the USSR in 1932.

Rational organization of equipment repair in the Soviet Union goes as far back as forty years. The first researches for improvement of equipment maintenance began in 1923 in the Oka mountain district (the Urals) and were conducted by A. G. Popov. In that same year, the planning principle in maintenance was adopted in the Soviet Union.

In 1931, A. G. Popov published his work, *Rationalization of Maintenance in the Plant*, in which he generalized the results of the research works he had carried out at various plants. In his work, A. G. Popov set forth three basic and very valuable principles relating to the organization of repair works:

(*a*) Repair should be carried out so that the equipment can be kept serviceable for a continuous period of time;

(*b*) Repair should be preventive by its nature and should be planned deliberately.

(*c*) During equipment repair, replacement of parts should be effected, proceeding from the deliberately determined life of the parts.

Within approximately one year, that is to say, in 1932, the planned maintenance of equipment became popular in all the machine-building plants of the Soviet Union. The planned maintenance is carried out on the basis of an elaborated after-inspection maintenance system. The particular system implies the following principle: Instead of equipment maintenance, inspections are planned to determine the technical state of the equipment, upon which this or that type of maintenance of equipment, including the time required for its accomplishment, is planned, depending upon the inspection results.

Organization of planned maintenance of equipment on the basis of the after-inspection system is comparatively simple and has two basic advantages: (*a*) it ensures the possibility of organization of preparation for fulfilment of maintenance works; and (*b*) it ensures timely maintenance of the equipment, thus preventing the machine parts and units from disastrous wear as a result of continuous operation of the equipment.

In the meantime, the practice of employing after-inspection maintenance systems in the machine-building industry has revealed a number of major short-comings, e.g., the estimate of inspection results is of a subjective character. Determination of the type of maintenance and the time required for its fulfilment, proceeding from the inspection results, is accompanied by the introduction of essential amendments into the deliberately elaborated monthly and annual plans of maintenance works.

In 1940, a more improved method of organization of maintenance works was elaborated in the USSR—a system of planned and preventive maintenance.

On the basis of generalization of the experience of industry and research works, the system of planned and preventive maintenance has been constantly improved and specified.

In 1955, a system of maintenance and rational operation of technological equipment, common for all the machine-building enterprises of the Soviet Union, was finally formulated and approved. This system embraces the basic varieties of equipment used in machine-building enterprises: metal-cutting, woodworking, press-forging, foundry, lifting and transport (including hydraulic and electrical parts).

The work, *Common System of Planned and Preventive Maintenance and Rational Operation of Technological Equipment of Machine-building Enterprises*, was first published in 1955. In 1964, the fifth edition of the book was published; 120,000 copies of it have been printed and circulated.

At the current time, the basic statements of this system are thoroughly checked and are practised well enough in the industry.

The system of the planned and preventive maintenance has also found wide application in Czechoslovakia, Eastern Germany, the Federal Republic of Germany, Poland and some other countries.

This system implies a combination of organizational and technical measures concerning the maintenance and repair of equipment, carried out in conformity with a deliberately elaborated plan having the objective of ensuring faultless operation of the equipment. The system of the planned and preventive maintenance envisages the execution of routine inspections and planned repairs (minor, medium and overhaul) after each unit has worked out the prescribed hours of operation.

The repairs and the maintenance works envisaged in the system are preventive by their nature. Thus, the basic tasks of the planned and preventive maintenance of the equipment can be formulated as follows:

(*a*) Maintaining the equipment in a serviceable state throughout its service life;

(*b*) Ensuring the rational operation and maintenance of the equipment;

(*c*) Increase of service life of parts and mechanisms in order to cut down the expenditure for spare parts and to reduce the number of planned maintenance operations;

(*d*) Reduction of tasks of a labour-consuming nature and the decrease of total repair costs, along with the increase of their quality.

The machines may possess a high reliability and may be operated for a continuous period of time, provided the system of the planned and preventive maintenance is properly organized in the enterprises.

Planned and preventive maintenance of technological equipment includes its maintenance also.

Maintenance includes the operations to be done during interrepair maintenance, inspections, checking for geometrical accuracy, washing and changing of oils in the equipment housings.

