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AIR INTELLIGENCE INFORMATION REPORT

COUNTRY OR AREA REPORT CONCERNS	DATE OF INFORMATION
USSR	1956

NAME OR DESCRIPTION OF SOURCE	EVALUATION
M: Assembly of Jet Engines, 1956 Moskva, by L. K. Nikolenko	

SUBJECT (Descriptive title. Use individual reports for separate subjects)

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ASSEMBLY OF JET ENGINES

SUMMARY *(Give summary which highlights the salient factors of narrative report. Begin narrative text on AF Form 112a unless report can be fully stated on AF Form 112. List inclosures, including number of copies)*

Forwarded herewith is enclosed verbatim translation of four chapters from the book "Assembly of Jet Engines" (Sborka reaktivnykh dvigatelyey) by L. K. Nikolenko and V. I. Sokolov. Published in Moskva, 1956.

The book was written as a textbook for aviation middle technical schools. The four translated chapters take up in detail the assembly of jet engines both with centrifugal compressor and with the axial flow compressor.

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ASSEMBLY OF JET ENGINES

CHAPTER I

METHODS OF ASSEMBLY

Paragraph 1. Basic Principles.

Classification of Engine Parts and Assemblies.

The modern aircraft turbojet engine consists of several thousand parts. Each part of the engine during the operation performs a certain specific function.

From the standpoint of assembly all parts of the engine can be classified into the following basic groups:

1) Basic parts of the engine (turbine blade, turbine shaft, turbine disc, compressor wheel, and others).

2) Fastening parts (nuts, bolts, dowel pins, threaded studs and others).

3) Locking parts (Grover washers, plate locks, locking rings, cotter pins and others).

4) Sealing parts (paper gaskets, rubber and lead rings, copper-asbestos gaskets, packing glands and others).

Furthermore, in the process of assembling the engine the following materials are used: asbestos cord, kapron or silk thread, various pastes for sealing, varnishes, insulating tape, and others.

Each part is covered by a drawing (blueprint) that contains the name of the part, its permament number, and the number of parts contained in one engine.

To provide better information for assembling the engine the design bureau in addition to detailed drawings issues a specification of parts which is a complete list of all parts that make up the engine. The specification lists the number of a part, its complete name, the number of the specific part per engine, and the name of the assembly in which this part is used.

The drawings and the specification of parts are needed both for laying down the technological process of the assembly and for the work of assembly itself.

The assembly shop must always have a complete set of parts blueprints for the engine and the specification of parts.

From the design schematic of the aircraft jet engine it can be seen that the parts that make up the engine are joined together in groups and such groups form assemblies. Thus. for instance, the compressor

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rotor consists of several parts, such as: compressor wheel, front and rear air intakes, front and rear shafts, studs and nuts. This whole group of parts joined together in a definite manner and fastened with studs and nuts forms the compressor rotor assembly. There are some complex assemblies which consist of several simple assemblies or sub-assemblies and parts; for instance, the combustion chamber consists of the combustion chamber casing, flame tube, air intake section, tubes, and fastening parts. The combustion chamber is an assembly. The combustion chamber casing and the flame tube are also assemblies, but they are components of the combustion chamber assembly. It is only necessary to point out that the combustion chamber is an assembly that is actually fitted or mounted together, while the flame tube and the combustion chamber casing subassemblies are welded assemblies.

The assemblies that make up the engine can be classified in the following basic groups: machined welded, and fitted

A machined assembly is a group of parts joined together because of necessity of machining of them all together as a group. The examples of such are, the compressor assembly, the middle bearing assembly, and the collector assembly.

Welded assemblies consist of parts joined together by welding, for instance, the flame tube and the combustion chamber casing.

Fitted assemblies are formed from parts, welded and machined assemblies and they are put together directly by assemblers in assembling teams in shops that produce complete units like engines or fuselages, or in assembly shops.

All machined, welded, and fitted assemblies are covered by the so-called assembly blueprints or drawings. The assembly blueprint specifies the magnitudes of fits or clearances between joined parts and they also indicate the means of fastening. In several cases assembly blueprints mention additional special requirements for testing the strength of the assembly. For instance, the assembly blueprint of a fuel hose together with its fittings states that it must be tested for airtightness with kerosene under the pressure of 200 atmospheres for 5 minutes and that it should not leak.

To facilitate work with assembly blueprints there is an assembly specification which is a list of all assemblies with the number of the assembly, its full name, and reference to which group it belongs (machined, welded, or fitted). It also contains the number of all assemblies in the engine, and the location of the assembly - whether it is mounted directly on the engine or it is a component part of another assembly.

Being in possession of blueprints for parts and assemblies and specifications of parts and assemblies the shop technologist can work out the flow sheet of assembling, and the assembler can put together such assemblies.

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For the assembling of the complete engine blueprints showing general views of the engine are required. As a rule, for every kind of engine there are drawings of general views in several projections with cross-sections. Basic clearances and fits which have to be adhered to in the assembly of the whole engine are indicated in the general view blueprints. In addition these drawings contain notations indicating the numbers of assemblies and parts that go into the engine assembly.

In laying down the flow sheet for the assembly of the engine the technologist must have first of all general view and assembly blueprints. In addition every assembled item is covered by general and special technical specifications.

An engine can be disassembled into several complex assemblies and parts. These complex fitted assemblies can in their turn be disassembled into simpler fitted, machined, and welded subassemblies and parts. It is impossible to take an engine completely apart, because a large number of parts joined together into welded and machined assemblies and subassemblies cannot be taken apart without being damaged in the process.

In addition to individual parts and assemblies the engine has also accessories mounted on it. An accessory is also an assembly that performs some complete function necessary for the normal operation of the engine, for instance: fuel pumps, a starting pump, a pressure regulator, a starter, a generator, etc.

Accessories can be dismantled in the same manner as the whole engine into individual machine, welded, and fitted assemblies and subassemblies and parts.

Accessories containing moving parts are joined to the basic mechanism of the engine by special drives with springs and through them they receive motion from the engine, such are, for instance, fuel pumps, starter, generator, etc.

Accessories are interchangeable, i.e. fuel pumps, throttle valve and others can be taken off one engine and mounted on another of the same type, and such change would not cause any complications.

Several accessories are mounted on the engine, and only some of them are produced at the engine building plant, while the rest are delivered by special accessory producing plants.

Blueprints - of parts, of assemblies, and of general views - and technical specifications cover each engine accessory.

The Place of Assembly Operations in the General Technological Process.

Assembling operations are an integral part of the general complex of technological processes in the production of the reaction engine.

The present day trend in the production of reaction engines is expressed in the establishment of specialized shops for the production

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of aggregate units. Each such shop produces one or several aggregate units of the engine or its assemblies, executing within the shop the whole complex of technological processes of production of parts and of putting together machined, welded and fitted assemblies and sub-assemblies that are components of the engine accessories, aggregate units or engine assemblies.

In such cases only some technological processes are executed by other shops (forging, casting, and heat treatment).

When shops are organized on the principle of the aggregate unit, assembly operations are not concentrated in one place as it was done formerly, but are spread out among a larger number of shops.

An example of such distribution of assembly operations can be seen in the production of gas turbine rotors of the turbojet aircraft engine.

The parts of the gas turbine for the aircraft turbojet engine are produced in a shop that is specialized according to the aggregate unit principle.

The assembly of the turbine shaft which is a machined assembly is done by the group of machinists of this shop and the assembled shaft is delivered to the special assembly team of the same shop which assembles the turbine as a whole. The completely assembled gas turbine is sent to the assembly shop of the plant where it is mounted on the engine.

Similar instances covering other assemblies of the engine can be cited. For instance the assembly of the compressor rotor and of [illegible] nozzle box is done in shops that are specialized on the aggregate unit principle, and when completed these assemblies are merely mounted on the engine in the assembly shop of the plant.

Thus, it can be said that assembling operations are done:

a) by machinist teams or welding teams in specialized shops;

b) by special assembly teams of specialized shops;

c) in the assembly shop of the plant.

For the purposes of careful inspection of the condition of parts each engine after the hot test on the test stand is dismantled, inspected for defective parts, and reassembled. The re-assembly of the engine is done:

d) in the re-assembly shop or in the re-assembly department of the assembly shop.

The system of the organization of aggregate unit shops almost completely obviated matching and fitting operations in the assembly shop of the plant which resulted in a great improvement in the workmanship of assembly.

The Technological Process of Assembly and its Elements STAT

The sequence of assembly of operations necessary for putting together different assemblies and the engine as a whole is known as the technological process of assembly.

The well planned and tested in practice technology of assembling backed by proper technological equipment (special rigging equipment, tools and instruments, devices), as a rule guarantees the high quality of the workmanship of assembly and consequently the reliability in the operation of the engine.

The high responsibility for the quality of workmanship in the assembly of aviation jet engines demands rigid technological discipline in all links of the assembly process.

The basic element of the technological process of assembly is the assembly operation. The assembly operation is the sum total of jobs performed in the assembly of a unit, or an engine as a whole, without changing the equipment, at a single work place, by one or several workers.

The technologists of the plant prepare a technological chart for each assembly operation. This chart contains the number and the name of the unit to be assembled, the sequence number of the assembly operation and the description of assembly work together with a drawing or a schema of the unit to be assembled with numbers of parts that make up the unit.

The operational assembly chart indicates on what stand the assembly must be performed and what devices, tools and instruments must be used.

Thus, an operation consists of several actions of worker or of a team of workers at a single work place.

A part of operation which consists of a group of actions that are joined together by one purpose is called a suboperation (priyem). Suboperations are of two kinds: basic and auxiliary.

The basic suboperation consists of the achieving of the basic technological aim of the operation, for instance; "to place a gasket", "to place a washer", "to tighten a nut", "to place a cotter pin in the nut", and so forth.

The auxiliary suboperation consists of the implementation of the auxiliary actions, such as for instance, the placement of an assembly on a stand or a cart or taking it off etc.

The suboperation consists of the simplest elements expressed in uninterrupted single movements of the workmen. Such an elementary single uninterrupted movement performed by the worker is called a work movement. As an example the following can be cited.

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Such suboperation as placing an assembly stand consists of the following work movements: a) take the assembly, b) bring the assembly to the stand, c) place the assembly on the stand.

A part of a production operation which is performed without a change of work tools is known as transition. In several cases there may be only one suboperation in the transition, then the concepts of transition and suboperation become identical.

The whole technological complex of assembly operations performed at the plant can be divided into the following basic groups.

1. Operations for the assembly of machined assemblies. As a rule the assembly of machined units requires a constant contact of assembling operations with machining operations with the help of machine tools designed for cold machining of metals and for this reason these assembly operations are performed in machine shops or in the assembly groups of shops which are specialized on the aggregate unit principle.

   In the process of assembling of machined units, machining and fitting operations both performed by hand and by machinery are permissible.

2. Operations in the assembly of welded units performed in the constant contact with the operations of various kinds of welding which require special welding equipment are performed in welding shops and also in accessory shops. In the performance of these assembly operations, machining and fitting of parts is permissible.

3. Operations for the assembly of units and the assembly of accessories are performed separately from machining and welding and they are done either in special assembly groups of accessories shops in special rooms where the work places are kept especially clean or in the assembly shop (the first assembly).

4. Operations for the final assembly of engines are performed in the assembly shop of the plant (the first assembly).

5. Operations for the reassembly of engines after the work test in their turn are divided into four groups:

   (1) disassembly of the engine;
   (2) identification of defective parts and assemblies;
   (3) elimination of the defects;
   (4) assembly of units and the engine as a whole.

All four groups of operations are performed in the assembly shop of the second assembly or in the reassembly department of the assembly shop of the plant with the exception of a part of operations of the third group which in several cases have to be performed in those shops where these units or assemblies were assembled.

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6. Finishing assembly operations done in the shipping room before the shipping of engines from plant.

7. In the assembly of subassemblies or accessories, sometimes the so-called preliminary subassembly of a unit is done. It is necessary when parts are especially selected and fitted to provide for the flow of the necessary quantity of liquid or gases or to provide for required clearances. The subassemblies or assemblies in the preliminary assembly are put together in such a way that the necessary degree of fastness can be tested. When satisfactory results are obtained subassembly or an assembly is taken apart, the parts are branded with definite legend stamps which indicate that the different parts matched together, after which they are washed carefully and then the final assembly of the unit is performed.

8. In some cases subassemblies and details ready for the final assembly for some reason are kept aside and are not used for the assembly, then they must be greased and they are assembled together without paying attention to clearances but without damaging the parts. Such assembly is called mock assembly.

9. In the assembly of machined and welded subassemblies fitting and adjusting operations done either by hand or on the stand are permissible. Such matching and fitting operations are done when required clearances and tolerances are obtained in their final form when several parts are either machined or worked over together. In such cases the parts are marked mostly with the sequence number of the subassembly which indicates that the parts are individually matched and that they can be used only in this particular subassembly. Fitting and matching operations are permitted in machinists groups or in welding groups of the aggregate unit shops. In assembly shops these operations can be permitted only in exceptional cases.

The following job can be cited as an example of making a machine subassembly with the help of matching and fitting operations performed on a stand.

Figure 1 represents a machined subassembly – an oil pump housing. The subassembly consists of the aluminum casing 1 – in which 2 bronze bushings 2 are seated.

According to the technical specifications for the manufacture of the oil pump housing the bushing shoulders must be flush with the bottom of the gear chamber, i.e. they should not be either above or below the bottom of the chamber. Furthermore, the distance between the axes of bushings H must be maintained with the tolerance of 0.02 mm.

The subassembly is machined with certain tolerances for a and d (the internal diameter of the bushings); after the housing together with bushings is assembled these tolerances are brought to the final value.

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If both the housing and the bushings were machined with final tolerances before the assembly this would have complicated both the machining operations and the assembly. In such case in the machining of the housing the depth of machining for the seat of the shoulder would have to be achieved more precisely. The thickness of the shoulder of the bushing would have to be made more accurately and the evenness of the walls of the bushing must be made more precise. In the process of assembly both the housing and the bushings would have to be selected before the assembly on the basis both of the depth of the seat of the shoulder and of the thickness of the shoulder so that the difference between their sizes would equal zero.

