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07866

Distr.
LIMITED
ID/WG.87/28
23 September 1971
ORIGINAL: ENGLISH

United Nations Industrial Development Organization

Regional Seminar on Machine Tools
in Developing Countries of Europe,
Middle East and North Africa

Zlatni Pjassazi (Golden Sands) near
Varna, Bulgaria, 18 to 27 October 1971

MODERNIZATION AND RECONSTRUCTION OF MACHINE TOOLS IN BULGARIA 1/

by

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id.71-7620

Machining operations take the lion share of the whole production process in machine building. Thus for instance about 40% of the total labour used in the production of the C11M engine lathe goes to machining operations, while its share in the production of size 5 electric motors amounts to about 52%, and machining alone of spare parts takes up to 80% of the whole production process.

The basic mechanical equipment of the machine building and machine maintenance establishments is concentrated in the machining shops of the factories. The machines used in the machining shops, mainly metal cutting, are designed to produce comparatively complicated machine parts, which have to meet very high technical requirements, and which have no other way to be produced in, but by cutting processes. With the existing rapid development of the technical thought in view, the machines used in the shops grow morally old well ahead of the period of their physical exhaustion. Thus machine tools grow morally old within 5 to 15 years as from date of release of a given type, while their physical collapse occurs later. In fact, however, the main service period of the machines comes after they grow morally old. It is, nevertheless, quite impossible even for the most technically advanced countries to replace the morally old machines by new up-to-date ones as soon as they appear. That is why in order to keep up pace with the latest technical achievements and meet the increasing demand of ever more efficient machines a very important task is laid on the partial or full modernization of the existing morally old machines.

It is generally accepted that modernization means such a reconstruction of the old machines, which will enable them to improve their technical resources by strengthening of separate units, adding new elements and assemblies, etc.

Machine modernization harbours great possibilities for further technical development. All steps intended to modernize the machines can be divided into two main groups

1. Modernization aimed at cutting down machining time.

2. Modernization aimed at cutting down handling time.

MODERNIZATION AIMED AT CUTTING DOWN MACHINING TIME.

The basic measures related to machine tool modernization with a view to cutting down the machine time are directed to a more rational usability of the machine itself and of the tools it is equipped with by increasing the top limit of the spindle speeds, hence of machine efficiency. All this involves the replacement of one or other element in the working chains or change whole units in order to meet latest requirements. This, in turn, makes some further calculations indispensable.

Let us take up the example of modernizing some of the older types of lathes like FISHER, PLANET 200 and others, which have very rugged guideways and comperatevily good feed boxes and aprons. Machines like them suffer mainly from inadequate perfection of their speed gear boxes. This makes them incapable of achieving highly productive machining rates suitable for a full utilization of the modern carbide-tipped tools. To overcome this difficulty the equipment of these machines with prefabricated C5M and C11M speed gear boxes seems most rational as such a step will increase the productivity of the said machines at least two times.

Such a step might eventually bring to light the inefficiency of other elements in some of the rest of the mechanisms. They can, however, be easily recalculated and changed with new ones which might readily meet the requirements of the increased working rates.

Practice has so far proved that such sort of modernization requires basically the strengthening of the elements of the kinematic train in the main power transmission and very rarely those in the ancillary transmission trains.

It is naturally very dufficult to prescribe a suitable remedy for each separate case apt to be met in practice, but in tackling the problem of modernization with a view to cutting down machining time one can freely refer to the achieved and permissible cutting speeds shown in Table 1.

Table 1

Average cutting speeds for steel cutting on modern machine tools.

Type of operation	Average cutting speed, m/min		
	Ability of machine	Ability of tool	Actual in pradice.
Turning	400-600	150 - 400	80-200
Boring	300-500	125 -200	60-100
Drilling	50-100	15-30	15-30
		(High-speed steel)	
Grinding	35 m/sec	35 - 50 m/sec	25-35 m/sec
Milling	400-500	150 - 300	50-150
Hobbing	40-50	20-35	15-35
Shaping	50-75	50-80	30-50
		(Carbide-tipped tools)	
		20-50	15-25
		(High-speed steel)	

The table clearly shows that in most cases the machine is able to withstand higher cutting speeds than the tool it uses.

The data in the table refer, however, only to modern, highly productive machine tools. Machine building factories allover, however, use a great many machine tools unable to achieve the pointed values of cutting speeds. In trying to cut down their machining times through modernization one may use the data in the table as a base to start with.

Besides cutting speed feed rate is factor, too. Table 2 gives the feed rates achieved by machine building industry in Bulgaria and abroad and they must also be considered during the modernization calculations of a machine.

Table 2.

Maximum feed rates achieved with various machining operations

Types of operation	Feed rates achieved
Rough and fine turning, mm/rev.	3 - 10
End milling, mm/tooth	0,8 - 1,2
Milling with cylindric cutter, mm/tooth	1,0 - 1,5
Hobbing, mm/rev.	3 - 8
Shaping, mm/double stroke	5 - 100

The data in table 1 and table 2 are given for the purpose of orientation, but are quite adequate to put the designer on the right way when embarking on some modernization of existing machines. It should be also born in mind that widely universal machines are generally designed with inherent structural reserves for higher loads. That is why the tests must be carried out with a view to full loading of the separate units in accordance with the reserves envisaged. During the last 15 - 20 years the average cutting speed of the different kinds of machines has increased 3 to 5 times but the reserves are yet to be exhausted. In practice the cutting rates generally used are only 30 to 40% of the possible maximum indicated in the official manuals.

Table 3 shows the permissible percentage of the cutting speeds depending upon the properties of the most often used BK8 and T15K6 carbide tips, considered for 100%.

Table 3

Permissible cutting speeds with the most popular carbide tips when processing cast iron and steel

Type of carbide tip.	Cutting speed %	Type of carbide tip	Cutting speed %
BK8	100	T15K6	100
BK6	120-125	BK8	50
BK4	130-140	T15K10	65
BK3	140-150	T14K8	85-90
BK2	190-200	T15K6T	120
	more	T30K4	140
		T60K6	180

When modernizing a machine one must also take into cosideration the properties of the carbide tips as well.