A. *Maintenance*

Interrepair maintenance includes control over fulfilment of the equipment operating instructions listed in the technical manuals of the manufacturing plants, mainly those relating to the control mechanisms, guards and lubricating facilities. It includes also the timely elimination of minor faults and the adjustment of mechanisms. Interrepair maintenance is carried out during the stretches of time when the unit is inactive so as to avoid disturbing the production process. Such maintenance is carried out by the workers servicing the units and, in some cases, by the personnel of the shop repair agency on duty (mechanics, electricians, lubricators etc.).

Interrepair maintenance of automatic lines is carried out either daily or less frequently, depending upon the purpose of the line. If the line is operated during two shifts, maintenance will be carried out during the non-working shift; and if the line is operated during three shifts, then the maintenance will be performed in the space of time between the two shifts. Maintenance of automatic lines is carried out by the personnel and operators who are responsible for setting up the machine.

Inspection is carried out for the purpose of checking the state of the equipment, eliminating minor faults and determining the scope of preparatory works to be fulfilled during the nearest planned maintenance.

Inspections between the planned maintenances of the equipment are carried out by "locksmiths" with the participation of the personnel servicing the particular equipment.

Checking for geometrical accuracy is carried out at regular intervals after the planned maintenance and in accordance with a special schedule established for precision and finishing equipment.

All types of the equipment which operate in dirty conditions should be washed.

The list of units and assemblies to be washed is determined by the department of the chief mechanic of the enterprise, in accordance with the requirements set forth in the manufacturing plant manuals and with the account of conditions under which the equipment is going to be operated.

Washing is performed by "locksmiths" during technological pauses in the operation of the unit, non-working shifts and days off so as not to avoid disturbing the production process.

Oil change is performed in accordance with a special schedule for all equipment with centralized and housing systems.

B. *Repairs*

The system of the planned and preventive maintenance envisages three basic repairs, namely, minor, medium and overhaul.

The scope of each of these repairs makes it possible to compensate for the wear of separate parts and mechanisms which have been operating throughout the interrepair period.

Minor repair is a kind of planned maintenance during which the worn-out parts are either replaced or reconditioned, or the mechanisms are adjusted, thus ensuring normal functioning of the unit until the forthcoming planned maintenance.

Medium repair is a kind of planned maintenance dealing with the partial disassembly of units, the overhaul of separate units, the replacement and reconditioning of a considerable number of worn-out parts and the assembly, adjustment and testing of the equipment under load.

Overhaul is a kind of planned maintenance during which the unit is completely disassembled, worn-out parts and units are replaced, base and other parts and units are repaired and the equipment is assembled, adjusted and tested under load.

In the course of medium and overhaul repairs by adjustment of co-ordinates, the geometrical accuracy of the equipment and the power and efficiency should be restored for the period until the planned repair medium or overhaul.

The comparative labour consumption nature during the overhaul and medium and minor repairs is characterized by the ratio 1 : 0.6 : 0.16. The labour consumption nature of "locksmith" operations is 2.3 2.5 times higher than that of machining operations.

The interrepair cycle is a combination of repair and routine operations performed during machine operation in the period from date of commissioning until the overhaul, or in the period between the two successive overhauls. The structure of the interrepair cycle is determined by the sequence of the repair and routine operations, as well as by the priority of their fulfilment.

Thus, the structure accepted for universal metal-cutting machines consists of two medium repairs (C), six minor repairs (M) and nine inspections (O). The particular structure may be lettered and put down in the following way: **H O-M O-M O C O M O M O C O-M-O-M O-K**, where **H** new machine and **K** overhaul.

The structure of interrepair cycle envisages twenty-seven inspections for complex and automatic line equipment since the probability of faultless operations with these equipments is of utmost importance.

Other types of equipment have different structures of repair cycles. Thus, two medium repairs, three minor repairs and twelve inspections are envisaged for the forging hammer.

The interrepair period is the period of machine operation between the two successive repairs.

The duration of both the interrepair cycle and the interrepair periods can be determined, depending upon the type of equipment and the conditions under which the equipment is being operated. The durations of the interrepair cycle and interrepair periods are given in the hours actually worked out. However, said duration may also be determined from the number of calendar shifts (by introducing a correction factor for the equipment as it stands idling) or by using any other value indicating the number of working cycles of the equipment (number of machined parts).

The duration of the interrepair cycle is determined by the service life of the location and the most important parts which can be repaired or replaced during complete disassembly of the machine in the course of its overhaul.