It is evident that to manufacture an oil pump housing as a machine subassembly is cheaper than to assemble it from finally prepared parts.

The Classification of Assembling Operations on the Principle of the Interchangeability of Parts

In the practice of the production of aviation engines presently there are the following three methods of assembling:

(1) assembly with the full interchangeability of parts, subassemblies, and assemblies.

(2) assembling with limited interchangeability by means of special selection of several parts and subassemblies to meet the requirements of the blueprint and of the technical specifications (selective assembling).

(3) individual assembly of each subassembly from parts specially made according to special blueprints or drawings or with the use of fitting and matching operations.

The most ideal method is that of assembling with full interchangeability of parts, subassemblies and assemblies.

In the production of each detail tolerances for adjoining surfaces in this case must not exceed half of the assembly tolerance for this joining, and in practice they must be even more rigid, because within the tolerances the parts may have conicity and ovalness.

The principle of complete interchangeability has been already implemented in the production of aviation engines in the case of a considerable amount of various parts, subassemblies, and assemblies.

As a result we may cite the case of fastening parts which are completely interchangeable if they are of the same nomenclature.

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However, there are still parts and subassemblies to which the principle of interchangeability cannot be completely applied because of rigidity of tolerances in their sets or for some other reasons.

As an example of parts and subassemblies the assembly of which is implemented by means of selection of proper parts can be cited the assembly of a turbine shaft and of the roller bearings, and joining the compresser rotor with the roller and ball bearings.

For proper fitting of bearings on the turbine shaft and on the shafts of the compressor rotor it is necessary to select bearings in accordance with the geometrical size of the bearing seats and for this reason the procedure is to measure the shafts and the bearings and to select those bearings which in their sizes approach the closest size of the seats for bearings.

In assembling and mounting bevel gears a special selection on the basis of the imprints of the dye is necessary. The blades of the air intake apparatus are selected so that the spaces between the blades would be identical. This is necessary to create the uniformity of the gas flow along the whole contour of the air intake. The turbine blades in process of assembly are selected on the basis of their weight and magnitude of the play in the lock etc.

Individual matching of opposite parts in several cases presents an opportunity to obtain a more precise fit at the smaller cost. Thus, for instance, by means of the selection of parts it is possible to obtain the degree of fit of the first class of precision in spite of the fact that the surfaces of adjoining parts were prepared in accordance with the requirements of the second class of precision.

Let us suppose that in fitting together some two parts which have the diameter of the hole and of the shaft 60 mm the technical specifications call for clearances from .01 to 0.035 mm. The sliding fit would be the most suitable because of the clearances for this diameter. In the preparation of these sizes for sliding fit of the second class the minimum clearance would be 0 mm and the maximum clearance would be 0.05 mm. Separating all prepared parts into 3 groups as it is indicated in table 1 and then fitting together the shaft and the holes within the limits of the same group we would get the minimum clearance of 0.013 mm and the maximum clearance of 0.034 mm. Both of those clearances meet the requirements. At the same time if we evaluate the precision of the fit then we will see that it will be actually in a class of precision above the first because for the first class for sliding fit we have tolerance of 0.031 mm and in this particular fit it is 0.021 mm. Thus, using the method of selection we can get more precise fit without increasing the accuracy or precision in the manufacturing of parts.

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Table 1

The Separation of Parts into Three Groups in Selective Assembly

Group	Hole in mm				Shaft in mm				Clearance in mm			
	min	max	min	max	min	max	min	max	min	max	min	max
I	60.00		60.01		59.98		59.987		0.013		0.030	
II	60.011		60.021		59.988		59.995		0.016		0.033	
III	60.022		60.030		59.996		60.00		0.022		0.034	

As it can be seen from the above cited instances the method of matching parts presently finds a wide application in the production of aviation engines. Matched mating parts must be labeled to avoid a mix-up.

The third kind of assembly, and that is the individual assembly, is widely used in the overhaul of aviation engines. In this case sub-assembly is assembled after its dismantling, washing, and finding the defective parts and it is assembled only with the use of those parts and subassemblies from which it was assembled to begin with, and shifting parts from one assembly to another one of the same nomenclature is not permitted. Furthermore, in the overhaul repair parts instead of defective parts may be used (they may be either larger or smaller size as compared to the normal size). As a rule, when these parts are assembled together, individual matching and fitting operations to assure the proper fit are used.

Organizational Forms of Assembly

From the standpoint of the organization assembling can be divided into two basic kinds: the complex assembly and the differentiated assembly.

Complex assembly. The complex assembly or, as it is often called in production practice, the individual-team assembly is that kind of assembly in which the whole complex of operations for assembling a unit which is planned for the shop or the part of the shop is performed by the same worker or by one and the same team of workers.

Thus, if 15 different units are being assembled together in a shop simultaneously this assembling will be done by 15 workers or 15 assembly teams and each one of those 15 assembly men or each one of the 15 teams of workers will assemble from the beginning to end one of the 15 units that are being assembled without participation in the assembly of the remaining 14 units. It is quite evident that the

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complex assembly can be carried out only during one shift, because the continuation and the completion of the assembly, in case the process of assembly requires more than 8 hours, or the time spent in minutes does not amount to one of the multiples of 480, cannot be turned over to another assembler or to another team. This complex and labor consuming process necessitated by this kind of assembly makes it imperative for the assembler to be able to perform a great deal of diverse assembly operations, both simple and complicated ones, and that requires a high skill on the part of the assembler. The complex assembly is usually used in the production of an experimental aviation industry. As a rule, the complex assembly is performed at a stationary work place and on an immovable object of the assembly.

Differentiated Assembly. The differentiated assembly, or as it is usually called in the production practice, the operational assembly is that kind of assembly in which the whole complex of operations in the assembly of a unit or a subassembly planned for the assembly shop or for the assembly department or shop is broken into several individual operations of which each one is performed by an individual worker or an assembly shop in which the assembly is being done. Thus, in this case every worker of the shop participates in the assembly of each unit performing on each one of them certain operations.

Dividing large complex of work into individual operations simplifies the work and, therefore, it does not require such a high degree of skill on the part of an individual worker as it is done in the case of complex assembly. The fact that an individual worker in the operational assembly does only a limited amount of operations presents an opportunity for a better organization of the work place, and in so doing the labor of the worker becomes more productive. Furthermore, while in the complex method each work place must be equipped with a whole set of tools and gigs and other devices necessary for the whole technological process of assembly of the unit, in the operational assembly every work place must be equipped only with those tools and devices which are necessary only for the performance of one certain operation. This results in a considerable reduction in the number of tools and gigs necessary for the shop. The differentiated assembly can be easily organized for 2 or even 3 shifts because in practice the technological process can be always broken into several such operations the time for which, expressed in minutes, would be a multiple of 480.

The differentiated assembly can be implemented with the permanent work place and the movable object of assembly, and vice versa with an immovable object of the assembly and movable work place.

In the first place the object to be assembled is moved by hand or transported mechanically from one work place to another until the whole cycle of assembly operations is finished. In the second case the objects of assembly are immovable while workers in a definite sequence move from one object of assembly to another performing the assembly operations with which they are charged. The assembly with the stationary work place and movable object of assembly is more efficient because in this case the worker does not have to spend his

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time moving from object to object and for carrying the tools and devices which quite often are quite cumbersome. In the case of a heavy object of assembly it may become more profitable to conduct the assembly with the stationary object of assembly and movable work place.

From the standpoint of the organization of production the best form of the differentiated assembly is the continuous (potochnaya) assembly.

The continuous assembly is the differentiated assembly in which the assembly operations are conducted in uninterrupted sequence one after another until the whole unit is assembled as a whole.

The continuous assembly can be organized both with the stationary work place and with the movable. The mandatory requirement for the organization of continuous assembly is the identical rhythm of the work on the part of every productional worker. This means that the complex of operations for each work place must be selected in such a way that the time spent on it by worker should be identical or the same for all work places. In this case all workers will begin and finish the complex of their operations at the same time. Thus, every worker will repeat the complex of operations with which he is charged regularly within a definite period of time which is called rhythm or tempo of assembly. Because the last operation of the assembly is conducted also within or during rhythm, it becomes perfectly evident that a new unit will be produced at the end of each rhythm.

Thus, if the assembly shop produces a completely assembled engine every 10 minutes then the rhythm of a work of the shop will be 10 minutes and each work point of the assembly must complete its complex of operations within 10 minutes. The continuous assembly method requires a high degree of the organization of production because a delay on any of the work points may stop the whole subsequent stream of assembly.

At the same time the continuous assembly is more economical than plain differentiated assembly. Under continuous assembly methods less auxiliary area is required because there is no necessity to have special shelves for storing material necessary for the assembly. Furthermore, the production cycle is decreased in the continuous assembly method and planning and the organization of work places are simplified.

The continuous assembly usually has several lines or streams of assembly. One of those lines on which general assembly is done is known as the assembly line, while the remaining lines of assembly or subassemblies are known as auxiliary or feeder lines.

For the sake of most convenient organization of the stream of parts and subassemblies the main line of assembly is placed in the middle while the auxiliary or feeder lines are located on both sides of the main line (Fig. 2). When the object of assembly undergoing continuous assembly is moved from place to place mechanically the assembly is

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called the conveyor assembly or simply conveyor. The conveyor is in the track on which the assembly stands move by means of a mechanical drive (an endless chain). The movement of conveyor may be continued and interrupted. In the first case the conveyor moves slowly throughout the process of assembly. In the second case the conveyor during the process of assembly does not move and it is moved only in the intervals between the two adjoining rhythms for the time necessary for moving the object to be assembled to the next work place.

The conveyor moves objects to be assembled throughout the line simultaneously.

2. Tools, Devices, and Equipment Used in Assembly

The complete description of the tools and devices is contained in appropriate general textbooks on tools and equipment. In this section of the book only such tools, devices, and equipment which must often are used in the process of assembling aviation engines is given.

Working Tools

The basic work tools used in assembly operations are the simplest assembly hand tools: various wrenches, screwdrivers, hammers, punches, and so forth.

Wrenches

In the assembly for the series production it is permitted to use only wrenches with fixed jaws. In the series assembly it is forbidden to use adjustable wrenches because whenever adjustable wrenches are used not carefully enough, the flats of the nuts can be damaged, and this can be hardly avoided even by skilled workers. Furthermore, such wrenches lower labor productivity.

Wrenches are the basic work tools of the assembler. A separate set of wrenches is produced for each design of the jet engine. The greater is the number of nuts and bolts of different sizes in the engine the greater number of wrenches must be provided for the assembler. For each size of a nut or of the head of a bolt of the engine there should be its own wrench. On the basis of this all wrenches may be classified according to the dimensions of the open end.

In the process of designing aviation jet engines the designers attempt to decrease to the minimum the dimensions of the engine and its weight, therefore, the access to several jointed parts of the engine quite often is very difficult due to the lack of room for the hand of the worker and for the tool. This necessitates the production of wrenches of special design which can be used for assembling in certain places of the engine to which access is difficult. For this reason in the majority of cases, for each nut or bolt joint of the aviation engine as a rule there is its own specially fitted for this place wrench which has its own name (mnemonics).

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According to the configuration wrenches may be classified approximately in the following manner:

(a) flat single open end;

(b) flat double open end;

(c) flat box wrenches with single end;

(d) flat box wrenches with two heads;

(e) socket wrenches with an open socket;

(f) socket wrenches with closed socket;

(g) special wrenches of various kinds: Allen type wrenches, spanners and others which are used depending upon the kind of fastening parts found in the engine.

Wrenches for the assembly of aviation engines are made with thin walls and of most diverse shapes. To make wrenches strong and long lasting they are made of structural alloyed steels of the following marks, 40X, 38XA, 30X CA and others.

The simplest and the cheapest wrench is the open single or double end wrench. This wrench can be used whenever the access to the nut is comparatively free, because the ends of such wrenches as a rule are fairly massive (Fig. 3).

The surfaces of the jaws of the wrench must be sufficiently firm so that the flats of the jaws wouldn't be damaged. The size of the jaw of the wrench must be such that the wrench could be freely put on the serial production nut of the corresponding size. In practice the jaw of the wrench must be equal to the largest size of the corresponding nut plus 0.1 – 0.3 mm (depending upon the dimensions of the nut). The jaw or the end of the wrench must be periodically checked by caliber because first of all it gets worn out, and, secondly whenever excessive force is applied it may unbend. Because of this in time there may be a large clearance between the wrench and the nut or the flats of the jaws of the wrench may not be parallel which will cause damage to the flats of the nut.

As a rule, wrenches are made double end to accomodate two adjoining dimensions of nuts. This economizes materiel and reduces the number of necessary wrenches. Large wrenches from alloy steel often are made single end and with a short handle and applied cross piece which is placed on the handle of the wrench and which permits the application of proper torque for tightening the nut. Furthermore, this presents an opportunity to save on expensive structural steel and the handle of the wrench in this case becomes more convenient.

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Box wrenches (Fig. 4) are not as susceptible to bending as the open end wrenches and for this reason the head of the wrench may be more compact. Box wrenches are made with 12 point ends so that the turning angle of the wrench would be smaller. In this case the minimum angle of turn must be kept below 30°. Box wrenches are made both single end and double end. When the expected angle of turn of the wrench is below 30°, nuts with triangular splines instead of flat nuts are used. The box wrench in such case is made accordingly (Fig. 5).

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The socket wrench (Fig.6) is more convenient and economical wrench. While the open end box wrenches can be moved by one motion of the hand to the angle from 60 to 90°, the socket wrench can be used to turn the nut to the 180° angle. Furthermore, during the operation the socket wrench is not removed from the nut, but only the hand is removed to a new position on the handle. For faster work with the socket wrench, that is, for faster work in the case of free turning of the nut (before tightening of the nut) the turning handle of the wrench is extended by means of welding another piece that would be parallel to the arm of the wrench or one side of the turning handle is made longer and bent parallel to the arm of the wrench (Fig. 7). Such wrench permits a constant turning without changing hands.