Reconstruction of a machine too aimed at cutting down its production costs is of particular importance. Thus Fig. 1 shows the original and the iproved C11M speed gear boxes, an item of long run production programme of the ZMM machine tool plant-Sofia. In this special case the reconstruction of the transmission is almost full, with only a minor part of the original parts being used again. The frame of the box and a part of the rotating elements have been made more economical, while assembly operations have been substantially alleviated. Separate units are preassembeled and then mounted in the box. The kinematic properties of the speed range have also been improved. This complex reconstruction of the main gear train, made possible by means of a change in the production programme, has rendered modern not only the technical parameters and the economy of the machine, but its general appearance as well featuring straight lines and harmonious forms. Fig.2 anf Fig.3 show the old and the modernized types of C11M and C11C machines.

Therefore the highly productive cutting rates are the main way to a shorter machining time. In the different cases of practice these highly productive cutting rates may be realized in different ways: higher cutting speeds, greater feed rates or coarser chip. It all depends upon the structure of the machine, upon the tool and upon the component machined.

MODERNIZATION AIMED AT CUTTING DOWN
HANDLING TIME.

The additional equipment of the machine with various universal and specialized accessories and quick handling devices designed to increase labour productivity while reducing handling time in the floor-to-floor cycle is generally known as modernization aimed at cutting the handling time. A typical feature of this type of modernization is that it has nothing to do with the cutting rates. Therefore in most cases the stresses on the separate units of the machine remain the same as before. The increase of labour productivity in this case is achieved mainly by an improved control of the ancillary operations included in the full production cycle of the component.

Quite often the handling time reduction iprovements achieved through special accessories and quick acting devices are erroneously mixed up with common tooling required by the specific character of a given production. The quick acting devices have in most cases a wider range of applications and not for a particular type of component. When production program is changed these same devices may readily be changed to a certain extent to meet the requirements of a new production while the tools and special devices are basically reconstructed or simply scrapped.

The broad use of quick acting devices opens up a wide field of possibilities for increasing labour productivity. While cutting speeds have grown up 3 - 5 times during the last 20 years while machining time has gone down at the same rate, the total labour productivity has gone up by less than two times alone. The explanation of this phenomenon is to be looked for in the insufficient reduction of the handling time by 20-30% for the same period of time. This provides the inference that the main line of labour productivity increase in the machining shops should go through the mechanization and automatisation of the handling processes during machining.

In order to make the effect of abundant equipment with quick-handling devices still clearer, Table 4 provides the devision of a turner's shift time related to the total amount of working time. It shows that handling time takes 20 - 30% of the total time available. With small batch production it takes up to 2,5 hours and even more of the total shift working time. With other machining operations the picture is similar. Taking into acount down-times due to other causes it becomes clear that the machines are engaged in actual useful work for about 20 - 45% of the total shift time. This is a clear indication of the impelling necessity of increasing the machining time at the expense of handling time.

Table 4

The devision of a turner's shift time as related to the total working time.

Character of the work	Production in %		
	Job prod.	Small batch production	Big batc prod.
Machining on a lathe	20,6	36,3	47,5
Handling operations	30,1	28,3	20.6
Lead time	18,3	11,4	9,0
Maintenance of working site	6,5	5,4	4.9
Down time due to organizational and technical failures	24,5	18,6	18.0

About 30% of the total handling time during turning and milling is devoted to centering and clamping of the work on the machine. About 50% goes to machine control and about 20-25% of the handling time is used for taking measurements of the work. These data refer to universal type of machines. The picture appear to be similar with other types of universal machines.

The ways to reduce handling time and increase labour productivity appear to be as follows:

1. Fitting the machine with additional devices leading to more efficient control during a definite working process.

2. Introduction of accessories and devices intended to reduce the centering and clamping times.

3. Reduction of measuring time and introduction of tool changing devices.

Best effect can be achieved by machine control pre-set off the machine. Such type of machine control has now gained the name of programme control. Programme control machines have been working now for a certain time with a definite economical effect. Such machines are also produced in Bulgaria.

Besides the full programming of the machine tool control brought about by designers and producers, a lot of further possibilities are at hand for partial mechanization of a number of handling operations by the users themselves.

Such a measure may be the introduction of mechanisms for quick traverse of some parts of the machine like heavy saddles , carriages tail stocks, multi-start thread deviding units, similar units for spline cutting, quick change and quick clamping chucks and tool holders, linear movement reading dials, copying devices, etc. Some of them will be discussed further down.

An important item in the modernization process of the machines

...ce the various jigs and devices for reducing the setting time. Table 5 provides some data on setting time with no use of special facilities.

Table 5

Setting time with no use of special devices

Type of operation	Type of setting	Character of centering	Weight of component kg. 1	3	5	10	20
			Duration of setting, min.				
Turning	Three-jaw scroll chuck.	No centering	0,4	0,5	0,6	0,7	1,0
		With centering	0,9	1,1	1,3	1,5	[illegible]
	Four-jaw scroll chuck	Medium complex	3,5	4,2	5,0	5,8	7,0
		Complex	4,[illegible]	5,5	[illegible]	8,0	11,0
	Faceplate	Medium complex.	–	4,3	5,9	7,0	10,0
		Complex	–	7,0	9,2	11,0	15,0
Milling	Machine vice	Simple	0,6	0,8	1,0	1,2	1,4
		Medium complex	0,8	1,1	1,5	1,9	2,4
	V-supports, bolts and strips.	Simple	1,0	1,2	1,5	1,8	2,0
		Medium complex.	1,3	1,6	1,8	2,2	2,5
	On machine table with bolts and strips.	Simple	1,4	1,6	1,9	2,3	2,8
		Medium complex.	2,0	2,4	2,9	3,3	3,9

Table 6

Setting time with the use of special devices

Type of operation.	Type and number of supporting points.		Weight of component, kg				
			1	3	5	10	20
			Duration of setting, min.				
Turning.	Mechanical clamping with a key or a handle.		0,31	0,36	0,56	0,45	0,55
	Pneumatic clamping				0,1 - 0,2		
Milling	Directly with handle.	1 handle	0,46	0,52	0,58	0,64	0,72
		2 handles	0,58	0,64	0,68	0,76	0,86
	With a key or wrench	A vice	0,48	0,54	0,56	0,60	0,68
	Pneumatic	With an oil control valve			0,1 - 0,2		

N O T E: If the component is to be clamped at several points each clamping time is to be added when operated by individual drive.