The duration of the interrepair period depends upon the service life of the basic, mostly loaded, parts of the mechanisms (gear-wheels, splined shafts etc.). The increase of the duration of interrepair periods increases the degree of utilization of the equipment and reduces the repair expenses (see fig. 3). In the meantime, a wide interrepair period may bring about emergency machine idlings, as, in this case, the limit of wear of several parts may take place before the nearest planned repair.

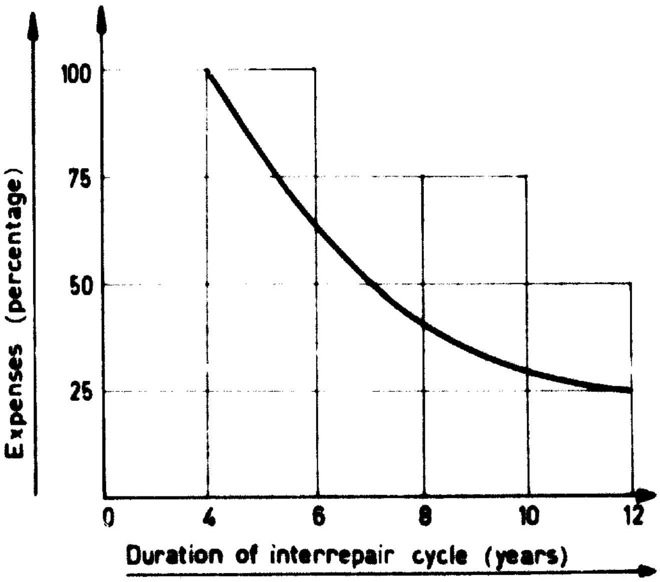

Figure 3

VARIATION OF AVERAGE ANNUAL REPAIR AND MAINTENANCE EXPENSES PER REPAIR UNIT

The shorter the interrepair period is, the more frequently will the repair operations alter and the greater will be the possibilities for repair or timely replacement of the defective parts (to ensure the full use of parts' service lives up up to the ultimate permissible values). However, the possibility of fulfilment of various repair works is connected with the equipment idlings, whereas frequent assembly and disassembly of the mechanisms, without a sufficient reason, adversely affect the operation of mated parts in the mechanisms.

To reduce idlings of machines when under repair, it is necessary to have a sufficient stock of spare parts in depots. The spares include those parts which are used for replacement during the interrepair maintenance and the planned repairs (minor, medium and overhaul).

Knowledge of the nomenclature of wearing parts and their service lives will permit the timely purchase or manufacture of the required spare parts, so as to have them in depots at all times.

The duration of the interrepair cycle (T) in actual hours is determined from the following equation:

$$T = an \cdot au \cdot ay \cdot acm \cdot A \qquad \text{(Equation 3)}$$

where

an, au, ay, acm — coefficients characterizing the conditions of operation

A — constant. For metal-cutting machines, it is accepted to be 24,000.

Changing of the conditions under which the equipment is being operated should correspondingly involve a change in the duration of the interrepair cycle. A number of coefficients are introduced for taking into account the influence of the various conditions under which the equipment is operated upon the duration of the repair cycle.

In serial production, the equipment is operated more intensively than in the case of piece production; and in mass production, the equipment operates more strenuously than it does with serial production.

Coefficient *an* takes into account the influence of the character of production. With the machine being operated in mass and multiple production, the value of *an* is accepted to be 1.0; in series production, it is 1.3; and in piece production, 1.5.

When machining steel and non-ferrous metals, the bed guides, lead screws and other parts and mechanisms of the machine are less contaminated than when machining cast-iron, whose disintegrated chip is known to contain a large quantity of abrasive particles. Coefficient *au* is introduced to take into account the influence of the material under machining. For the machining of cast-iron and bronze materials, the value of *au* is accepted to be 0.8 and for structural steel, 1.0.

The influence of the application of abrasive tools for processing machine parts, as well as the general dustiness of the production premises, is taken into account by common coefficient *ay*. The value of *ay* for equipment operated under normal conditions in the mechanical shop equals *ay* = 1.0; and *ay* for the equipment installed in a separate building protected from soiling is 1.3.

Since the share of the machine time (when operating heavy-duty and precision machines) which falls to the time of total unit operation is less than when operating normal machines, another coefficient, *act*, is introduced to take into account the conditions of operation of heavy-duty and precision machines. For multipurpose machines having a weight of about 10 tons, *act* = 1.0; for heavier and larger machines, *act* = 1.4.