Socket wrenches are made either milled with inserted turning handles, or with welded turning handle and welded sockets and also tubular. The length of the turning handle is calculated for each specific wrench; the use of a longer turning handle is not permitted. Socket wrenches may be one end and double end. Frequently socket wrenches have removable sockets which are joined to the wrench through a rectangular hole in the socket (Fig. 8). Such sockets may be freely interchangeable whenever the socket is worn out, or if the size of the nut is different. To prevent dropping of the socket off the wrench whenever it is moved from nut to nut the wrench is equipped with a ball lock (Fig. 8, a). The turning handles of socket wrenches may be inserted through the arm of the wrench. So that the inserted handles would not drop out, some drops of metal are welded on the end of the handle or some rings are welded on them. If it is desirable to have a removable turning handle, it is possible to make a ball lock to prevent it from falling out of the handle, as it is shown on Fig. 8, a, to the right above. Sockets may be made either integral (Fig. 8, c) or welded (Fig. 8, d). If, according to design, the arm of the socket wrench must be at a certain angle to the nut then the arm is made offset or a universal joint is used (Fig. 9). For the same purpose the socket may be made with a universal joint (Fig.10). For nuts with internal hexagonal flats socket wrenches with external hexagons are used (Fig.11). The advantages of the socket wrench are in the fact that it can be used to tighten nuts that are located within wells or the nuts that are surrounded by protruding parts which interfere with the access with an open end or box wrench. Hook and pin spanners are also often used in addition to the above mentioned wrenches.

Spanners (Fig. 12) are used for tightening splined or round nuts with holes. These spanners are not used for strong tightening of the nuts because the whole stress would be received only by one tooth or pin.

Splined box wrenches would be stronger wrenches to be used in such cases (Fig. 13). For tightening of plugs and taps rachet wrenches are often used (Fig. 14). A wrench that is used for tightening and loosening of round knurled nuts of sleeves is a bent lever to which a canvas strap is attached (Fig. 15). The canvas strap is wrapped around the sleeve and the free end of it is pressed by hand to the lever. Whenever the lever is turned the strap tightens on the sleeve and with the turn of the wrench it moves the sleeve.

Screwdrivers. A screwdriver serves to tighten and loosen screws. It consists of the steel shank to one end of which a handle is attached and the other end is in the form of a thin plate or a blade (Fig. 16). The working part or the drive end of the screwdriver is made in the form of the wedge and only the very tip (1), which enters the slot on the head of the screw has parallel surfaces (Fig. 17). The tip of the blade is made of different thickness depending upon the width of the slot of the screwdriver; it must enter the slot with a small clearance (0.1 - 0.2 mm). The handle of the screw is made either of wood or plastic. On Fig. 18, a, - a round fluted handle is shown while Fig. 16,b - a handle with added wooden sides. From the standpoint of convenience the handle shown on Fig. 18 is preferable; in addition with this kind of handle a greater amount of torque can be created than with the handle that is shown in Fig. 16. In grinding the tip of the screwdriver it should be remembered that the tip must have parallel sides. If the tip surfaces are ground on an angle the screwdriver will jump out from the slot of the screw and would damage (burr) the slot. When the blade is properly ground, minimum force can be used for pressing the screwdriver to the screw and, on the contrary, whenever the tip is ground in the form of wedge then much greater force has to be applied to press the tip of the blade to the screw.

The analysis of the forces applied indicate that in the case of wedge tip first of all the area of sideways bearing is reduced to a line, and secondly there arises a vertical force that tends to remove the screwdriver from the slot of the screw (Fig. 19). In individual cases in order to increase the magnitude of the torque the turning handle is welded to the screw handle or the handle is made in the form of T as it is done with socket wrenches. Usually such screwdrivers are used for tightening plugs.

Figure 20 shows the screwdriver for screws with cross slots (Phillip's type). Blade screwdrivers with a guide have been used (see Fig. 18,b). In this case the screwdriver is centered on the head of the screw by means of a guide which is released from the screwdriver by springs. The worker slightly pressing on the handle and turning it puts the tip of the blade into the slot.

Mechanically driven wrenches and screwdrivers. The mechanization of tightening and withdrawing nuts and screws as yet has not been adequately worked out. Most of the nuts and screws are tightened and withdrawn in the process of the assembly of aviation engines by means of ordinary wrenches and screwdrivers in spite of the fact that there are several mechanically driven devices which make possible tightening and withdrawing of nuts and screws by means of electric and pneumatic nut setters.

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Figure 21,a shows a wrench with electric drive. The wrench consists of a housing, 1 which contains a high rpm reversible electric motor running on the current used in industry. The wrench is turned on by means of a switch 3 located in the handle 2. The direction of the rotation of electric motor is changed by means of a slide 4. The spindle 5 rotating with 350 RPM's is driven through a reduction gear with the general transmission ratio of 8.4 and the set of reduction gears consists of 4 gears, 6,7,8, and 9. Chuck 10 which with the help of a pin is joined to one half of a cam clutch 11 enters into the spindle. The second half of the cam clutch is made integral with the spindle of the wrench. When idling the spring 12 presses back the chuck and disengages the clutch because of which in idling of the wrench the chuck does not rotate. When the handle of the wrench is pressed, the spring is compressed and the chuck is pushed inside the spindle and both halves of the clutch become engaged and they rotate the chuck.

The teeth of the cam clutch are beveled so that after the maximum tension of nut or screw is reached the clutch would disengage. The chuck has hexagon sides inside to accomodate the removable socket. The socket is held in the chuck by means of a sleeve with ball lock 13.

Before the socket is inserted into the chuck the sleeve of lock 13 is pressed by hand towards the housing of the wrench, because of this the ball lock will be free to move in radial direction and it would permit the tail of the socket to enter the internal square of the chuck. After the sleeve is released the spring will press it back and will lock the ball lock.

Electric screwdrivers and stud drivers have the same design.

Table 2 presents the specifications for electric wrenches and screw-drivers.

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Table 2

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(According to the data of the Khar'kov Power Tools Manufacturing Plant)

Parameter	Electric Wrench И-60	Electric Wrench И-61	Electric screw-driver И-62	Electric Stud Setter И-63
Greatest diameter of tread in mm	6	12	6	12
Number of RPM's of the spindle	980	630	260	475 for driving 870 with-drawing
Frequency of current in cycles	200	200	200	200
Voltage in Volts	36 or 220	36 or 220	36 or 220	36 or 220
Capacity of Electric Motor in Watts	200	600	200	
Dimensions in mm	140 X 300	470 X 600	140 X 320	460 X 470
Weight in Kilograms	2.2	8.7	2.2	7.3

Wrenches and screwdrivers with pneumatic drive differ from electric wrenches only in their drive which is an air driven turbine that operates under the air pressure of 5 kg/cm_2. Table 3 presents specifications of pneumatic wrenches and screwdrivers.

Table 3

(according to the data of NIAT)

Parameter	Pneumatic wrench D2-TR	Pneumatic Screwdriver RPO-650-1	Pneumatic Screwdriver RPO-350-2
Maximum diameter of tread in mm	10	6	12
Number of spindle RPM's	300	650	350
Operational air pressure in atmospheres	5	5	5
Maximum capacity horsepower	0.3	0.2	0.3
Consumption of compressed air while idling in m^3/min.	0.38	0.4	0.4
Maximum torque in kg/cm	320	100	200
Inside diameter of the hose in mm	13	13	13
Dimensions of the wrench in mm	425x125x58	250x50x132	250x50x132
Weight of the wrench in kilograms	4.7	1.9	1.9

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To hold studs in the stud setter and to transmit the torque upon the stud, special sockets are used. The socket (Fig. 21,b) consists of a housing 1 which is connected with the tail part 2. Inside the housing there is a nut 3 that touches upon the ball 5 that is supported by the seat 6. After the stud is tightened the nut and the ball will start slipping which will serve as a signal to end the operation.

One of the defects of electrical and pneumatic wrenches and screwdrivers is their considerable weight (up to 9 kg). For convenience in operation heavy electric and pneumatic wrenches are suspended on a pully with a counter balance, due to which only a small effort for vertical movement of the wrench is required. The reduction of the weight of pneumatic wrenches and screwdrivers can be achieved by increasing the pressure of the compressed air that fits the pneumatic tube.

Hammers. Various kinds of hammers are used as stiking tools. The most popular is a machinist cross peen hammer weighing 400 grams (Fig. 22). The face of the hammer must have a hard surface and at the same time it must not be brittle so that there wouldn't be any falling off of small pieces which may get into the object that is assembled and which may cause injury. The handle of the hammer must be made of hardwood which can be well polished: beech, birch, dogwood, etc. The handle must be polished and covered with gasoline resistent varnish. After the head is set in the handle the latter should be wedged, that is, either a metallic wedge (Fig. 23) should be driven in the handle to spread it or a wooden wedge which would be kept tight with glue. The length of the handle of the hammer is approximately 350 mm. The free end of the handle of the hammer should be rounded to avoid splitting of the end after striking some parts.

For driving in small parts, for instance, small locking pins, splines and so forth, hammers weighing 100-150 grams (Fig. 24) are used. Hanldes of such hammers are made shorter, approximately 300 mm.

A machinist hammer in the majority of cases is used together with a punch which would protect a part from deformation at the time of striking.

In addition to the ordinary machinist hammers in case of assembling brittle parts the so-called soft hammers are used: made of red copper, lead, rubber and rawhide. Such hammers are used without punches.

Punches. A punch is a rod 150 - 200 mm in langth made of a softer material than the assembly parts (brass, copper). The tip of the punch is ground to a cone or it is made spherical in order to avoid scratching hands on the tips of the punches. In time the tips of punches split and crack. They must be periodically filed in order to avoid the possibility of injury to the worker.

A better way would be to use composite punches (Fig. 25). In this case the punch is made of low carbon content steel and only its tip is made of nonferrous metal (copper, brass, aluminum). The steel rod of the punch is less liable to spread under the blows of hammer than

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a rod made of brass or copper and it will have a better resistance to buckling. To press bushings by means of hammer and a punch an aligning tail part is used which centers the punch in respect to the bushing. The aligning end of the punch must enter the bushing to be pressed with the clearance of 0.1 - 0.2 mm to prevent the wedging in of the tip of the punch in the bushing after it has been pressed in. In case the tip of the punch comes in contact with the spherical surface of the part it is expedient to make this tip with a reverse sphere in order to increase the area of contact of the part and of the punch (Fig. 25,c).

Tools for the elimination of small defects. As a result of transportation of parts and assemblies and their handling by workers and preliminary assemblies certain burrs and dents and uneven places may by formed on the parts, and these should be removed without changing the geometrical dimensions of the parts before the final assemblies of either assemblies or finished product.

Such parts must be presented both before the elimination of small defects and after it to the personnel of the department of technical control, i.e. to controllers or controller foremen.

Tools for the elimination of small defects include:

a) burnishers which are curved round rods made of steel with carefully polished surfaces of the working part. Wooden handles are set on the end of burnishers. With the help of burnishers small dents or burrs are smoothed over on the surfaces of parts made of such metals of aluminum, brass, and bronze;

b) scrapers; only small scrapers of various shapes - flat, semiround, triangular etc. are used. The basic purpose of scrapers is the elimination of small dents and burrs and sometimes elimination of the lack of airtightness of the joint done by evening surfaces of the parts.

c) Files; only small files and needle files of various shapes - flat, triangular, round, semirounded are used to remove dents and burrs;

d) stones or hones; of various shapes, round, square, semiround also serve for the elimination of small defects;

e) taps; only small and middle size taps are used to correct the thread in the holes;

f) dies; are also used to correct the outside thread;

g) reamers; are used to correct surfaces in openings that do not correspond to each other in size;

h) drills; are used for withdrawing broken studs or whenever plugs are changed and holes need improvement.

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It is categorically forbidden to use the above mentioned tools that produce metal shavings directly at the place of the assembly. The parts and assemblies of subassemblies are turned over to special working places for the elimination of defects. After the defects have been removed, the parts and assemblies are washed and shavings and metallic dust are blown off by means of compressed air.

Measuring Instruments and Technical Means of Control i. e. Inspection

In spite of the fact that parts that come to the assembly have been already inspected by the department of technical control, in the process of assembly several measuring instruments and gages for checking individual dimensions of parts and assemblies are required. Furthermore, by means of measuring instruments the magnitudes of tightness and clearances obtained in the process of assembly of certain units are determined. Because the detailed description of the measuring instruments is found in special literature this chapter merely presents a list of specific instruments widely used in the assembly of aviation engines.

For measuring holes or openings the following measuring instruments are used:

1) indicators graduated to 0.01 and to 0.02 mm for precise measurements;

2) vernier calipers graduated to 0.1 mm for rough measurements;

3) plug gages round and flat and sets of plug gages for classifying holes in technological groups within the limits of tolerances for the hole;

4) thread gages of various dimensions;

5) special gages for measuring irregularly shaped holes.

For measuring outside diameters the following are used:

1) ordinary micrometers graduated to 0.01 mm for various diameters;

2) micrometers equipped with a dial graduated to 0.002 mm for various diameters;

3) snap gages with dials graduated to 0.01 and 0.002 mm for various diameters;

4) rigid snap gages and sets of snap gages;

5) vernier calipers graduated to 0.1 mm for various dimensions;

6) micrometers and snap gages for measuring the average diameter of thread;

7) special snap gages, simple ones and equipped with dial for measuring outside variously shaped profiles.

Feeler gages of various shapes and sizes from 0.03 to 5 mm and above are used for measuring clearances.

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For measuring conical holes and outside conical diameters beveled gages of various dimensions are used.

For measuring depth and length, depth gages, simple and equipped with dials, are used.

For visual inspection of parts magnifying glasses of various magnification from 2.5 to 10 are used.

Luminescent inspection apparatus and magnaflux are used for special inspection to discover cracks in the metal.