Table 6 contains the same setting duration data(in min.) with the use of special clamping devices.

Fig.4 shows a diagram of the advantages obtained by using special jigs and devices for quick adjustment and clamping of components to be machined. The diagram compares the required times of machining for components equal in weight and size.

Some of the more important jigs and devices designed to **modernise** the machines run as follows according to their purpose:

1. Jigs and ancillary devices designed to promote the universal resources of the machines and create conditions of a fuller utilization of time and machine power.

2. Jigs and devices promoting faster adjustment and clamping of the component to be machined.

3. Devices promoting faster checks of the finish of components to be machined or already machined

4. Devices which feed in and withdraw the work automatically.

The drive of all the newly developed devices, jigs or complex units is a common problem.

Contemporary handling devices in the machining shops are normally using hand, mechanical, electromechanical, hydraulic, pneumatic and hydro-pneumatic drive. In some cases a combined drive may prove most suitable. In general all types of drive are in use with the different requirements.

A number of advantages exhibited by the pneumatic drive have gained for it somewhat broader scope of applications, but that does not mean that the rest of the drive types are lacking them.

The major advantages of the pneumatic drive may be formulated in the following way: Manual operations can readily be mechanized with the help of simple means. Quick clamping allowing easy automatisation of chucking and releasing the component. The power medium is only air, which is comparatively cheap and provides for finer adjustment of the clamping force. It necessitates the provision of a plant compressed air line, which is normally envisaged in the construction blue prints of the factories. The provision of such a facility in a plant speaks of higher manufacturing culture and cannot be dispensed with.

The hydraulic drive, as compared with the pneumatic, shows sum undisputable advantages, which should also be borne in mind.

The hydraulic drive power provides for high pressure - up to 150 kg/cm^2 (Instead of only 4-6 kg/cm^2 in pneumatics), a feature which proves to be of paramount iportance quite often. Small hydraulic cylinders provide great forces thus making the unit very compact. The sealing problem of the hydraulic system is a disadvantage since loss in power are greater in hydraulics than in pneumatics due to leakage. Hydraulic power cannot be centralized and each power pack has a high initial and operational cost. The hydraulic jigs and devices themselves are more difficult to produce and more susceptible to damage during operation.

The advantages of both these systems are, however, united in the hydro-pneumatic power systems.

In cases when the popular electro-mechanical drive is unable to meet the requirements, then hydraulic or pneumatic power should be employed. When the question of choice comes up, then the final decision should be based on a thorough analysis with a preponderance to the pneumatic system. Only when the latter proves to be utterly unacceptable should another solution be looked for. Hydraulic power is especially expedient when provisioned on a machine already equipped with hydraulically operated devices. Most often this occurs with the grinding machines.

FIXTURES AND DEVICES PROMOTING THE VERSATILITY OF MACHINE TOOLS.

These fixtures and devices help a universal type of machine tool produce components normally machined on a special-purpose unit, of which a given factory may not avail or if it does, they may not be of adequate capacity. Additional fixtures and devices make the machine more universal and fill up its working time more rationally. The degree of mechanization is also increased. One of these devices, normally used with universal engine lathes, for instance is the copying device.

The copying devices may be hydraulic or electromechanical. The first are preferrable to the latter in that they may be mounted on old models of machine tools with negligible reconstruction. They help promote the control of the lathe during the machining of a given work piece. As an example we may consider the KC200 range of hydro-copying devices (Fig.5 shows a KC203 hydro-copying device), designed to produce stepped shafts with cylindric and tapering journals, components of shaped surface, covers, flanges, etc. These copying devices are used to modernize universal, production and automatized lathes with a maximum machining diameter of 400 - 500 mm and a 12 KW main drive motor.

The KC201, KC202 and KC203 are distinguished for their high degree of automation and technical resources.

- KC201- manually operated

- KC202- electromagnetic infeed and withdrawal, suitable for single-pass automatic work.

- KC203 - electromagnetic infeed and withdrawal, automatically indexed five-position turret, rough and fine cypying, suitable for automatic multi-pass operation.

The power packs can be furnished with several output hoses to power or control of copying devices and chucking units on the lathes.

Fig.6 shows a typical example of a turning operation on a shaft and-pinion helped by a KC203 copying device, thus increasing productivity rate by 1,5 to 2 times as compared to manual control of same operation.

Copying devices bring the machines up to a higher development level on the way of their modernization by augmenting the degree of its mechanisation. Similar effect have some other devices as well, like quick-change tool holders on lathes, indexing turrets on drilling machines and lathes, vertical and horizontal milling heads, various grinding devices, change tables on plano-milling machines, etc.

Fig.7 shows a range of two, three and four spindle heads designed for simultaneous drilling in cast iron. The use of such multi-spindle heads has proved to be quite economic with a view to its respective cost. They help increase labour productivity substantially in drilling operations. Such heads are normally so designed as to possess a universal character. Besides radial drilling machines they can be also used for the modernization of pillar drilling machines(Fig.8).

The so called pallet machining on plano-millers is gaining ever larger application lately. The use of change tables(Fig.9) carrying the components, results in a drastic cut of handling time thus leaving much more time for machining during the shift period.

MECHANICAL CLAMPING FIXTURES AND DEVICES

The clamping and releasing of the component during their machining in most cases require a considerable length of time. In general an average of 30% of the total handling time goes to clamping, centering and releasing the work and this affects to a large extent the labour productivity in batch production. Very often complicated components with holes, splined step shafts, and the like allow efficient machining by subdividing it into several separate operations, but the difficulty here results from the imperfection of the clamping systems. Thus for instance the common three-jaw scroll chuck operated with hand requires more than 30 sec., while a mechanized chuck takes not more than 3-[illegible] sec. And when one bears in mind the frequent repetition of the clamping and releasing operations during a shift period the effect can easily be calculated.