Table 1 gives the approximate durations of interrepair cycles for metal-cutting machines used for two-shift processing of ferrous metals.

The degree of complication of the unit repair and its repair peculiarities are estimated by the categories of repair complicacy.

The category of equipment repair complicacy depends upon the design and technological peculiarities of the equipment. As initial data for establishing the category of equipment repair complicacy, one should take the technical characteristics tabulated in the machine logs (accuracy, weight, degree of automation, complicacy of mechanisms etc.).

The more complex the machine is and the greater its over-all dimensions and weight, the higher will be the accuracy obtained on the machine and the higher will be its category of repair complicacy.

Thus, for instance, a screw-cutting machine with a maximum working diameter of 400 mm and a maximum take between the centres of 1,000 mm, is referred to repair complicacy category 11. The labour consumption required for its overhaul constitutes 250 hours for the "locksmith" operations and 110 hours for the machining operations.

A boring machine with a boring bar 85 mm in diameter is referred to the category 18 of repair complicacy. The single-frame jig-boring machine whose over-all table dimensions are 320 × 450 is referred to the category 22 of repair complicacy. The labour-consuming nature of

Table 1

DURATION OF MACHINE OPERATION UP TO OVERHAUL

Type of production 1	*Machines* 2	*Weight characteristics of machines* 3	*Duration of machine operation up to first overhaul* 4
Mass and multiple	Normal accuracy	Light and medium, having a weight of about 10 tons	5.5–6.5
		Large and heavy, having a weight of 10–100 tons	7.5–8.0
Serial		Light and medium, weighing up to 10 tons	7.0–8.0
		Large and heavy, weighing 10–100 tons	9.0–10.0
Mass and multiple	High accuracy	Light and medium, weighing about 10 tons	6.0–7.5
		Large and heavy, weighing 10–100 tons	8.0–10.0
Serial		Light and medium, weighing about 10 tons	8.0–9.0
		Large and heavy, weighing 10–100 tons	10.0–12.0

its overhaul is 500 hours for "locksmith" operations and 220 hours for machining operations.

III. ORGANIZATION OF REPAIR WORKS

Fulfilment of repair works in a brief space of time and with the minimum expenditure of means can be obtained if such works are organized in the most rational way and ensure:

(*a*) The technical preparation of production of works on technical maintenance and repair;

(*b*) The planning of all kinds of works to be carried out during technical maintenance and repair;

(*c*) The application of progressive technology of repair and mechanization of handwork;

(*d*) The availability of the necessary spare parts and units before the repair works have begun.

As a production base for fulfilling operations on the maintenance and repair of the equipment, there should be a repair and mechanical shop, as well as repair bases in the production shops of the industrial enterprises operating the equipment.

The repair and mechanical shop manufactures those spare parts which cannot be purchased or whose purchase is inexpedient from the point of view of economy. In addition, the overhaul and medium repairs of equipment, as well as its modernization, can be carried out in a centralized way in the repair and mechanical shop.

To perform these works, the repair and mechanical shop should be outfitted with the necessary repair facilities. Table 2 describes an approximate set of the minimum equipment to be found in the repair and mechanical shop.

The repair bases are entrusted with a mission of fulfilling all the works concerning the technical maintenance of equipment, including minor repair. In some enterprises, however, the shop repair bases also perform the medium and overhaul repairs.

A repair team of "locksmiths" is usually entrusted with the task of fulfilling repair works in the shop repair bases. The whole equipment of the production area or shop is appointed to this repair team, which is also responsible for the repair and maintenance of machines of various models. Thus, idlings of the equipment will be reduced, due to the general personal interest of the whole repair team. Furthermore, the repair works are carried out without removal of the machines from the bed plates and, thus, the duration of machine idling, while under repair, is shortened. However, this particular form of organizing the labour of the repair men has significant disadvantages, since there is no specialization and this influences the labour productivity and the quality of repair.