Prisposobleniya*

In the work of assembly the term prisposobleniya is given to a mechanism or a structure which is designed for creating convenience in work (locking devices) or for increasing the degree of precision of work (guiding or centering devices) or for convenience and precision in the process of inspection, or finally, for increasing productivity of work (mechanizing devices). Devices in the modern assembling process play an enormous role. A correctly designed and made device provides not only convenience of operation and high degree or workmanship, but also increases labor productivity.

Devices must answer the following requirements:

1. Simplicity of design.
2. Simplicity and convenience of operation.
3. Profitableness of operation.

A device simple in design as a rule is cheaper in the cost of production and it is better mastered by workers. The assembly devices must be stably fixed on the bench or upon foundation and they must have locks which make them in proper times immovable. Whenever these devices are moved, steps should be taken to reduce the noise connected with the movement. Each device must have an easy access to it. The height and the shape of a device must be made such that they would be the most convenient for the operator. Whenever using the device the worker must spend a minimum of time that is not directly concerned with production. Finally, the device must be safe which is achieved by precluding the possibility of dropping parts out of this device, by setting up proper safeguards, and by means of other measures taken in the process of designing and manufacturing this device.

Analyst's note: *The Russian genetic term "prisposobleniya" covers many English terms and does not have a corresponding proper equivalent. From the following paragraphs in text it will be seen that prisposobleniya may mean gigs, fixtures or pieces of portable equipment, in other words, devices. For the purposes of this translation, unless a specific term like a gig or a fixture can be substituted in each specific case, the word prisposobleniya will be translated as devices.

A universal holding device is the mechanic's vise with parallel jaws for clamping small parts that have projections with parallel surfaces. To prevent damage to the surface of a part the clamps of the vise are equipped with removable linings made of soft material (copper, lead, and aluminum alloy). In cases when the part is of the shape that is not conveniently clamped by the jaws of the vise other intermediary devices are used. Figure 26 illustrates a device for holding and fixing shafts in the process of assembling rotors. It consists of a column with a plate which is fixedly mounted on a bench or a special support and of a strong collar with a hinged cover that is mounted on the column. The collar is equipped with inserts or linings made of soft material (aluminum). Whenever inserts of various sizes are used this device can be operated for clamping shafts of various outside diameters.

Figure 27 shows a screw clamp which is used for setting springs is compressed state. The spring is inserted into the screw clamp in a free state then it is compressed by means of a screw to the magnitude of 1-2 mm less than the operating position, then the screw clamp is placed on the seat of the spring and the spring is beaten into the seat with a soft hammer.

For pressing in and withdrawing small parts and also for temporary clamping, screw clamps illustrated in Fig 28 are used. For assembling subassemblies which are large in size and weight special assembly stands or assembly carts are used.

Figure 29 shows a cart for assembling of small subassemblies (air intake apparatus, the transmission gear box and so forth). The cart consists of a tubular welded frame 1 mounted on wheels 2. Plate 3 is mounted on shafts that go into the bearings 4 that are inserted on the support of the frame. The plate can rotate 360° around horizontal axis. If necessary, the plate can be turned on an angle which is a multiple of 60° and locked in this position by means of a fixing lock 5 which enters into one of the six holes of the locking disc that is welded to the jackshaft. In the middle of the plate there is an opening through which protrude the projecting parts of the object that is being assembled. The assembly is fastened to the plate by means of studs. To avoid the damage to the basic surface of the assembly the plate is equipped with lining 7 made of soft material (delta-wood pulp, plastics etc.) which is fixed to the plate by means of screws with countersunk heads. Rubber tires are put on the wheels of the plate in order to reduce the noise whenever the cart is moved in the shop, the rubber should be resistent to gasoline.

The cart shown on Fig. 30 serves for assembling the aviation jet engine with axial compressor. The cart consists of a frame mounted on wheels, two supports or vertical members 4 and 5 with lugs and the turning mechanism. In the middle to make the frame rigid it is fastened by a crossmember 2. For the convenience in transport one pair of wheels 3 is made in such a way that they are capable of turning around. Lug 6 of the upright 4 is connected with a hinge to the support and it can turn 360°. The lug 7 of the support 5 is rigidly joined with a worm turning mechanism 8. The worm turning gear makes

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it possible to turn by means of a steering wheel the unit to be assembled to any angle and to lock this unit in this position. The hot part of the engine is fixed to the lugs by bolts which are inserted into the side bosses of the support.

The cart shown on Fig. 31 serves for assembling compressor and for the general assembly of an engine with centrifugal compressor. The cart is made of a strong tubular frame 1 which is mounted on wheels 2, two of which are made turning wheels. At the top of the frame there are bearings 3 for jackshafts of the cradle 2. Two openings 5 are in the cradle. These are for the lug of the engine and for the support pin 6. The cradle is turned by means of turning mechanism 7 and its handle 8. The turn can be fixed in a certain position by means of a lock 9. For convenience the cart is equipped with foot rests 10 which are covered with riffled aluminum sheet.

One of the most widely used auxiliary devices in the assembly shop are pullers. From the standpoint of design and the principle of operation pullers are divided into 3 basic kinds: screw, lever, and impact pullers.

The simplest type of screw puller is a push-out or a squeeze-out bolt the end of which is made spherical (Fig. 32). In the process of dismantling two parts such a bolt is screwed in a specially made threaded opening in one part and it rests upon the second part with its spherical tip. When the bolt is being tightened the bolt bearing with its tip upon the second part creates a pulling stress applied to the first part and this stress pulls one part from another. The end of the bolt is made spherical for the following reasons; first, in this manner the friction between the tip of the screw or bolt and the support surface upon which it bears is considerably reduced and, secondly the spherical surface does not score or scratch the support surface upon which tip of the bolt bears. For the purposes of dismantling usually no less than 2, and for round housings no less than 3, squeeze-out bolts are used. In the process of dismantling the parts all squeeze-out bolts are tightened gradually and evenly so that the pressure would be applied evenly, otherwise if the part is in any way out of line then great force has to be applied for dismantling and in case the part is badly out of line it may lead to the damage of the part (such as appearance of cracks on the shoulders and their breaking off). Before the bolt is inserted its thread must be greased. Such squeeze-out bolts are used in dismantling housings and cases of large size which are assembled with a drying gasket (to create air tightness), and dismantling of parts and assemblies or subassemblies that do not have protruding parts which could be used for taking them apart by means of a puller with jaws.

The most widely used puller is shown on Fig. 33. The puller consists of a cross member 2 in the middle of which is threaded hole for the screw 1 which is equipped with a handle 4 and jaws 3. The cross member is made of forged steel and in case the screw is of a large diameter the thread for it is not made directly in the cross member but in a bronze bushing which is pressed into the cross member. The bronze bushing reduces the friction in the thread and it prevents

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sticking of the screw in the cross member. The screw is made of carbon steel. The thread of the screw of small pullers is V-shape, metric and for large pullers it is ribbon thread.

To reduce the friction on the end of the screw its tip is made spherical or a special spherical tip is inserted into the screw. Furthermore, the very large pullers are equipped with safety tips (Fig. 34) in the form of a steel cap within which there is a heat treated steel seat. Two pins (Fig. 3) that fasten the cap to the screw are inserted into the ground out slots on the screw, they are inserted with considerable clearance. This is done in order to prevent a dropping off of the cap from the screw. The large clearance presents a possibility for the cap to deflect from the axis of the screw which compensates for small errors in setting the puller and it permits a free rotation of the screw in respect to the cap. Thus, during the process of dismantling of the assembly the cap would be firmly pressed to the part and it would not rotate which would prevent the possibility of seizure of the contact surface. The arms of the puller are made in the form of rods with eyelets for mounting upon the cross member and with the jaw for holding the part to be pulled. The jaw of the arm is made in the form of a beam of uniform strength (Fig. 35). This makes for strong construction of the jaw and the access to the part is not made difficult. The contact surface of the jaw must be even and strictly perpendicular to the axis of the eyelet so that it would be pressed against the part throughout its surface.

When contact surfaces of the jaw and of the part are small then, in the process of pulling, the jaws may slip off. To prevent slipping off the jaws are tied to each other by means of screw clamp which does not permit the arms to bend thus preventing the slipping of the jaws. In case when the part to be pulled does not have any protruding projections that could be held by the jaws of the puller three threaded openings are made in the part in the process of manufacture and the jaws are made in the form of bolts which pass through the openings in the cross member and which are threaded into the body of the part. In this case the pull is transmitted through the cross member to the head of the bolt and then through the body of the bolt upon the part.

In using pullers the following rule should be observed. The screw of the puller must be set exactly along the axis, or the part will be pulled unevenly. The thread of the screw must be clean and it should be greased with a semiliquid grease. If there is no safety cap on the screw then a steel strip should be placed between the surface of the part to be pulled and the tip of the screw in order to prevent damage to the part. The arms should be placed at an even distance from the screw, because otherwise the pull that is applied to each jaw would be uneven which may cause warping of the part. The jaws of the arms must come in contact with the surface of the part in the greatest possible surface because if the contact is on a small surface then the jaws may slip or damage the part. If in spite of the fact that the area of contact is sufficient and the arms have been properly set, the jaws still slip then they should be examined to see whether they are bent and the contact surface of the jaws must be made again perpendicular to the axis of the screw. Figure 36 presents a screw puller for pressing out the combustion chamber muffle.

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In the assembly of jet engines the lever pullers are used seldom. STAT This is because of the fact that to create a large force the lever of the puller would have to be very large which makes the puller cumbersome. Usually lever pullers are used in cases when comparatively small force must be applied.

In dismantling small parts (locking pins, plugs, etc.) impact pullers are very convenient. An impact puller consists of rod 1 (Fig. 37), to which a head is welded 2; the other end of the rod is threaded and this threaded end of the rod is inserted into the part. Before the rod is threaded into the part a steel cylinder 3 with a hole in the middle is placed upon the rod. This cylinder being the impact mass may slide along the rod from the part to the head of the rod. After the rod is threaded into the part the cylinder is sharply struck against the head of the rod. The force of the impact is transferred from the cylinder upon the head, acts through the rod upon the part and separates it from another part. The same device can be used for joining two parts.

In addition to the above mentioned devices and tools of the general kind in the process of assembling jet engines a large quantity of special tools and devices is used, the most typical of these devices and tools are shown in the discussion of the technological process of assembly in chapters 2 and 4.

Equipment Used in Assembling

To create facilities for best workmanship in assembly operations diverse equipment is required. The basic kinds of necessary equipment are as follows:

a) hoisting mechanisms;

b) means of transport or conveyance;

c) washing and pumping installations;

d) cabinets and baths for heat treatment and cooling installations;

e) installations for hydraulic and pneumatic tests;

f) stands for preliminary testing of assemblies and subassemblies;

g) stands for dynamic balancing of rotors;

h) inspection equipment (magnaflux, luminescent inspection).

In addition to the above mentioned technological equipment assembly shops must be provided with the following facilities:

a) ventilation;

b) electric lights of high and low voltage;

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c) heating system;

d) compressed air of high and low pressure brought to work places;

e) water;

f) fire fighting apparatus or installations;

g) sewerage.

Because of the fact that the description of various kinds of technological equipment is found together with the description of the methods of assembly of various assemblies, the present chapter discusses only hoisting mechanisms and means of transport or conveyance.

Hoisting mechanisms. Hoisting mechanisms used in assembly operations can be divided into three kinds:

a) hand hoists;

b) pneumatic hoists;

c) electric hoisting mechanisms.

Of late hand hoists in the form of handdriven pulleys, hand cranes and winches have almost disappeared from assembly shops. Pneumatic hoists are found also very seldom.

Presently, replacing hand operated and pneumatic hoisting mechanisms electric hoisting mechanisms mostly in the form of electric hoists electric hoists equipped with trolleys and tracks and electric cranes are used on wide scale in the assembly shops.

Electric hoisting mechanisms are very convenient in operations and they facilitate the labor of men engaged in assembling and yield high productivity.

As a rule, in assembling subassemblies electric hoists or other electric hoisting mechanisms with the load capacity up to 250, 500, and 1,000 kg are used. In the general assembly of the engine to set it and to remove it from assembly carts and conveyors electrical mechanisms with load capacity of 1500, 2,000 and 3,000 kg are in use in assembly shops.

Electric hoist is used for lifting the load. Figure 38 shows the general view of an electric hoist with the load capacity of 2 tons.

The hoist is suspended on a trolley which in its turn is suspended on a track along which it can move. The schematic design of this electric trolley is indicated in Fig. 39. The hoist is driven by a three phase short circuited asynchronous electric motor 1 through the set of reduction gears 3, the electric motor rotates the cablegram 2. The steel cable goes around the roller of the hook pulley 5. The hook has a ball seat so that it could be easily turned wherever needed.

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To prevent spontaneous slowing of the hook after turning on the electric motor an electromagnet brake 6 is braced on the shaft of the reducing gears. The brake is set on by spring 8 and is taken off by three electromagnets 9 which are wired in parallel with the electric motor. For this reason putting the brake on and off occurs automatically simultaneously with closing and turning the electric circuit of the motor. Force of the spring of the brake is regulated by screw 10.

When the hook is raised to the limit the circuit is automatically broken by the terminal switch 7 when it comes in contact with the housing of the pulley of the hook.

The recommended speed for raising and lowering the load with the electric hoist for assembling operations (the moment of joining of parts) is from 0.5 to 1 meter per minute. For greater productivity it is recommended to use electric hoists with two speeds: up to 1 m/min for joining and separating parts and up to 8 m/min for free hoisting and lowering. The two speeds for raising and lowering the load are usually obtained by double winding of the motor. The speed of movement of the trolley can be satisfactory for assembly operations within the range of up to 10 m/min and for transporting -- 20 m/min.

Means of Transport. The assembly shop and assembly departments in other shops should have well organized intrashop transport. The intrashop transport facilities together with hoisting mechanism create a general complex of technical means of the shop with the help of which, the movement of a great mass of parts and assemblies is accomplished with the minimum expenses. This movement embraces conveying from the warehouse to the work places of production teams and the conveyance along the whole flow between work places or subsequent assembly operations. In planning a shop for a given technological process of assembly it must be specified exactly what means of transport should be used for transporting parts and assemblies between work places. In several cases hoisting mechanisms, such as, for instance, cranes and electric hoists mounted on trolleys suspended from the tracks, etc., i.e. mechanisms which move loads both in vertical and horizontal directions are used. However, in practice of assembly shops in addition to these technical means, conveyor lines, mostly around washing machines, and hand trucks are used.