Fig. 10 shows an electric and a wedge clamping chuck for lathes of the C[illegible] and C[illegible] types. They are also successfully used with the special purpose and the universal type of lathes, especially with large batch production. Two sizes are available depending upon the maximum driving power provided: I size - 3500 daN, II size - 5000daN Thus the 200, 250,320 and 400 mm dia. wedge clamping chucks are mechanized.

A range of quick clamping machine vices are produced in Bulgaria designed to modernize the drilling, milling and shaping machines. Some of the smaller sizes (80 and 100 mm) may also be used with tool grinding machines. The design of these vices is based on the following principle: using a cam type of mechanism for the 80 and 100 mm sizes(Fig.11) and an electromechanical clamping device in two sizes for the 125, 160, 200 and 250 mm vices(Fig.12). The cam type vices provide a maximum clamping force of 500 daN and 700 daN respectively. The electrical clamps for the vices featuring initial torque of 6 daNm and 12 daNm provide a chucking force of 2400 daN per jaw for the 125 and 160 mm vices, and 4000 daN for the 200 and 250 mm vices.

The quick clamping vices facilitate greatly the operation of the above said groups of machines by reducing human muscular strain to a minimum. On the other hand handling time is cut down and labour productivity increased.

DEVICES TO CHECK THE FINISH OF MACHINED COMPONENT.

The devices designed to check the work piece after each operation and following the full machining also promote labour productivity. In this field modernization of machines still avails of certain reserves.

A number of checking devices designed on electric or pneumatic principle find a wide application in this field. purely mechanically operated devices are widely used as well

Air operated checking devices enjoy a number of advantages with respect to their design features and promote the amount of checking work done.

Thus for instance they check inner diameters without surface contact, i.e. The outer diameter of the gauge mandrel is smaller than the smallest tolerated size of the hole. This method of checking has this great advantage, that eventual damage of the inner surface of the hole is obviated while the measuring force is actually equal to zero.

Fig.13 shows an air-operated taper-hole checking device. An example of a special checking device is shown on Fig.14. This air operated device is specially designed for use with flanges, disks, rings, washers, etc. where geometry is important. The air required for such measurements is provided by a small compressor or taken from the central compressed air supply line. Before fed into the instrument the air is purified and its pressure stabilized.

The instruments mentioned here above are normally used for checking a finished component. More important, however, is the equipment of the machines with devices able to control the very process of machining. This is a new line now persued in a number of countries. Such devices are generally known as "inprocess gauging" items. On reaching the predetermined size the device releases a suitable impulse and the machine stops. This arrangement provides for achieving the required accuracy within the tolerances, while the finish of the piece is certain right on the spot. Such devices permit [illegible] knowledge of [illegible] is going on with the component machined [illegible] moment of the process. This problem becomes essentially acute with machines designed to give the final geometry of the part produced. In most cases of this character grinding machines are involved after being equipped with such devices.

Fig.15 shows a universal cylinder grinding machine of the SK252 type, modernized by being equipped with in process gauge control.

AUTOMATIC LOADING AND UNLOADING OF THE COMPONENT.

One of the most labour consuming operations from technical point of view is undoubtedly the automatic loading and unloading of the component on and from the clamping device.

A great variety of technical solutions already does exist in this respect, especially when production of small parts is concerned. Some successful solutions are to be met with transfer lines in which the very design of the line provides for automatic feeding, clamping, releasing and unloading of the components. In a number of bar material automata, this problem has also found its successful solution. Such devices are especially valuable in batch production, where their implementation is fully justified.

When batch production is carried out by highly productive programme controlled machines, then automatic transport and clamping devices acquire special importance.

Fig.16 shows a diagram of a feeding arrangement for center held components by means of a mechanical arm provided with a gripping hand. The arm is traversed on a transverse beam. A similar arrangement is shown on Fig.17 where chuck held components are involved.

CONCLUSION

This brief review of the existing trends, methods and means of modernization of machine tools does not pretend to be a comprehensive review of our practice in this field. To a large extent it makes clearer the existing problems and points to the way of their solution. It may be considered as an example of overcoming the production difficulties during the metal cutting processing in machine building establishments.