Table 2

LIST OF EQUIPMENT OF REPAIR AND MECHANICAL SHOP OF MACHINE-BUILDING PLANT

Description of equipment 1	*Model* 2	*Basic data* 3
Screw-cutting engine lathe	1K62 1G620	Swing over bed: 400 mm Takes between centres: 710; 1,000; 1,400 mm Number of spindle speeds: 23 Range of spindle speeds: 12, 5–2,000 rpm Number of cross-feeds: 42 Range of cross-feeds: 0.07–4.16 mm rpm Power of main electric motor: 10 kW Weight of machine: 2,160; 2,300; 2,400 kg
	163	Swing over bed: 630 Takes between centres: 1,400; 2,800 mm Number of spindle speeds: 24 and 22 Range of spindle speeds: 10–1,250 rps Range of speeds: longitudinal feeds, 700 mm rpm; cross-feeds, 250 mm rpm

Table 2 — continued

Description of equipment 1	Model 2	Basic data 3
Screw-cutting engine lathe	163	Power of main electric motor: 14 kW Weight of machine: 4,350 and 4,500 kg
Universal milling machine	6M82	Working dimensions of the table (over-all width × over-all length): 320 × 1,250 mm Maximum travel of table: longitudinal, 700 mm; cross, 250 mm; vertical, 330 mm Range of distances from the axis of spindle to the table surface: 30–410 mm Maximum angle of table turn: ±45 degrees Number of spindle speeds: 18 Range of spindle revolutions per minute: 31.5–1,600 Range of table feeds: longitudinal, 25–1,250 mm/min; cross, 25–1,250 mm/min; vertical, 8–400 mm/min Power of main electric motor: 7 kW Weight of machines: 2,800 kg
Vertical milling machine with a swivel head	6M12N	Working dimensions of table (over-all width × over-all length): 320 × 1,250 mm Maximum travel of table: longitudinal, 700 mm; lateral, 260 mm; vertical, 420 mm Range of distances of vertical guides up to the middle of the table: 210–170 mm Angle of swivel-head turn rightwards and leftwards: ±45 degrees Number of spindle speeds: 18 Range of spindle revolutions: 31–1,600 minutes Range of table feeds: longitudinal, 25–1,250 min/min; cross, 25–1,250 mm/min; vertical, 8–400 mm/min Power of main electric motor: 7 kW Weight of machine: 3,000 kg
Horizontal shaping machine	7M36	Maximum and minimum slide movement: 150–700 mm Maximum distance from the cutter-support surface to the machine (spindle travel): 840 mm Working dimensions of table surface (over-all width and over-all length): 450 × 700 mm Maximum table movement: horizontal, 700 mm; vertical, 320 mm Maximum vertical travel of the cutting head: 200 mm Range of table cross-feeds per double movement: 0.25–5 mm Weight of machine: 3,200 kg
Slotting machine	7A420	Maximum travel of slotting ram: 200 mm Diameter of table operating surface: 500 mm Maximum table movement: longitudinal, 500 mm; cross, 400 mm; circular, 360 degrees Maximum angle of cutting-head travel: 90 degrees Number of double movements of slotting ram per minute: 40; 64; 102
Slotting machine	7A420	Ranges of longitudinal and cross-table feeds per double movement of slotting ram: 0.1–1.2 mm Power of electric motor: 2.8 kW Weight of machine: 2,100 kg
Vertical drilling machine	2H125	Maximum diameter of drilling: 25 mm Maximum spindle movement: 175 mm Working dimensions of table: 350 × 350 mm Spindle travel: 260 mm Range of spindle speeds: 165–2,300 rpm Range of spindle feeds: 0.104–0.837 mm/rpm Power of main electric motor: 2.2–2.8 kW Weight of machine: 600 kg
Radial drilling machine	2H55	Maximum diameter of drilling: 50 mm Maximum spindle movement: 350 mm (spindle travel); 1,600 mm Range of spindle speeds: 30–1,700 rpm Range of spindle feeds: 0.05–2.2 mm/rps Power of main electric motor: 4.0 kW Weight of machine: 4,100 kg
Surface-grinding machine	3671M	Maximum dimensions of the ground articles: 630 × 200 × 320 mm Cross movement of table: 235 mm Range of longitudinal movement of table: 70–710 mm Operating dimensions of table (over-all length × over-all width): 630 × 200 mm Range of cross automatic feed of table per movement: 0.2–4.0 mm Dimensions of grinding-wheel: 250 × 75 × 25 mm Power of main electric motor: 3.4 kW Weight of machine: 1,900 kg
Cylindrical grinder	3A161	Maximum dimensions of the work to be set up on machine: diameter, 2.80 mm; length, 700 mm Power of main electric motor: 7 kW Weight of machine: 3,800 kg
Gear-milling machine	5K32A	Maximum outer diameter of wheels cut by machine: 300 mm Maximum modulus of teeth of wheels cut by the machine: for steel, 10 mm; for cast-iron: 12 mm Power of main electric motor: 7.5 kW Weight of machine: 7,000 kg

IV. Specialization and Centralization of Repair Works

The technical standards and organization of metal-cutting equipment repair in the industrial enterprises operating the equipment are subject to the conditions of piece production and the use of the means and forces of these enterprises and, as a rule, fall below the standards for manufacturing the equipment at the plants.