Hand trucks may be divided into three kinds:

1) hand trucks for conveying parts and small and medium size subassemblies. The truck has a loading platform of 0.8 sq. meters in the area, and 3 wheels on solid rubber tires. The rear wheel can turn. The diameter of wheels is 200 - 220 mm. At the rear of the hand truck there is a bent bar so that the hand truck can be pushed by worker without bending. Due to its small weight and because the wheels are mounted on roller bearings the operation of this truck is very easy. Parts or assemblies should be placed on the platform in special boxes.

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2) The cart for transporting or conveying large assemblies of the engine. The dimensions and the mechanism of the hand truck are the same as of the first class but instead of a loading platform it is furnished with a special stand on which the assembly of the engine is placed. The assembly is fastened to the frame of the truck depending upon the design of each either with collars, eyelets or bolts. Such hand trucks are used when it becomes necessary to send an assembly of engine in the direction away from its basic route along the productional flow.

3) A truck for conveying assembled engines. This truck can be moved by hand and it can also be towed by an electric truck. The wheels of the truck have solid rubber tires. The engine is fastened to the truck with bolts.

For transporting parts and assemblies between the shops electric trucks to which platforms can be attached are used.

In all cases of movement of parts and assemblies between shops the load must be carried in special boxes and covered either with a piece of canvass or a piece of vinyl chloride plastic, especially if the trucks are moved outdoors.

3. ASSEMBLY OPERATIONS

Parts may be joined together or connected together in two basic types: so that the joint becomes either immovable or movable. The immovable joints include such in which in the process of operation there should not be any shift in the respective positions of the two parts. Immovable joints in their turn are divided in two classes: permanent or fixed and detachable. In the first case it is understood that the joined parts after the assembly cannot be disassembled because in the process of disassembling either the original dimensions would be changed or the contact surfaces or joining surfaces would be damaged which would make it impossible to reassemble the parts. As an example of immovable permanent joint connections those made by means of forced fits or by means of welding etc. can be cited. Immovable but detachable joints can be separated and joined together again several times, and in such cases no damage would be done and every time such joint should satisfy completely technical specifications for assembly. Such are among others joints or fits made by means of keys, splines, grooves, cones, flanges etc.

The movable joint is a joint which permits limited shifts in the position of one part in respect to the other. Movable joints must always have clearances between joined parts. In most cases movable joints are detachable, however they can also be not detachable (ball and rolling bearings that cannot be disassembled).

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Assembly of Fixed Non-Detachable Joints

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Fixed non-detachable joints are characterized by considerable tightness. Resilience forces which develop between the surfaces of the hole and the shaft which are being mated, retain the relative position of the two with a sufficient margin of safety. In some instances such joints are further braced by smooth or threaded locks. To these non-detachable joints should be added joints made by means of welding, soldering, flaring and bending or riveting.

Joints of considerable tightness are usually made by two methods: by introducing the shaft into the hole using great force (pressing in) or by heating the aperture, previous to joining, and cooling the shaft which results in a positive instead of a negative allowance between the parts, after which the joining is done by hand. Or, a combination of these two methods may be used.

Producing drive fits by means of impact force when the parts being joined are of large diameter cannot be recommended because this method lacks in precision and may produce scoring of the surfaces and other disagreeable results.

Press Force. A press is used in force fits. When comparatively small force (up to 5,000 kg) is needed, screw and rack presses are used (Figures 40, 41). However, when considerable force is needed for making the joint, hydraulic presses (up to 50 t[1]) are used. The parts joined by the press must have clean, smooth surfaces (around 7 ▽▽ 8) free from burrs, nicks and flaws, and must have tapered entering surfaces for a quicker and more precise self-centering of the parts. Burrs, flows and nicks on the surfaces which are being mated, first of all necessitate extra effort in pressing and, secondly, impair the surfaces both of the mating member and of the base part, and may lead to jamming of the pressed parts. Before pressing, the mating surface of one of the members is lubricated with industrial grease, industrial vaseline or aviation oil. The lubricant must be dehydrated before it is used. Lubrication prevents jamming of mating part, especially when the metal used is the same in both parts.

In pressing, the base part (i.e. into which the other part is being pressed) is placed strictly on the axis of the main screw of the press, so that the pressing force acts on the axis of the mating parts, because otherwise skewing may result in burring of the mating surfaces or in sticking of the parts. Placement of the parts and the main screw of the press on the same axis is achieved with the help of special devices (Fig. 42, a). The aperture in the plate of the press is coaxial with the spindle and in its turn may serve as a base for the main part or for the adapter bushing which may also serve as a base plate for the

1. The authors do not give stress calculations which are necessary for press fitted joints, since they consider these calculations much space consuming and lacking in sufficient precision. The press capacity is usually decided on the basis of practical experience. Those interested in the data present in literature on the press stress calculations may be referred to the book by A.F. Lesokhin "Allowance and Fits," ONTI, 1954, where these calculations are presented.

part. Fig. 42, b illustrates the method of coaxial setting in press fitting of bushings. In this case of press setting, the bushing is placed on the holder sleeve which enters, with a small play, the hole in the base part and places it coaxially with the main screw of the press.

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Quality control of the press fit is maintained in the following way. In the majority of the cases, previous to press fitting of the parts of the main assemblies the diameters of the hole and of the shaft are measured in their normal temperature. These measurements permit the determination of the actual tightness resulting after press fitting and, consequently, assure dependability of a given joint. The snug fitting of end surfaces is also tested (ends of shoulders). This adherence is tested after press fitting with a 0.03 mm feeler gage which should not be able to pass.

For a better guarantee of press fitting it is possible to test the quality of fit by the amount of press stress, which is especially easy when hydraulic presses provided with manometers which indicate pressure in the compression cylinder are used.

Very tight fits may be achieved by thermal expansion of the hole and by thermay contraction of the shaft. Selecting proper temperatures of heating the part with the mating hole and cooling the shaft, it is possible to obtain such an expansion of the diameter of the hole and shrinkage of the shaft diameter, that a positive allowance results instead of a negative one and the mating of the parts may be done by a simple insertion of the shaft into the hole. The part is usually heated in an electric thermostat or in an oil bath. Electric thermostatic heating is preferable since this operation is simpler, safer from the point of view of fire hazard, and is cleaner. The entire part is immersed when the part is heated in an oil bath, and to take out a slippery hot part is not too easy in the first place, and in the second place the oil dripping from the part soils the floor, equipment, and clothing. To retrieve a heated part from an electrothermic oven, the hands should be protected by special heat insulated gauntlets or special handling devices should be used to hold the heated part.

Dry ice is used for cooling of shafts. Dry ice is placed in a special thermostat which is made to fit the part. For a more effective and even cooling of the part it is recommended to mix dry ice with alcohol or kerosene. Such solution is capable of cooling the part to -70° C. In such a bath the entire part upon immersion in the cooling reagent cools down rapidly and evenly. The cooled part should be handled with canvas or leather baize lined gloves to protect hands.

Temperature for the parts being mated is taken depending upon the tightness according to the following formula: STAT

$$C = A [1 + (t_1^o - t_0^o) \alpha_1] - B [1 + (t_2^o - t_0^o) \alpha_2],$$

where A - hole diameter in mm;

B - shaft diameter in mm;

t_1^o - terminal heating temperature in C°;

t_2^o - terminal cooling temperature in C°;

t_0^o - initial temperature of parts (shop) in C°;

$\alpha 1$ - coefficient of linear expansion of the metal around the hole;

$\alpha 2$ - coefficient of linear expansion of the shaft metal;

C - added amount for clearance in mm.

The added amount for clearance is necessary, first of all, to ensure freedom of fitting and, secondly, to compensate for reduction in clearance due to changes in temperature of parts during the process of assembly. Value C depends upon the duration of the immediate union of the shaft with the hole, the mass of the mating parts and the area of the surface of the parts. Consequently, it is safest to test the selected value C experimentally.

When the parts are ready for mating, it is necessary to verify the dimensions of these parts with a special gage in order to have assurance that the dimensions are of the proper size. Verification of dimensions and assembly of the parts should be done quickly inasmuch as after the parts are taken out of the thermostat and cooler the heated part cools down while the cooled part warms up rapidly due to the considerable difference in the temperature of the parts and of the outside air. This process of heat exchanging goes on even more rapidly during the actual mating of the parts. Previous to the assembly operation, impact tools must be held in readiness in the event that the hole begins to seize the shaft before it is fully inserted and must be driven, as a last resort, to its place (if the heating was correctly calculated, and the work continues without incidental delays, this is not necessary as a rule). As in the case of pressing operation, one of the parts is usually lubricated with dehydrated mineral lubricant.

One of the parts must rock slightly during the mating, since during the assembly operation the parts usually join slightly on a slant creating an impression that they were not properly treated thermally. This is especially true in the case of heavy parts which have considerable fitting length.

If, in spite of rocking, the shaft enters the hole with difficulty, the parts should be separated immediately and the thermal treatment repeated. In those cases when parts mate with difficulty from the very

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start, it should never be attempted to help with hammer strokes since the effect of thermal treatment lasts a very short time and the shaft may be left seized half-way in the hole. In this case separation of the parts takes a long time and in some cases is impossible without damaging one of the parts. In practice, entering part must enter freely all the way in and after placement should be given two or three rocking movements around its axis to ensure proper centering. When the parts have additional bracing, such as splines or keys, which do not permit relative motion of the parts, the absence of slant is ascertained with the help of a feeler gage which is inserted into the gaps between the surfaces of both parts. After cooling of the parts there may appear a slight clearance between their end surfaces (especially in the case when the parts have different coefficients of expansion). This should not serve as a cause for alarm since clamping of one part to the shoulder of the other is necessary mainly for the purpose of fixing of the location, while the change in the position of the part upon cooling is small enough to be disregarded.

If the parts are additionally fastened by a locknut, it may be placed and tightened immediately after the assembly of the parts. Before the locknut is tightened, it must be lubricated with a mixture of industrial grease and graphite. If, previous to the screwing of the locknut the shaft had been heated, the clearance for the mean diameter would decrease, the locknut would screw on with difficulty and possibly would seize. It should be possible to screw in the nut all the way by hand, if, however, it enters with difficulty the operation should be stopped and resumed only after the shaft has cooled. Placing of the nut immediately after joining of the parts is done because the clearance between the surfaces of the part after cooling will be then rather small. After cooling of the mated parts the nut should be tightened according to specifications and locked only then.

Before the unit is conveyed to the point of further assembly it must be cooled naturally, which takes a comparatively long time, or by a steady blast of cold air, or finally, in a special refrigeration unit. In the case of artificial cooling it is absolutely necessary, in order to avoid buckling, (especially of thin, large-sized parts) to ensure an even cooling of all parts of the assembly.

Assembly of Non-Detachable Threaded Joints

Joints made by means of threading may be of two types: non-detachable (end of stud screwed into the part) and detachable (nut fitted end of stud, as well as bolts, tie nuts, etc.). On one end the stud has a normal, so-called fastening thread, for screwing of the nut, while on the other end - a thread with an increased pitch diameter (so-called tight thread). The stud may be screwed into the part both to the end of the thread (Fig. 43, a), or to a given depth with a certain length of the stud left above the surface of the part (Fig. 43, b). The studs which are screwed into the primary parts are selected according to the torque to be applied which fully protects the threaded joint against unscrewing and breakage or seizing of the stud as it is screwed into the threaded hole (for instance, centrifugal compressor impeller rotor vanes, bolts which attach gas turbine disk to the shaft, etc.).

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Internal threads are divided into two or three groups for the purpose of matching, in the same way as in case of studs. Group numbers of studs are stamped on their nut end immediately after their production. The group to which the bore thread belongs is determined before the insertion of the studs.

Two special gages are used to determine the group of the internal thread in the case of three groups. The first gage is go gage for the second group of thread and no-go gage for the first. The second gage is go gage for the third group of thread and no-go gage for the second.

Using these gages to verify the pitch diameter of the threads, the group to which the stud hole threads belong is determined, and the number of the group is written in pencil near each hole. After this, a stud of the same group is selected for each hole and is screwed into it.

When there are only two groups it is sufficient to have one gage, which is no-go gage for the first group of internal threads and go gage for the second.

To join the stud and the housing it is necessary to have a clean thread, without burrs or nicks, otherwise the stud may seize or strip the thread during screwing. To avoid seizing, stud thread is lubricated with industrial vaseline before screwing, while studs subjected to high temperature are lubricated with graphite lute. The studs are screwed in with the help of a device which is known as a tool post (Fig. 44).

When the stud is screwed into the part, the tool post is turned at first at a slight angle in relation to the stud, there ensues a considerable friction between the thread of the stud and the tool post, caused by the pressure of the bolt on the stud, and the tool post forces the stud to follow and screws it into the well. If the stud must be screwed in not as far as the end of the thread, special rings-templets (Fig. 45) are placed under the tool post which ensure screwing of the studs to the desired height. The screwed in stud must fit tightly in the well and must not unscrew itself when the nut is screwed on, the axis of the stud must be perpendicular to the plane of the well the height of the stud must correspond to the specified size, and finally, the free end of the stud on which the nut will be placed must have no damaged threads.

The tightness of the fit of the stud in the well may be tested by feel, in trying to unscrew the stud. Actually this is never done, since the criterion of the tightness of the joint is the torque with which the stud is inserted into the well. The skewing of the stud in relation to the surface of the well is checked by means of a special square which is placed on the surface of the well. As a rule, skewing of the stud is caused by skewing done while drilling the hole for thread or skewing of the tap during threading. This usually takes place in hand drilling and when tapping is done by an unexperienced worker. If skewing of the stud handicaps proper joining of the parts or proper fit of the nut to the surface of the part, the stud is removed and the threaded well readjusted for another stud.