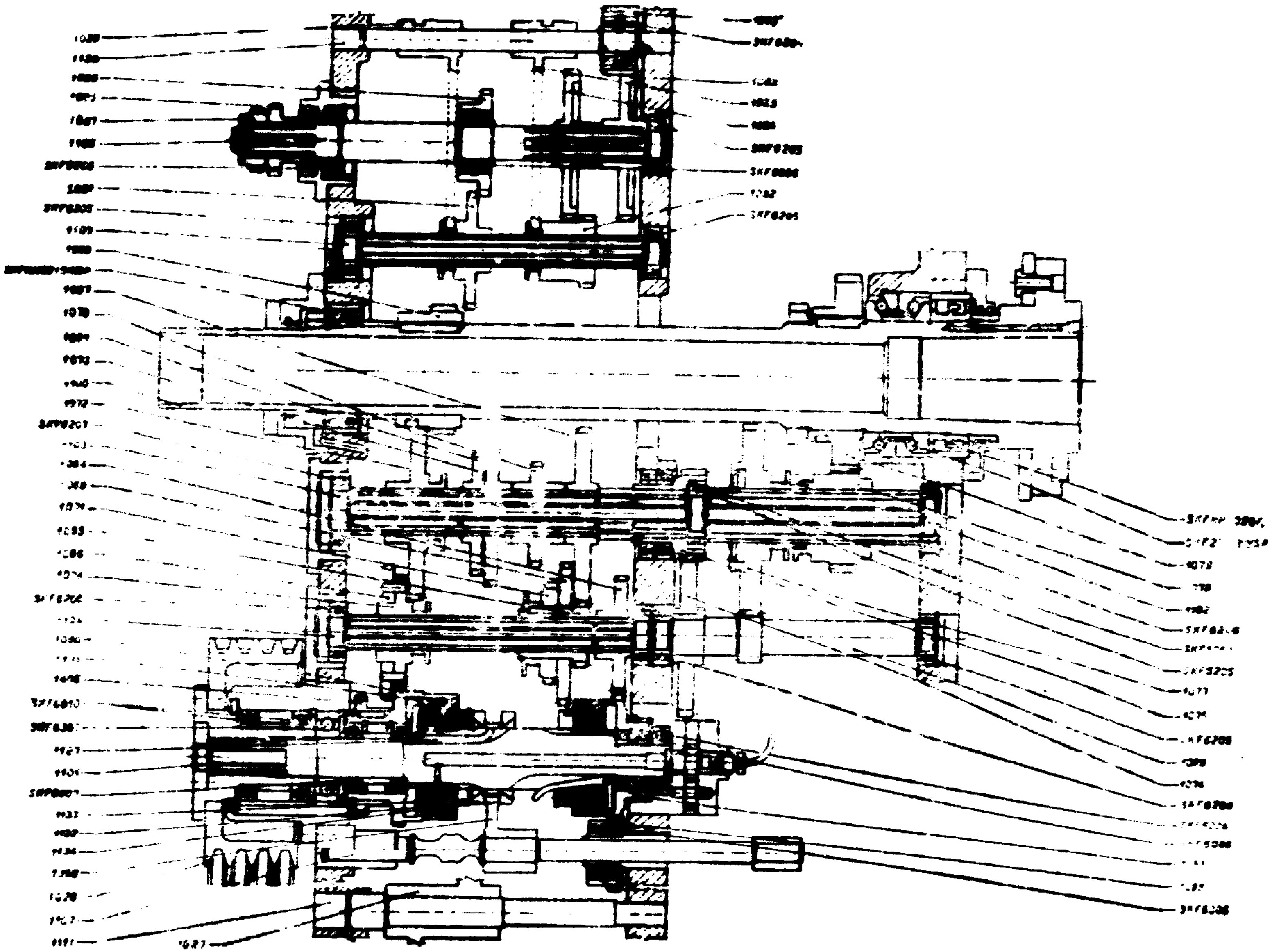

Fig.4.[illegible] - Gear box for 31M Lathe

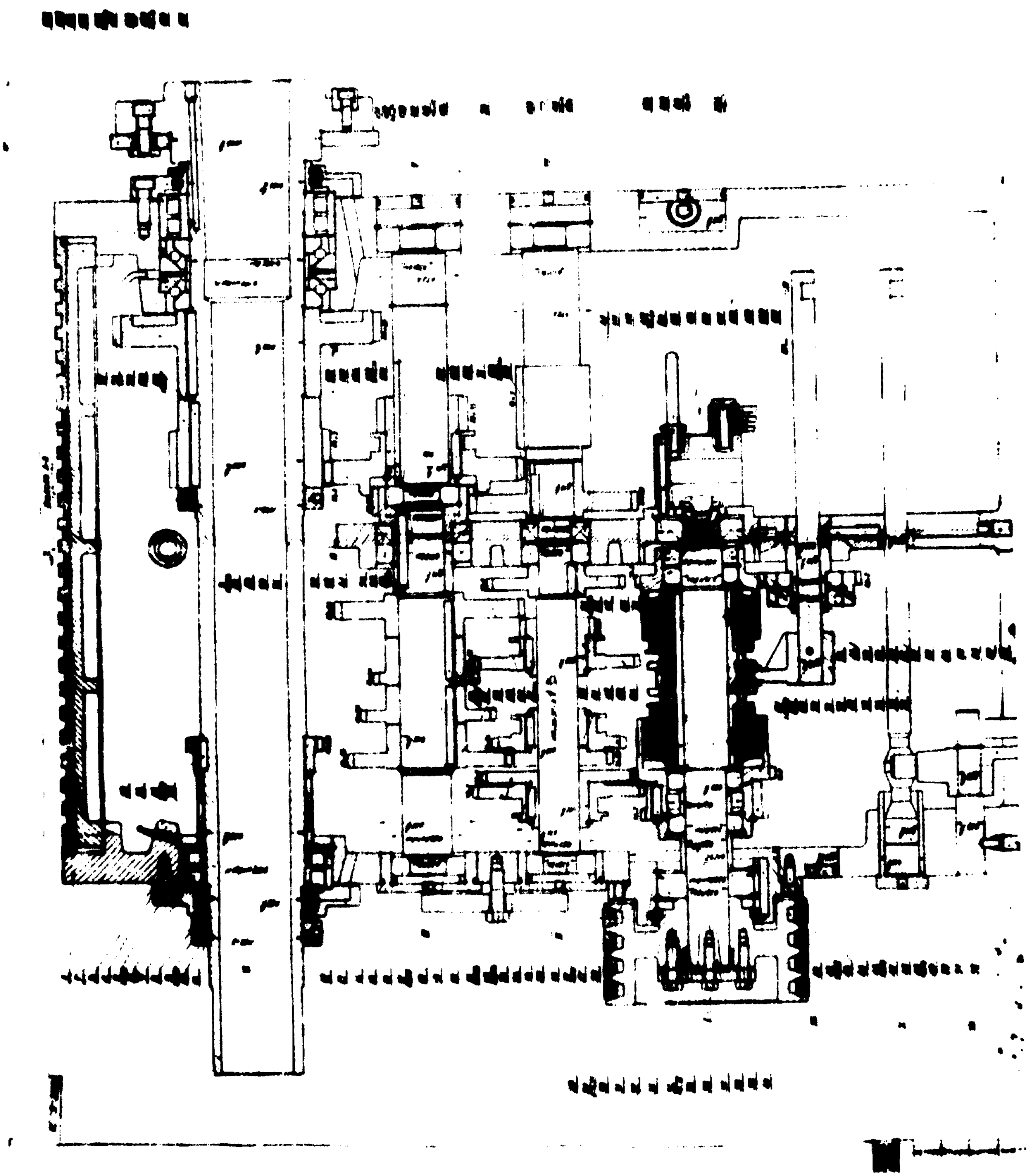

Figure 1(a)