Figure 4 shows the dynamics of alteration of labour consumption required for manufacturing a new screw-cutting engine lathe and that required for its overhaul.

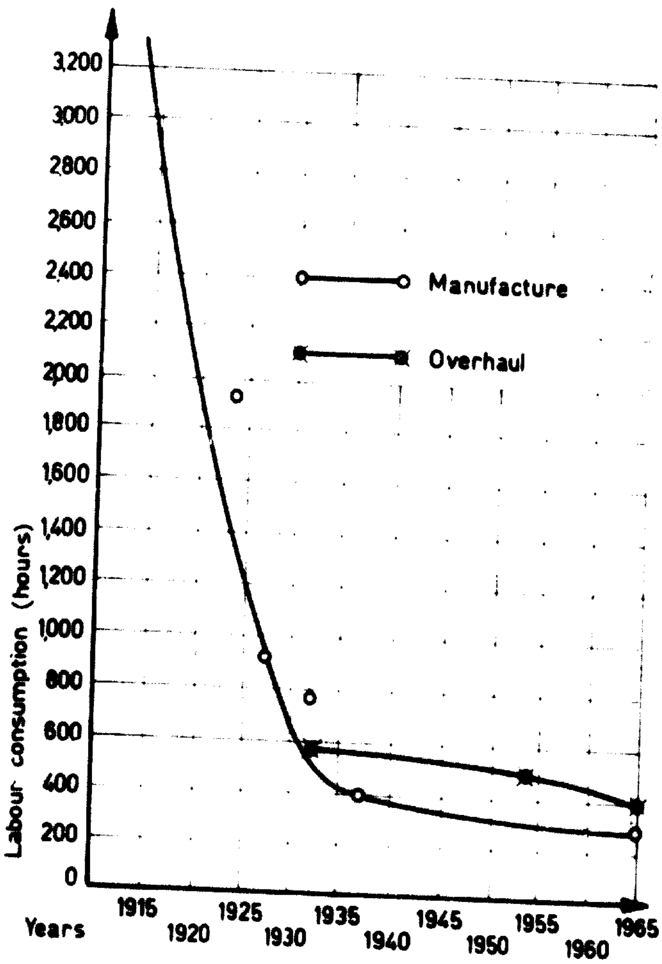

Figure 4

VARIATION OF LABOUR CONSUMPTION REQUIRED FOR MANUFACTURING AND FOR OVERHAUL OF SCREW-CUTTING ENGINE LATHE WITH 200-MILLIMETRE SWING OVER BED AND 1,000-MILLIMETRE TAKES BETWEEN CENTRES

Repair technology sharply differs from the technology which is accepted at the manufacturing plant. Wide nomenclature of the equipment under repair and rare repetition of the models make the application of special technological rigging ineffective; manual works predominate in the course of repair works; and, therefore, many of the technological processes used in the manufacturing plant turn out to be unprofitable and practically inacceptable under repair conditions. This particular factor adversely affects the fulfilment of repair works.

The complicacy of preliminary technical preparation during fulfilment of a single repair work may bring about considerable idlings of the equipment as it is being repaired. In the course of a single performance of repair works, the equipment of the repair and mechanical shop is proved to be insufficiently utilized. In connexion with this, it becomes reasonable to change the organization of repair works in the industrial enterprises.

Specialization and centralization are considered two of the most progressive trends in the organization of repair works in the industry. Both centralization and specialization create favourable conditions for progressive technological processes, as well as for rational organization of the production.

At the current time, specialization and centralization are being widely applied and may be carried out either within the enterprise which operates the equipment (inside-plant) or outside it.

Specialization and centralization of repair works on an enterprise level may be carried out by way of:

(*a*) Concentration of works to be performed in the repair and mechanical shop during the overhaul and medium repairs of the equipment and in making up special teams for the repair of common-type equipment. For instance, teams may be organized for the repair of grinding machines, turret lathes, semi-automatic and fully automatic lathes etc.;

(*b*) Making up teams with a limited sphere of repair duties (repair of hydraulic systems, repair of conveyors etc.);

(*c*) Organization of centralized performance of machining operations in the repair and mechanical shop.