It is possible to remove a stud with the help of two nuts which aSTAT screwed on the free end of the stud and a wrench which is placed over the bottom nut. In unscrewing the stud it is recommended to turn the wrench first in the direction of the thread of the nut followed by a turn in the opposite direction. Should the stud fail to respond immediately, it will be necessary to repeat this operation several times., until the stud will start to loosen.

A stud wrench is very convenient for removing studs (Fig. 46). The wrench has a hole of the diameter of the stud and knurled cam which turns freely on its axis. The wrench is placed over the stud and then the cam is turned by hand in such a way as to press it against the stud. In unscrewing, the stud itself tightens the cam in such a way that the wrench will not move in relation to the stud. After being unscrewed with the help of a stud wrench the stud's thread on the nut end of the stud is usually damaged and the stud cannot be used again. If in removing, the stud breaks off flush to the surface, the remaining part may be taken out with a drill of a diameter equal to, or 0.1 - 0.2 mm smaller than the inside diameter of the stud. When the stud is extracted with such drill, parts of the thread remain in the seat and are taken out with a special scriber. Fragments of metal which remain in the hole thread are extracted by means of a compressed air jet aimed into the hole. After a complete removal of shavings out of the hole, the burrs which have probably appeared should be removed with a tap.

Broken studs must be removed by experienced workers. To avoid deflection of the drill and damage to the well thread in unscrewing of the broken studs, the use of a jig is recommended. Fig. 47 shows several other methods of stud removal.

In Fig. 47, a the protruding end of the stud is filed to fit the wrench and the stud is unscrewed with the help of a nut wrench. In Fig. 47, b the stud is unscrewed with the help of two nuts, the wrench used on the lower nut; to prevent the nuts from coming off, the upper nut is held by another wrench. In Fig. 47, c a hole for a tap is drilled in the stud. The tap with a counter thread is screwed into the drilled hole and the stud is removed with the help of the tap. In Fig. 47, d a tetrahedral rod is driven into the hole drilled in the stud and the stud is unscrewed with a nut wrench

In Fig. 47, e an extractor is driven into the drilled hole in the stud; the extractor is a screw with a very shallow thread, counter to the thread of the stud, and the stud is unscrewed by turning the extractor with a nut wrench.

Among other, less commonly used methods, are removing studs with nitric acid and by electrolytic erosion. Removal of studs with the help of nitric acid is done only when the seat of the stud is made of aluminum alloy. Nitric acid dissolves steel but has very little effect on aluminum alloys if their composition does not include zinc or magnesium. This process takes place in the following manner: an acid-resisting barrier (made of wax), in the shape of a well, is built around the broken stud. This well is filled with nitric acid of 1.15-1.2 specific gravity. The acid will dissolve the stud gradually without affecting the aluminum casing into which the stud was screwed. The acid isSTAT changed periodically until the stud has been eroded completely. After this, the threaded hole, out of which the stud has been removed, is washed carefully with soda water, which neutralizes the acid, followed by a washing with hot water. Erosion process is more rapid if the part is heated to 50 - 60°C. This operation should be conducted very carefully since the acid may cause burns. Nor should the acid be allowed to touch steel parts to avoid damage to them. After the erosion process is completed the remaining fragments of the stud are removed carefully out of the seat, the hole thread must be checked with a number three tap. This method of removal of broken studs is not widespread due to its meticulousness and the amount of labor consumed but is completely justified in removal of taps broken in aluminum casings.

Electrolytic erosion method of stud and tap removal is mainly used in case of small parts since special equipment is needed in case of larger parts.

Should the stud be screwed in too deeply it is not recommended to correct the situation by unscrewing the stud by several threads to the needed height; this may weaken the fit of the stud. In this case it is better to unscrew the stud completely, to check the hole thread with a tap and to screw in a new stud of the next in size thread gage.

Assembly of Detachable Threaded Joints

Deflection of the part due to faulty tightening should be avoided when the parts are assembled with the help of bolts, studs and nuts. Bolts and studs should be tightened with an equal force and in a definite sequence. This is especially important in the case of block studs of large-size parts which have a great number of studs or bolts.

The major requirements in stud tightening are a close contact of butt surfaces without warping or buckling during tightening, and absence of overstrain in the body of the stud. The first requirement is achieved by a selection of a definite order in the sequence of stud tightening; the second, by the use of special devices or wrenches while tightening of studs. First of all a so-called setting is conducted in which all nuts are tightened evenly and in a specified sequence. Following this all nuts are loosened, then screwed in to the contact with the seat surface of the part, and finally, the threaded joints are tightened. A normal nut should screw in with ease until its contact with the seat surface.

Difficulty in screwing or seizing of the nut indicates local damage to the thread of the nut or of the bolt (nicks, burrs, metal sticking, etc.) or faulty geometric dimensions of the bolt or nut thread.

Small local damage to the thread of the stud may be corrected with the help of a triangular neelde file, or by rethreading with a threading die. Similar defects in nuts may be eliminated by rethreading with a number three tap.

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If tightness in screwing is due to error in geometrical dimensions, which is rarely the case, the bolts and nuts are rejected. If this STAT concerns the stud, another nut, of greater pitch diameter is found, or the thread of the stud is rethreaded with a threading die which is in good condition. In case of faulty pitch or faulty angle of the thread, the stud is rejected and replaced by another. If the thread of the bolt and nut is cadmium plated, the tightness in screwing of the nut on the thread of the bolt may occur when cadmium layer is somewhat thicker than specified (cadmium layer of the thread is approximately 0.005 mm thick), and the pitch diameter of the thread approaches the minimum in case of the nut, and maximum in case of the bolt, i.e. the clearnace at the threaded joint approaches zero. In this case it is necessary, either to replace the nut, or to force the nut along the thread of the bolt or stud with the help of a wrench, applying only a slight hand pressure.

All major force-transmitting threaded joints are tightened with a specified tightening force which is determined according to the elongation of the stud or bolt which is being tightened, according to the locking angle of the nut after its contact with the seat of the part, and according to the maximum torque. The most precise test of the tightening force is a check which determines the elongation of the stud or bolt, this method, however, cannot be always applied. The two remaining methods, especially the third, may be used almost in any case of threaded joints, but these are less precise, inasmuch as a number of such variable factors must be considered, as thread friction, and friction between end surfaces, which depend upon the quality of threading and of contact surfaces. Besides, in tightening according to the locking angle, considerable effect will be exerted by the elastic deformation of the stud torsion and contortion of contact surfaces. Measurement of the tightening force according to the value of the elastic elongation is based on Hooke's law

$$\Delta l = \frac{Pl}{EF},$$

where Δl - linear elongation in mm;

P - applied load in kg;

l - stud length;

E - modulus of elasticity of the first type in kg/mm^2;

F - stud cross-section area in mm^2.

Assuming the value of tightening force P, it is possible to determine the values of elongation of bolt or stud after tightening.

The tightening process itself is as follows: First of all the bolt length l_1 is measured in its free, untightened state. Then tightening takes place, length of the bolt is again measured and the value l_2 if fixed.

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If the measurement difference $l_2 - l_1 = \Delta l$ is of the needed STAT, the tightening was performed correctly. If the obtained value Δl is smaller than the one assigned, it means that the tightening already performed must be increased. To avoid too many measurements and over-tightening of the bolt, it is wise to conduct the tightening process in the following way: bring the nut in contact with the part, then turn the nut 90° and press the joint. This is to be followed by releasing of the nut, measuring of the bolt length and again bringing the nut in contact with the part, turning the nut 90° and measuring the elongation of the bolt. Now it is possible to calculate the approximate angle by which the nut must be turned in order to obtain the required elongation Δl, and consequently the required tightening force. In case of overtightening of the bolt, i.e. the elongation obtained greater than required, it is necessary to release the bolt in such a way that the value Δl becomes slightly smaller than required, and then, turning the wrench carefully, to tighten the bolt to its norm. Since the elongation after tightening is usually measured in hundreds, or maximum in tens of one millimeter, the measurements of initial and final bolt lengths should be made with considerable accuracy.

A method of precise measurement of bolt length is shown on Fig. 48. Here, both ends of the bolt have conical grooves into which are inserted two balls and the length of the bolt is measured from one ball to another. To prevent the balls from falling out, they are clamped by a special spring clamp which presses them to the surface of conical grooves. The clamp should be installed in such a way as to have the balls get into their old places each time. This will eliminate the error which may arise due to the difference in the size of the balls. If the stud length cannot be measured, its elongation due to tightening may be determined by measuring the distance of the end of the stud from some permanent base.

Fig. 49 shows a method of measuring stud elongation due to its tightening in the rotor of a centrifugal compressor. As a measuring base is taken a device which is made fast to the shaft of the compressor. An indicating depth gage is installed on the surface of this device with the help of which the distance between the scraped surface of the device and the stud end, into the conical groove of which a ball has been inserted, is measured. Tightening in this case is done twice. The first tightening serves for pressing of the joint and selection of possible clearances at the ends of the studs which are screwed into the impeller. After the preliminary tightening one of the nuts is unscrewed to its contact and then tightened for the last time. In the same way all the other studs are tightened in sequence.

In tightening according to the locking angle method a calibrated scale with a hand indicator is used. Depending upon convenience, the scale and the hand may be attached either to the wrench, or to the body of the part (Fig. 50). A preliminary tightening is made, in the locking angle method, to eliminate looseness in the joint and with this, the free play of the nut. Then the nuts are unscrewed, brought to the contact by hand, after which the stud is given a final tightening by a turn of the nut to the required angle. In tightening of long studs it should be considered that the angle of the turn may be considerable, especially in case of considerable friction of the thread. In the case

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when the tightening of a detachable threaded joint is desired according to the torque in kgm, it is necessary to apply dynamometric (torque) wrenches, which indicate the value of the torque, applicable in tightening of the threaded joint, or limit wrenches, calibrated to the desired torque.

Dynamometric wrench, shown on Fig. 51, is the least complicated in design. The wrench consists of a head (1), connected by means of precision (without play) threading, to a resilient rod (2), provided with a handle at its end. A calibrated scale (3) is attached to the head of the wrench, and indicator (4) to the resilient rod. In tightening of the threaded joint the rod (2) will bend and the indicator (4) will travel over the scale (3). Before its application the scale of the wrench is calibrated to the desired torque and the scale is correspondingly marked in accordance with the desired torque. During the tightening of the threaded joints the worker must see to it that the indicator reaches the scratched mark on the scale.

Dynamometric (torque) wrench shown on Fig. 52 is made of a duralumin holder (1), to which a plate (2) is attached by means of eight screws, holding the mechanism of the wrench, shown separately on Fig. 53. Resilient rod of the wrench (7) is connected with the square aperture in the head of the wrench (6). The value of the torque is fixed by the hand of the indicator (3). To ficilitate its operation one end of the holder of the wrench has a form of a handle (4).

To screw in a nut in a hard to reach place a hinged joint (5) is provided. Both resilient rod (7) and the square of the joint have ball locks.

Wrench mechanism (see Fig. 53) consists of a resilient rod (7), welded to plate (2), lever (8) connected to guide (9), which sits on the same shaft (10) with a toothed sector. The toothed sector (11) (Fig. 54), which has 12 operating teeth, and can turn both ways (for right-hand and left-hand thread, meshes with a gear (not shown), the shaft (12) of which also serves as the shaft for the indicator hand. The gear has twelve teeth and consequently, during the maximum shift of the toothed sector together with the indicator hand will execute a 180° turn. To eliminate play in the meshing of the teeth and a reverse movement of the indicator hand, a spiral spring (13) is provided. The scale of the indicator is divided into two semicircles (right and left-hand thread) each having 30 graduations. Each graduation on the scale corresponds to 5 pound-foot or 0.69 kgm. The indicator scale rotates so that it could be set at zero.

Fig. 55 shows a spring limit wrench. A turn of the handle (3) can adjust the wrench to various values of the torque from 100 to 200 kgcm. The moment of complete tightening of the threaded joint is found by the worker by feel when the mechanism of the wrench begins to slip. This corresponds to the position of the guide (18) as it is shown on Fig. 55, left top.

The worker should watch carefully for slippage of the wrench, because if the tightening process is not stopped at this moment, with further turn of the wrench, the guide (18) will rest on the casing (27) and the tightening will continue above the required torque breaking the threaded joint.

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Calibration of limit and dynamometric (torque) wrenches may be d STAT on a machine for torsion testing of the samples.

Test data are added to the wrench. Tightening by means of dynometric or limit wrench is performed in two operations. First, the threaded joint undergoes a preliminary tightening according to the desired torque (reduction) then one nut at a time, in sequence, is loosened, followed by a final tightening, at the same time bringing the nut under a splint. Tightening must be done evenly, without interruptions or jerks, since in starting the dynamometric wrench will show at first a slightly greater value. The same takes place in jerking.

The precision of a threaded detachable joint, is affected besides eveness in value of tightening of each threaded element of the connection, also by the sequence of tightening of bolts and studs, especially if these are present in great numbers. When there are four studs located on the circumference, the tightening is done as it is shown on Fig. 56.

Fig. 57 shows the sequence of stud tightening when they are located along the axis. Such sequence ensures the best contact of butt surfaces since even if both butt surfaces are buckled, in tightening this buckling will be straightened as a result of shift of the case halves in both directions.

Fig. 58 shows the sequence of tightening of studs of a round flange of an engine equipped with a centrifugal compressor. In this case the process is started by tightening four studs located crosswise, followed by tightening of studs in each of the four sectors approximately in the same order as the first four. Flange connections with a large number of threaded detachable joints are tightened in approximately the same way. To avoid burrs and corrosion in the threading, it is recommended to lubricate the threaded joint, before its joining, with a mineral lubricant. It is recommended to lubricate force transmitting threaded joints, which reauire considerable tightening force, with industrial grease. Threaded joints which require sealing, are assembled with the help of whiting, minium, hermetic sealer, or silk thread. Threaded joints which are sealed are hard to dismantle, consequently this method of thread sealing is recommended for those joints which are never taken apart, or rarely dismantled.