BOTTOM - Gear box for C11C lathe

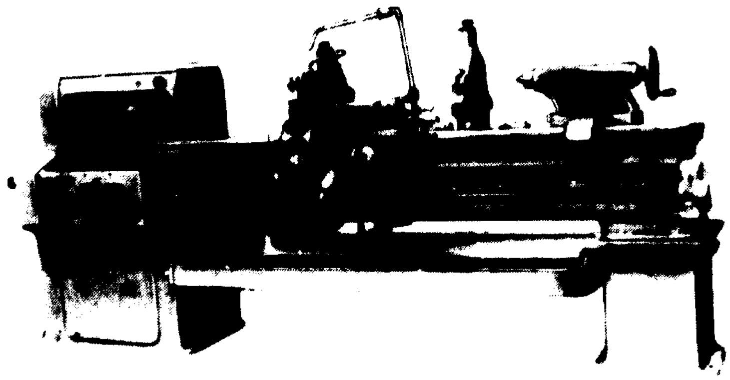

Fig. 2. C11M universal Engine lathe

Fig. 3. C11C Universal Engine Lathe

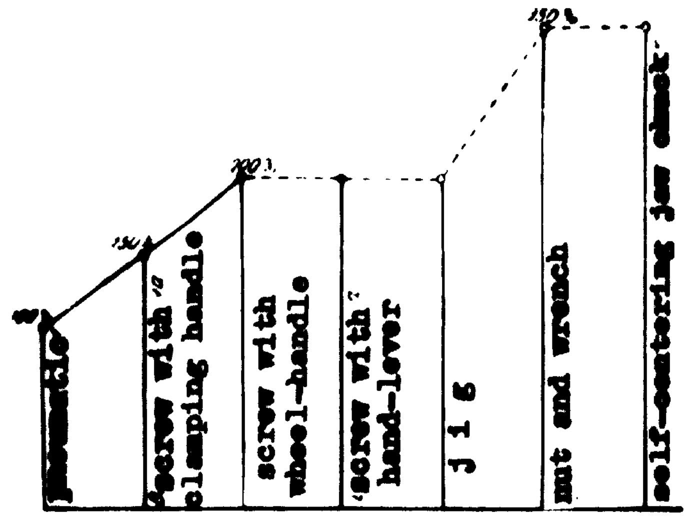

Fig. 4. Required time for various types of clamping

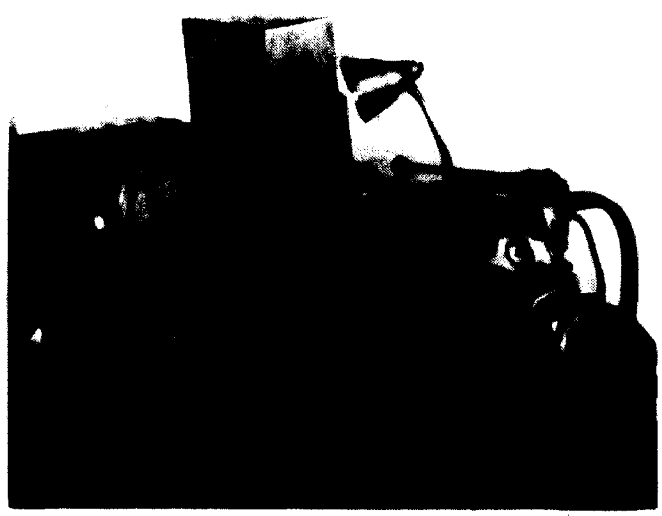

Fig. 5. Hydro-copying device KC203 mounted on a CP403 lathe

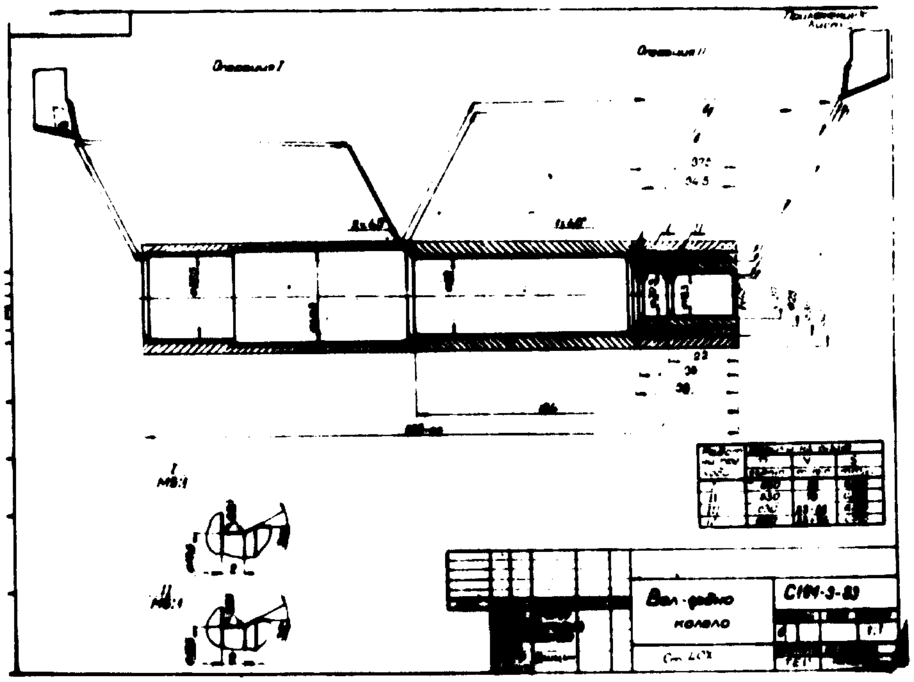

Fig. 6. Example of machining a shaft-and-pinion with the help of a hydraulic copying device.

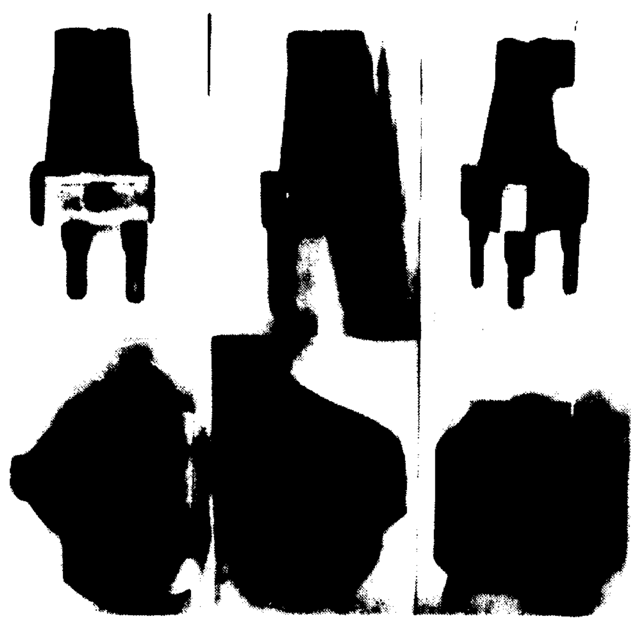

Fig. 7.