Concentration of the overhaul and medium repair works for the common types of equipment presents an opportunity for properly equipping the repair team with universal and special appliances and for mastering the repair technology.

With centralization inside the plant, it is reasonable to ensure the concentration of several commonplace machines, as far as the repair time is concerned. For this purpose, it sometimes becomes necessary to shift somewhat the time-terms of the repair works.

Organization of repair during which all kinds of works are carried out by the personnel operating the equipment of the industrial enterprise is not yet the optimum plan. It is more effective to carry out the overhaul and medium repairs of the equipment in a centralized way either in equipment-manufacturing plants or in specialized repair plants.

For outside-plant centralization and specialization of repair works, there can be effected two basic forms of organization of repair works, namely:

(*a*) Organization of repair works ensuring fulfilment of the overhaul and medium repairs in the equipment-manufacturing plant, in which case the technical maintenance and minor repairs will be performed by the repair and mechanical shop and shop repair bases of the industrial enterprise which operates the equipment;

(*b*) Organization of repair works ensuring concentration of the overhaul works in the shops and enterprises which are especially designed for fulfilment of repair works.

The following are the repair works which it is advisable to carry out in specialized repair enterprises or specialized repair shops:

(*a*) Overhaul and medium repairs of the widely distributed models of universal metal-cutting machines;

(*b*) Manufacture of spare parts (which cannot be received from the manufacturing plant) for all kinds of repair works;

(c) Repair of precision and heavy-duty machines with departure to the enterprise's consumers.

Organization of the centralized repair of precision and heavy-duty machines is explained by the fact that transportation of precision machines is not advisable from the point of view of economy, since it will require a large expenditure of means and a waste of time for its assembly. In the meantime, heavy-duty machines are practically non-transportable.

Furthermore, during the centralized repair of complex and precision equipment, every favourable condition is created for the repair works to be performed on a high technical standard and with the wide utilization of various means and methods, ensuring both the mechanization of the repair works and obtaining high accuracies.

For centralized repair, it is advisable that the common types of machines be concentrated for repair during those definite calendar periods which create favourable conditions for the technical preparation of the repair works and, more particularly, for the manufacture of spare parts.

The following advantages can be obtained through the centralization of repair works:

(a) Reduction of labour consumption required for repairing machines and manufacturing spare parts and units;

(b) Reduction of cost price of parts and units for repair, at option of increasing labour productivity and decreasing the norms of metal expenditure.

(c) Increase of labour productivity while performing repair works;

(d) Reduction of the number of machines engaged in the repair of basic technological equipment;

(e) Extension of the interrepair cycle at option of increasing the quality of repair and reduction of machine idlings because of inferior quality of repairs.

During the centralized repair of the equipment, special shops may be organized for the reconditioning of worn-out metal and labour-consuming parts.

Specialization and centralization of repair works may reduce the expense of equipment repair by 25 30 per cent, while equipment idlings while in repair may be reduced five or six times. They may, in addition, ensure the provision to the industrial enterprises of the spare parts required for all kinds of repair works and will, therefore, assist in the increased quality of repairs.

When repairing the equipment in a specialized enterprise, it is advisable to combine the repair of the equipment with its modernization. It is advisable to effect modernization of the equipment simultaneously with the overhaul of medium repairs. Combination of the overhaul with modernization brings down the expenses, since the volume of "locksmith" disassembly and assembly operations is considerably reduced, as is the time of equipment idlings.

Modernization, depending upon the technical trend, is known to be of two kinds:

(a) General technical modernization ensuring the execution of a complex of measures aimed at the increase of technical status of the operated equipment by way of approximating its technical and operational characteristics to up-to-date machines used for the same purposes;

(b) Technological (target) modernization ensuring the equipping of the machines with various arrangements and mechanisms, as well as modification of their designs in order to solve certain technological production problems, introduce advanced technological processes, automate the equipment and effect automatic progressive assembly and mechanized lines using the modernized machines.

Modernization of equipment may be effected only if it is of economic value. An estimate of the economic effectiveness of the equipment modernization should be carried out by way of comparing the cost of the modernization of the machine and its subsequent operation with those of the purchase and operation of a new machine having an improved design. It would be wrong to estimate modernization by way of comparison of these expenses before the equipment modernization and after it.