Locking of Threaded Joints

As a rule, all threaded joints of an engine are locked after tightening to prevent self-unlocking due to vibration. Fig. 59 shows the usual types of locking. As a rule, locking or safetying parts and materials, with the exception of special locknuts, are used only once and after dismantling are thrown out regardless of their condition. Among such materiel and parts are: binding wire, cotter pins, lockwashers, locking terminals, the teeth of which are bent back in locking, etc. In cotter pin safetying it should be remembered that the pin must fit the hole tightly, with little play, and must have its length protrude above the nut approximately equal to one facet of the nut. Longer cotter pins, requiring nipping off their ends to the necessary length, never should be used. Cotter pins should be trimmed at a distance from the place of assembly to avoid falling of cuttings into the engine.

Protruding cotter pin ends must be bent back carefully over the STAT of the nut, or as it is shown on Fig. 60 (over the facet or over the end of the bolt or stud), and tightly pressed to the facets with hammer blows. In locking with the help of wire it is necessary to guard against over-twisting of wire leading to cracks at the place of the twist.

Castellated nuts (Fig. 61) should be tightened with a wrench by 120-180° after screwing on the thread. The teeth of locking terminals after they are bent over the facet of the nut should be tightly pressed to it with hammer blows.

Assembly of Flanged Joints

Flanged joints are widespread in engine-building practice. Gas turbine of a jet-propulsion engine may be given as an illustration. Major requirement in a connection made by means of flanges is perpendicularity of the axle ends being joined and concentricity of the pivotal axis of the holes made for bolts or studs. Non-perpendicularity of flanges brings about a greater or lesser break in the axle with all the ensuing consequences. In particular, in the above given illustration of a gas turbine rotor this brings forth pulsation of the disc butt end. In case of non-concentricity of holes made for the bolts of the rotor axle there is pulsation along the circumference of the disc. It is also very important to align the axis of each hole made for bolts or studs, especially in case of templet bolts. This is ensured by a simultaneous reaming of the holes in the flanges being joined. Connecting bolts are tightened according to standard practice.

Assembly of Cone Joints

Cone joint connection serves both as a method of centering of two parts and to make a stationary connection. In the first case the cone joining is done with a slight tightness and the immovability of the connection depends on additional fastening by means of a dowel. (Fig. 62). Besides, the part with an inner cone is protected from axial shifting by a lock nut. It is obvious that in order to tighten the cone joint with a nut, it is necessary to have the encompassing cone overhang the cone being encompassed thus having the capacity to move along the encompassed cone when the nut is tightened. The contact surfaces of a cone joint before being assembled, are ground reciprocally with great care. The quality of grinding is tested with paint; no less than 80% contact of the cone surfaces is required. Before assembly one of the cones is covered with graphite lubricant to prevent scoring of the surface in dismantling.

In assembly of a cone joint requiring considerable tightness the operation is carried out in the following way: after grinding, the cone hub is placed on the shaft with an abrupt movement to assure its tight fit on the shaft. Following this, the distance between the end of the shaft and the end of the sleeve (l_1) is measured with up to 0.01 mm precision with the help of a depth gage, (Fig. 63). Then the distance (l_2) is theoretically calculated, this distance corresponding to the position of the sleeve when it will sit on the shaft with a required tightness.

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The dimension (l_2) is found by means of formula

$$l_2 = l_1 + \frac{H}{2\,tg\,\frac{\alpha}{2}},$$

where l_2 and l_1 - distances in mm, shown on Fig. 63;

H - required value of tightness in mm;

α - cone angle.

Then the sleeve is taken off the shaft and heated to that temperature which will ensure an easy slipping of the sleeve on the shaft (distance from the end of the sleeve to the end of the shaft l_2); after cooling the sleeve must have the desired tightness H. The required temperature of heating may be determined by formula

$$H = A\alpha\,(t_1 - t_0) \text{ or } t_1 = \frac{H}{A\alpha} + t_0,$$

where H - required tightness;

A - size of sleeve hole in mm;

α - linear coefficient of expansion;

t_1 - sleeve heating temperature in C°;

t_0 - room temperature in C°.

Heated sleeve is quickly placed with an abrupt movement and the distance (l_2) is checked immediately. The surface of the shaft, before the sleeve is placed, is lubricated with light industrial grease to prevent scoring of the shaft or of the sleeve. In those cases when placement of the sleeve in the shaft cannot be done rapidly, the sleeve is heated to the temperature 50-100°C higher than that required, and during the placement of the sleeve in the shaft attention is paid to the retention of distance (l_2), which can be done easily before the sleeve has cooled and tightened in the shaft.

Assembly of Splined Joints

Splined joints with splines rectangular in their cross section differ in methods of their centering. Fig. 64 shows types of spline joint centering. Figure 64, a shows outside diameter centering, Fig. 64, b inside diameter centering, and Fig. 64, c centering along the side surface of the splines. The first two types are the most common.

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Since in preparation of splines there is always a possibility of error in the angle, it is necessary to find those grooves and splines STATch may be mated with the greatest ease. This position is affixed by stamping a spline of one part and the groove or a pair of corresponding adjacent splines of the other part. Before mating the collar with the shaft, the surfaces of splines of both parts must be checked carefully and all the minute scratches, nicks and burrs must be cleaned, otherwise seizing may occur in the splines. It should be also checked whether there is sufficient surface on the splines, contacting the radii of the grooves of the splines.

In joints made with the help of end splines (Fig. 65), the splines should be free of nicks, or dents, otherwise flanges will not lock tightly and the joint will be out of line. Chance nicks and dents on end splines should be dressed carefully with a barette file or scraper before joining. However, if the flanges still fail to join tightly, it should be ascertained with the help of paint, which splines interfere, and to find the best position for the splines by turning one flange in relation to the other by an angle between the bolts. When the best joining position is ascertained it is affixed by markings on the periphery of the flanges.

To improve joining of the splines, joints of large dimensions are pressed before assembly under 50-60 kg/cm^2 pressure.

Setting of Anti-Friction Bearings

The design of jet engine specifies, almost exclusively, the use of ball and roller bearings both of detachable and non-detachable type.

Due to high rpm of the engine very high performance standards are required of ball and roller bearings.

The major requirement of an installed anti-friction bearing is easy and smooth rotation of one ring of the bearing in relation to the other without noise or seizing.

During the assembly of anti-friction bearings, especially of the bearings of compressor and gas turbine, care is observed in preventing dust from entering the bearings and preventing oxidation especially of the working parts - bearing races, balls and rollers, where absolutely no corrosion is tolerated. Anti-friction bearings are stored in packages for their preservation until assembling. Unpacking of bearings takes place immediately before assemblying; the bearings are washed in pure gasoline after which they are dried with warm, dry compressed air, and examined for smoothness and ease of movement, and for traces of corrosion. If necessary, setting diameters of the outer and inner rings and diametrical and axial clearances are measured. It is recommended to wear clean cotton gloves while testing and measuring anti-friction bearings to protect them from fatty acids.

After examination anti-friction bearings are rinsed in clean spindle oil and stored until assembly in clean and dry cellophane packages or in spindle oil filled baths.

Non-detachable ball and roller bearings, as a rule, have a tight fitting ring on one side and a ring with clearance on the other STAT installing bearings it is necessary to guard against distortion of the ring as it is fitted tightly. Setting surface of a ball or roller bearing must be clean and greased to prevent possible scoring. The most expedient method of placing ball or roller bearings is by means of a press or a free "setting" accomplished by heating of the bearing.

Because the above mentioned methods are not always convenient due to the design features of the parts, an impact method of setting ball and roller bearings is often used. Whem impact method is applied the use of a special device which has the form of a tube, one end of which is fitted with a plug-head (Fig. 66) is recommended. The dimensions of the tube are taken according to the ring of the anti-friction bearing, on which the tube must rest; the outer diameter of the tube intended for outer ring is made 0.5-1 mm smaller than the diameter of the outer ring; the inner diameter of the tube intended for inner ring is made 0.5-1 mm larger than the diameter of the inner ring. This is done to prevent the tube from touching the surface of the housing, or the surface of the shaft, being fitted and scratching it during slight skewing or flaring of the tube end. The use of this tube is convenient because the force used on the anti-friction bearing as it is placed is distributed evenly over the entire area of the bearing ring and will ensure its movement along the axis without skewing.

Fig. 67 shows how to apply force in installing anti-friction bearings depending on which of the rings has a tight fit. If this rule is not observed, and the force is applied to the ring with clearance, the force used on the ring with a tight fit will be transmitted to the ball bearings through the balls, and through rollers to roller bearings

When the force is applied locally (by hammer and punch) the force will be transmitted only through one ball or roller, which results in increased tension at the point of contact and may lead to the occurrence of dents in the bearing-races of the ball bearing and cracks or breaks of the shoulders of the outer or inner collar of the roller bearing.

In both cases the bearings will be completely damaged and will have to be replaced. Removing bearings from parts (housing or shaft) is done with the help of clawed screw pullers. To prevent skewing, the puller is provided with three claws which grasp the bearing by tight-fitting ring. When anti-friction bearings are taken out with the help of a puller by grasping them by outer ring, grooves are made in the housing at the place where the bearings will be placed, for the claws of the puller.

If turning of the bearing, after its installation, becomes difficult, the bearing is removed and replaced by another which fits the given part less tightly. For individual bearings (compressor or turbine rotor bearings) the method of preliminary matching in accordance with the dimensions of the shaft or some other part is used. In these cases the setting dimensions of the bearing and of the parts being mated are measured and then the bearing and the parts which ensure the desired fit, are selected.

Thus, for instance, a bearing of the rotor of gas turbine TKVRD equipped with a centrifugal compressor, is selected first in aocoSTATce with shaft dimensions with fit tolerance of from 0.000 to 0.010 mm and then, in accordance with the dimensions of the outer ring the size of the bearing is selected with tolerance for fit of from 0.000 to 0.010 mm.

In case of single unit production such matching is not always possible due to a limited number of combinations of parts and bearings, and in this case this problem may be solved by corresponding finishing of mating parts.

The inner ring both of a ball bearing and roller bearing, after its placement on the shaft must fit tightly the corresponding shoulder of the shaft or the adjacent part. Tight fit of the face of the inner ring of the bearing and the adjacent part points to its proper position on the shaft (absence of skewing). Tight fit of the bearing face is tested with a 0.03 clearance gage which should not be able to enter the junction of the parts along the entire circumference of the ring. When the feeler gage can enter from one side but cannot enter from the other it means that the bearing is out of line in relation to the shaft and can be corrected with an impact device or by further pressing.

Looseness of fit of the inner ring face of the bearing with the face of the shoulder, when the circumference clearance is uniform, may arise if the chamfer of the shaft ring has a greater radius. In this case the chamfer radius should be corrected.

In case of detachable roller bearings outer or inner ring may be removed, while the second ring remains connected with the rollers which are encased in a cage. Both parts of the bearing are mounted on the corresponding parts separately and then the bearing is assembled simultaneously with the assembly of these parts.

Besides general rules to be followed in assembly of anti-friction bearings here must be observed also the condition of correct axial placement of one ring as against the other. If this condition is not observed, the rollers of the removable ring may fail to operate over the entire width of the races because one part of the roller may reach beyond the race on one side. In practice this occurrence is known as roller "droop" and it is ascertained with the help of paint. To do this previous to their assembly both rings and their rollers are wiped dry while the bearing race of the detachable ring is painted with a thin layer of Prussian blue. This is followed by the bearing assembly.

One ring of the assembled bearing (usually the inner) is turned 360° two or three times after which the bearing is disassembled. If the entire length of the roller becomes covered with paint it means that the connection was made properly. If, however, one end of the roller remains unpainted for a certain length, it means that roller "droop" is present. Roller "droop" is eliminated by moving one ring of the roller bearing axially in relation to the other by the corresponding length in the needed direction by selection of calibbated washers, which are introduced into the design especially for that purpose.

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In assembly of ball thrust bearings (Fig. 68) one ring (1) must fit the shaft tightly, while the other (2) must be seated with a clearance. This is explained by the fact that the ring tightly seated on the shaft of the ball thrust bearing, centers the entire bearing in relation to the shaft and rotates, as do the balls, together with the shaft. The other ring, which has a clearance in relation to the shaft, however, remains motionless during operation and is pressed tightly to the housing.

If, due to a mix up, the rings are changed in position, ring with a tight shaft fit will be pressed by the shaft against the housing, will heat itself due to friction and will be the cause of the bearing's breakdown and damage to the mechanism.

In a turbo-jet engines with axial flow compressor, the forward radial thrust ball bearing of the compressor rotor is often combined in pairs or in threes.

In this case, two or three radial thrust ball bearings are placed in a single common housing or, as it is called, assembled in a pack. This assembled pack is placed on the shaft of the compressor rotor.

When such ball bearings are assembled, besides following the general rules of assembly, it is necessary to observe the condition of uniform distribution of axial thrust among the ball bearings of the pack. This is achieved by having each ball bearing after its installation in a common housing pressed in the housing by the axial thrust equal to the axial load which the ball bearing takes on during the operation of the engine. After pressing of all ball bearings their position in their common housing is affixed rididly.

Sliding Friction Bearings

Sliding friction bearings or sleeve-type bearings in modern turbo-jet engine are mainly used as bearings in manual drives (cone operating gear, etc.). In design these bearings usually represent bronze flanged bushings.

Major requisites to be observed in the assembly of these bearings are as follows:

1. Tight fit in the seat;
2. Cooxiality of bearings on which the same shaft rests;
3. Ensurance of the required clearance;
4. Alignment of oil holes of the bearing with the oil channels of the housing;
5. Absence of possible creep of the bearing in its seat.

As a rule, these bearings are placed in the housing seat by means of a press fit which creates the necessary tightness of union between the seat and the bearing.

During press fit setting of the bearing it is necessary to watch for proper alignment of oil holes of the bearing with the oil holes cSTAThe housing. Alignment of the oil holes of the bearing with the oil channel which provides lubricant from the housing, is checked with a cylindrical probe, the diameter of which is 0.05-0.1 mm smaller than the diameter of oil hole of the bearing. For that reason the flange of the bearing and the seat are drilled together and threaded for a stopper. Then the stopper is screwed in and its protruding part is cut off.