Range of two, three and four spindle heads for simultaneous drilling in cast iron.

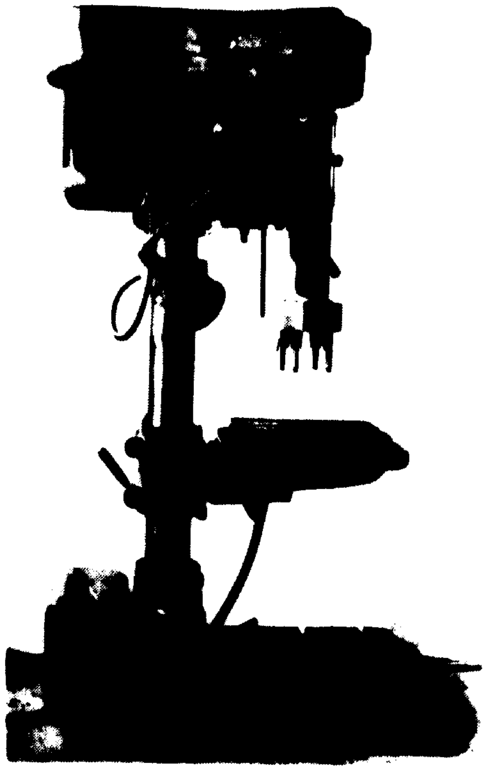

Fig. 8. A pillar drill fitted with a four-spindle head.

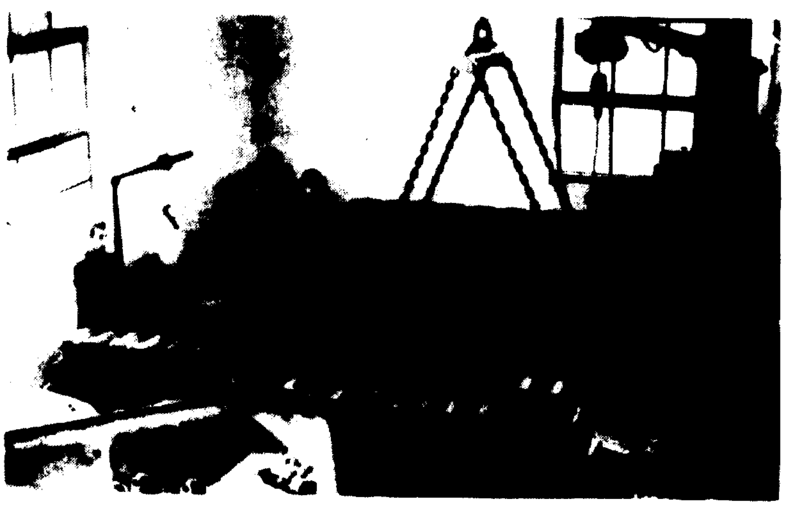

Fig. 9. Change tables for pallet machining on a plano-miller.

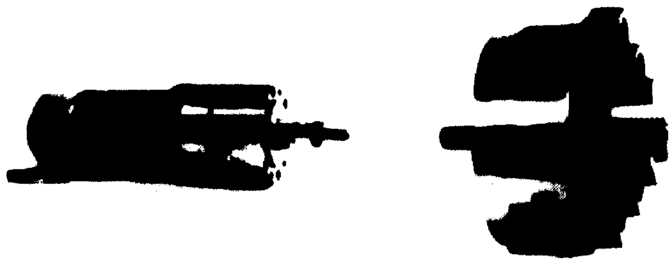

Fig.10. Electric clamping device and chuck

Fig.11. Cam type machine vice.

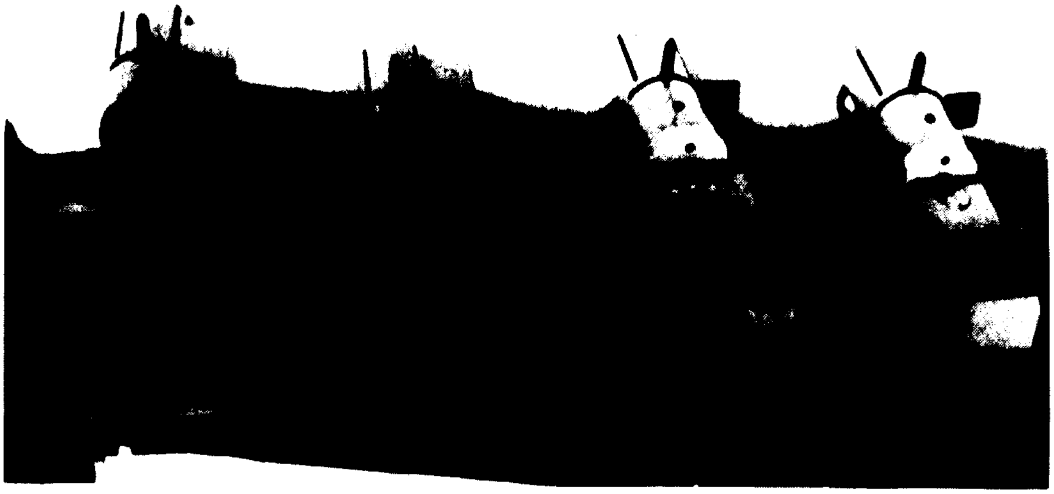

Fig.12. Electromechanically operated machine vices

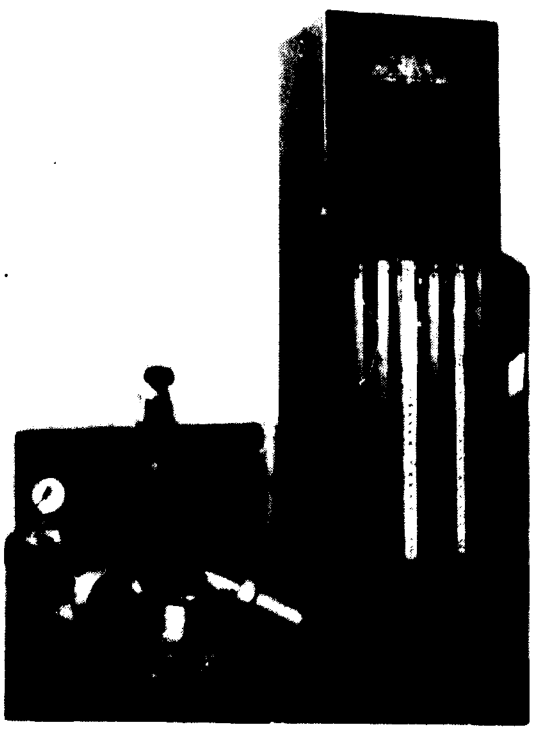

Fig.13. Taper hole measuring head(Pneumatically operated)