An exchange fund should be provided in the enterprises for centralized repair of equipment. In this case, the machine accepted for repair would be replaced with the one already repaired and, thus, the equipment idling would be reduced to two or three days. The number of machines which would be required for the exchange fund can be determined from the following ratio:

$$n \quad \lambda \frac{m \cdot t}{300} \qquad \text{(Equation 4)}$$

where:

- n number of machines in the exchange fund;
- m number of machines annually accepted for repair;
- t duration of machine repair (days);
- λ coefficient accounting for irregularity of machines' acceptance for repair.

Enterprises for the centralized repair of equipment may also have a narrow specialization in the types of machines to be repaired, as well as in organization of specialized enterprises for the centralized repair of the group of engine lathes, the group of milling and drilling machines, the group of grinding machines and the group of gear- and spline-milling machines.

In specialized enterprises, it is advisable to carry out the repair of equipment on the basis of the line production system.

In the mechanical shops of specialized repair enterprises, it is advisable to organize individual manufacture of separate parts and units. The mechanical shops of specialized repair enterprises may be provided with high-efficiency equipment.

The "locksmith" and assembly sections should be equipped with various assembly and disassembly appliances and with stands for stationary testing and running-in of the equipment units.

A. *Recommendations for organization of centralized repair*

With the centralized repair of equipment, the quality of repair can be substantially increased. The technical standard of repair is determined by the operational characteristics of the equipment after being repaired and the ability to preserve these characteristics in operation and for a continuous period of time. In the course of fulfilling the centralized repair of the machine, the following recommendations should be taken into account in specialized enterprises:

1. While repairing the machine, do not effect any design modifications that might adversely affect their technical characteristics (power, efficiency or the factor (of economy) as compared with the characteristics of the manufacturing plant;
2. It is advisable to combine the overhaul and medium repairs with the modernization of the equipment. However, the problem of equipment modernization should, in each particular case, be thoroughly considered from the economic point of view and should be co-ordinated with the customer;
3. The machine which has been accepted for repair should undergo inspection and testing for accuracy. The inspection results will be entered on the acceptance certificate.

   When disassembling a machine under repair, the parts and units should be assorted as follows:

   (*a*) Serviceable parts, which have no defects that might adversely affect their operation while the machine is active and which have maintained their dimensions or have insignificant wear;

   (*b*) Parts which are worn and have defects that can be eliminated by various reconditioning methods, including subsequent mechanical treatment of the faulty parts;

   (*c*) Parts to be replaced, i.e. those which are worn and have defects whose elimination is either impossible or economically impractical;
4. The materials for parts to be manufactured during the repair of machines should conform to the technological charts of the machine-building plants;
5. Manufacture of new parts to replace those which are worn out should be performed in a strict conformity with the dimensions, allowances and other instructions given in the charts;
6. Assembly of the machines under repair should ensure the faultless operation of all the mechanisms and should be performed in accordance with the requirements listed in the assembly charts;
7. The lubrication and cooling systems of the machine handed over to the using organization after being repaired should ensure normal feed of oil and coolant;
8. The scope of work on the machines' overhaul (medium repair) includes repair of the entire electrical equipment mounted on the machine or in separate cabinets, in addition to the repair of the machine's electric wiring;
9. The machine which has already been repaired should be subjected to outside finishing, painting and ornamental finishing of all the machined surfaces of parts;
10. After being repaired, each machine should be provided with a name-plate indicating the plant which repaired the machine and the date of its output;
11. Each machine, after being repaired and handed over to the using organization, should be subjected to an acceptance test, the latter being carried out in the following order visual inspection, idle-run test, testing under load and in operation, testing for accuracy and testing for rigidity.

B. *Testing*

When testing at idle run, both the quality of repair and the correct interaction of machine parts and units are checked, for testing of the main motion mechanisms should be carried out in all the spindle speeds and that of the feed mechanisms, at all the feed values.

Testing under load has an object of checking for the correct functioning and interaction of all the units under normal conditions of operation, as well as for the faultless operation of all the mechanisms (electrical and hydraulic apparatus systems of lubrication and cooling).

After machine running-in at idle run and under load testing, its geometrical accuracy should be checked, in addition to checking the accuracy of the parts to be treated on the machine.

The results of testing should not be lower than those envisaged in the standards or technical specifications of the manufacturing plant.

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