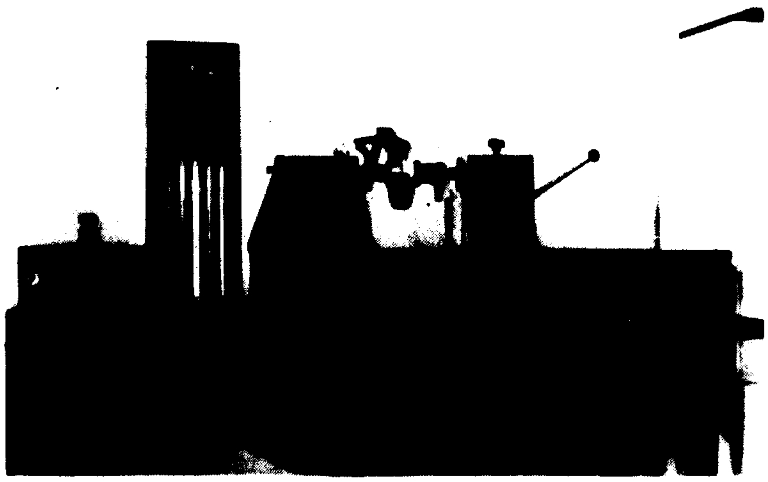

Fig.14. Air operated geometry checking instrument.

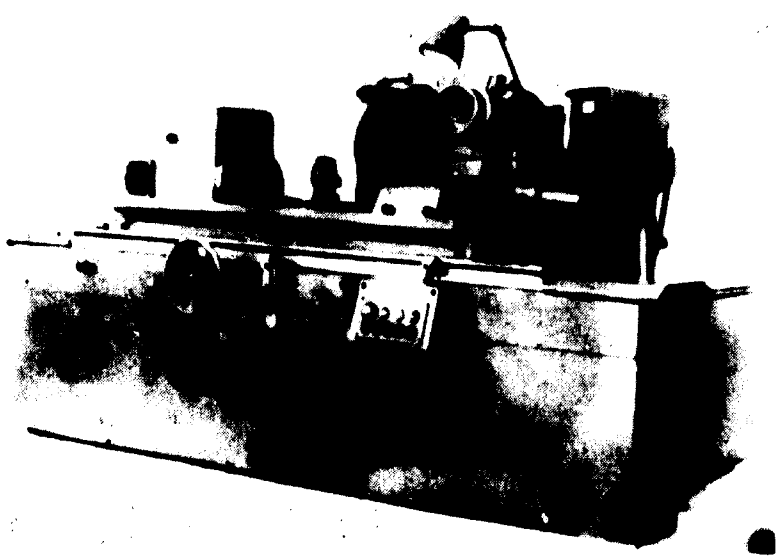

Fig.15. ŠK252 cylinder grinding universal machine provided with feed-back control. (in process measuring gauge)

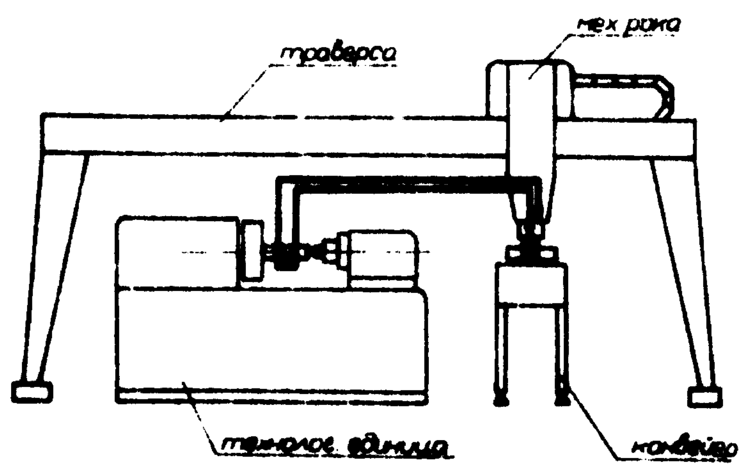

Fig.16.

Diagram of gantry feeder with mechanical arm handling center held components

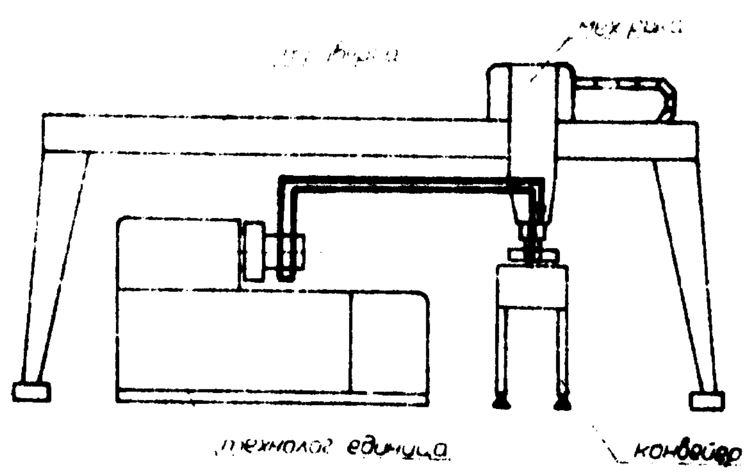

Fig.17.

Diagram of gantry feeder with mechanical arm handling chuck held components.

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