After the stoppers are installed, the bearings after press fitting are unscrewed simultaneously to obtain cooxiality and to restore the dimensions of the inner diameter. When especially clean surface of the outer side of the shoulder is required, the shoulder is faced.

Assembly of Gears

In aircraft jet engines gear assemblies with spur and bevel gears are used.

Assembly of gears requires the adherance to the following: a specified clearance between the teeth of the gears on the pitch circle; proper fit between the teeth of the gears at the moment of meshing, smooth rolling fit of the gears, and proper mutual arrangement of their shafts.

The size of the clearance between the teeth for each pair of gears is set by the designer in accordance with work conditions and the dimensions of the wheels. Increased backlash above that specified leads to increased impact load per tooth; decreased clearance leads to increased wearing away of the teeth, and in the case of a very small clearance results in jamming of the gears.

Proper fit of the teeth of the gears while meshing ensures an even load distribution along the width of the tooth and uniform wearing out of the tooth.

Smooth rolling fit of the gears serves as an indicator of the correct geometrical design of the tooth.

Incorrect arrangement of the gear shafts in respect to each other, which is seen in the gear shafts being out of line or in increased or decreased distances between them, worsens meshing conditions of the gears and affects the size of backlash.

Assembly of Gear Transmission with Spur Gears. Clearance between the teeth of the gears - backlash - e (Fig. 69) is checked with a feeler after their installation. For that purpose one of the gears is forced out in the direction of its rotation while the second in the opposite direction, and into the clearance thus formed between the engaged teeth a feeler is inserted. The feeler which corresponds exactly to the size of the backlash, must be able to enter the clearance tightly without jamming. The clearance, as a rule, is measured in three or four points, and the mean size of the clearance obtained during two or three turns of the gears is noted.

When it is impossible to measure the size of the clearance between the teeth of the gears with a feeler, a holding device and and indicat STAT are used. The holding device is installed on the shafts of one of the two meshing gears. A measuring spindle of the indicator is brought to the lever of the device. Having stopped one of the gears and turning the second to the right and to the left to the limit, the size of the clearance is calculated in each case according to the difference shown by the indicator. To avoid needless recalculations, the distance from the lever from the plane of contact of the lever with the measuring spindle to the shaft is taken as being equal to the radius of the pitch circle of the gear. Should it be necessary to increase or decrease the backlash, the gears are selected according to the thickness of the tooth.

Smoothness of meshing and turning of the gears is tested by feel while revolving one of the gears. In smooth operation the gears must roll without seizing or jerking, approximately with a constant torque, and must run silently.

Paint is used to check proper meshing of gear teeth and true mutual arrangement of the shafts on pitch circle. For that purpose teeth of one of the gears (driving) are coated with a thin layer of paint (Prussian blue), the gear is installed and turned in the working direction. The second gear (driven) is braked slightly, to create, during turning of the gears, a slight pressure on the teeth for a clearer imprint. After the gears have made a complete revolution the gear with unpainted teeth is taken off and the outline and the size of the obtained imprint made on it by the painted tooth of the first gear is checked on its teeth. In case of a good meshing of teeth, the imprint on the tooth of the driven gear will be found over the line of action (see Fig. 69) and its length should be 60-70% of the length of the tooth. When the distance between the shafts of the gears A is greater than allowable, the imprint will move itself toward the head of the tooth. When the distance between the shafts of the gears is smaller than allowable the imprint will move to the root of the tooth.

One sided imprint along the length of the tooth will mean that the gear shafts are out of line.

Assembly of Gear Transmissions with Bevel Gears. Clearance between the teeth of bevel gears is measured with an indicator in the same way as in the case of spur gears; the shoulder of the lever on which the contact of the measuring spindle of the indicator with the lever takes place, is taken equal to the radius of the pitch circle of the large gear. When there is a free access to the teeth of the gears, the measuring spindle is directly attached to the tooth of the gear along the pitch circle of the large gear.

When the clearance between the teeth of bevel gears is not of the proper size, it is brought to the needed dimensions either by bringing the gears together, moving them along their shafts (decreasing the clearance), moving them apart, or conversely, (increasing the clearance). It is possible to change the clearance between the teeth of the bevel gears during the process of assembly of gear transmission or, as it is usually called, regulate the clearance, by several methods. The easiest method of adjusting clearance between the teeth of bevel gears is that of selection of spacer rings with the help of which it is possible either to draw the gears closer to each other or to force them apart.

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[redacted]

For a more rapid selection of calibrated rings the following short calculation may be used. The size of the clearance between the teeth of the bevel gears and the distance by which none of the gears must be moved along its shaft, to make the clearance equal to zero (0), are linked by correlation

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$$e = B^2 \sin \alpha \sin \delta$$

where e - clearance between the teeth of bevel gears;

B - value of the distance by which one of the gears must be moved, to make clearance e equal to zero;

α - meshing angle;

δ - angle of pitch cone.

It is possible with the use of this ratio to calculate value B corresponding to the specified clearance e. After the bevel gears are installed one of the rings is moved along its shaft to the limit and value B is measured with a feeler (Fig. 70). If value B does not correspond to the rated one, the thickness of the calibrated ring is increased or decreased by the difference between the measured value B and the rated value B.

After the proper between the teeth of bevel gears has been established, paint is used to check abutting of the side surfaces of the teeth in the same way as in the case of spur gears. Following this the gears are taken out and the quality of their meshing is judged by the form, dimensions and location of the imprint.

The latest research establishes that the best conditions for the operation of the teeth of the bevel gears exist when the imprint of the idling gears is of the type shown on Fig. 71, a. This is explained by the fact that while in operation under load, the thinner part of the tooth will yield to a greater extent than the thicker part, and the contact along the tooth will be complete. Value A of the imprint for a good rating of tooth engagement must be equal to 0.5 to 0.75 of the tooth length.

The imprint may have a break (Fig. 71, b) or may recede somewhat from the edge (Fig. 71, c).

Permissible limit of the break in the paint imprint (see Fig. 71, b) is

$\Gamma_1 \leqslant \frac{A}{5}$, under this condition its length is not considered and the

entire A is taken as the imprint length. Deflection of the imprint from the narrow end of tooth Γ_2 (see Fig. 71, c) to 0.25 of A, and the length of the imprint in this case is considered to be value A.

Imprint on the side of the wide end of the tooth (Fig. 71, d) testifies to an abnormal meshing and overloading of one part of the tooth. As a rule, bevel gears with such an imprint are rejected and exception is

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made only in the case if the length of the imprint is not less than 3/4 of the entire length of the tooth.

If the paint imprint on the teeth is nearer to the root of the tooth (Fig. 71, e), it is possible to relocate the imprint toward the head of the tooth (dotted line on Fig. 71, d) by moving the driven gear along its shaft toward the point of intersection of gear cones which will result in diminished clearance, or by moving driving gear along its shaft away from the point of intersection of cones leading to an increased clearance. If the imprint on the head has no break (see Fig. 71, f) then, depending upon the length of the imprint and size of the clearance it is necessary either to move this gear along its shaft from the point of intersection of the gear cones, which will result in the appearance of a break and increase of the clearance, or to bring the assembled gear closer, which will result in a break in the imprint, decrease in clearance of the gear teeth.

In case of a satisfactory imprint changing of the clearance between the teeth of bevel gears should be done by means of an uniform bringing together or moving apart of both gears. No manual finishing of the tooth profiles to improve meshing of teeth is permitted.

CHAPTER II

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ASSEMBLY OF ENGINE COMPONENTS

1. Structural Designs of Engines Which Determine Technical Aspects of Assembly

Gas-turbine jet engines may be divided into two major groups according to their structural design: engines with centrifugal compressors (Fig. 72) and engines with axial flow compressors (Fig. 73).

Gas-turbine engines with centrifugal compressors may be broken down further into a number of assemblies according to their structural and assembly characteristics.

Compressor 1 together with inlet units, engine support trusses 3 and 5, and outlet air adapters 15, represents the major load carrying assembly. Two lugs are clamped to the body of the compressor with the help of which the engine is attached in the aircraft.

The housing of the center bearing 6, the housing of the rear bearing 12, and nozzle inlet ducts with a nozzle diaphragm 13 are attached in successive order to the backside of the compressor.

Combustion chambers 14 are located between nozzle ducts and air adapters. The gas turbine shroud 17 is connected to the nozzle diaphragm; the turbine rotor 16 is housed in the gas turbine shroud. To the body of the turbine are successively attached: exhaust cone outer shell 19 and outer exhaust hood 20. At the front side of the compressor, accessories case 10 is attached to the engine support truss, and oil pump case 11 is attached to the lower part of the support truss. Within the accessories case are located the drive gears to the accessories of the engine, while they themselves are mounted outside, on the drive gear accessories case. Rotation is transmitted to the gears from the front shaft of the compressor by means of a coupling shaft.

The engine has three main bearings of which the front, ball bearing, is located in the front support truss 3, while the other two - center ball bearing and rear roller bearing - are located in special housings. Cooling of the components of the hot part of the engine is done by air which is delivered by a cooling impeller 8. To safeguard turbine disc from being heated by exhaust gas and to diminish the losses at the turbine inlet a stationary exhaust cone 21 is installed inside of the exhaust cone shell.

The design of an engine with axial flow compressor (Fig. 73) is considerably different from the one examined above. Here, the main load carrying part of the engine is the support which, with the help of three lugs, is attached to the aircraft and carries the remaining units of the engine. Combustion chambers 12 are placed on the outside of the support, and are combined in a block with the help of common turbine inlet ducts, to which they are attached. Combustion chambers are covered by the support housing 11. Nozzle 14 and the rotor of gas turbine 13 are located within the inlet ducts housing. To the back side of STAT support housing is connected an outer exhaust cone 17, inside of which is located a variable cone with its servo-mechanism.

Axial flow compressor composed of housing or stator with guide vanes 2 and multiple-stage rotor 3 is attached to the front side of the support. Accessory drive power take-off housing 5 is attached to the compressor, inside of this housing are located accessory gears and couplings to accessories drive case 8, placed at the top of accessory drive power take-off housing, and main oil pump placed at the bottom of this housing.

Starter motor 9 and air inlet assembly 10 are attached to the front side of the accessories drive power take-off housing.

Some of the auxiliary assemblies are located on top of the accessories drive gear housing while others on top of accessories drive power take-off housing or in the compressor case.

The engine has four main bearings, two of which (front 4 is a three-row ball bearing and rear 6 is a roller bearing) support the rotor of the compressor while the remaining two (ball bearing in front and roller bearing in rear) support the rotor of the gas turbine.

Elements of the hot part of the engine are air cooled with air withdrawn from the compressor after the fourth stage.

Comparing both structural designs it may be said that each engine can be divided into a number of components, assembly of which may be done independently.

At the same time, structural differences of engine parts which possess same nomenclature create differences in the technical process of their assembly.

The compressor in the case of both engines may be assembled only during the process of general assembly, inasmuch as, in the case of the first design, the rear bearing of the compressor rotor, and in the case of the second design both bearings of the compressor rotor, are located outside of the compressor body.

Accessories drive case of the first design may be assembled completely with its auxiliary subassemblies, and in its completed state may be installed in the engine at any stage of the assembly operation. In the case of the second design the power take-off housing is assembled during the process of general assembly and may be installed only at a certain moment of the assembly (before the installation of the inlet assembly), while the accessories are placed on top of the accessories drive case during the general assembly of the engine.

2. Washing of Parts and Engine Assemblies

Cleanliness is of utmost importance in achieving high-quality engine assembly.

Even the slightest speck of dirt or sand, or a shaving may lead to most unfortunate results in the operation of the engine. Thus, for instance, dirt in the fuel plug may bring about an inaccurate flame jet which in turn will cause warping of the fire tube, and even its possible burning out, and overheating of gases, which may cause disintegration of turbine blades, i.e. complete breakdown of the engine. Penetration of dirt into oil may cause breakdown of bearings.

In ensuring necessary cleanliness of the parts and assemblies being fitted together a very important role in the technical process of assembly is played by washing, which is carried out:

a) Previous to initial assembly of engines, which are then conveyed to testing stations for final tests before delivery;

b) During the immediate assembly (if necessary);

c) After disassembly of engines which passed the final tests;

d) Before assembly of engines for control tests;

e) For the purpose of unpacking of parts and assemblies.

Washing agents are: gasoline, kerosine, white spirit[1], aqueous solutions, etc.

In the production of aviation engines most often gasoline and aqueous solutions are used for washing.

Parts and assemblies of complex contours, which may retain moisture or fine dust, anodized parts, bearings, as well as parts of oil and fuel systems, are washed in gasoline.

Aqueous solutions are used to wash parts which have simple contours, made of any metal except magnesium.

Washing of parts and assemblies is conducted in rooms specially equipped for that purpose. General equipment of washing department consists of open type vats for washing of parts in gasoline, closed vats designated mainly for washing fuel manifolds and other important parts, and washing machines where the parts are washed in aqueous solutions.

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[1] White spirit is a light petroleum fraction which is used in washing of parts since it constitutes a good oil solvent.

Wash rooms are equipped with exhaust and intake ventilation, hoists, transportation facilities, air delivery conduits wh STAT supply cold or hot (to 40-50°C.) air for blowing and drying the parts after washing, gasoline pipe line which feeds gasoline from tanks located outside of the wash room (in case of centralized delivery) and finally, blastproof electric motors and pumps, filters and small tanks for gasoline (for each vat), if there is no centralized feed of gasoline.

At serial production plants both feed and run-off of the used gasoline are usually centralized.

Gasoline, for washing parts in the wash rooms of the assembly shop, is delivered under pressure from the storage tank reservoirs through pipes. From this main gasoline trunk line, additional branches take gasoline to each wash vat, which in turn is equipped with pipes for used gasoline run-off through which gasoline flows by gravity into the reservoir. Delivery of gasoline into the shop from the storage tank is done by pumping inert gas into the tank under 1-2 atm pressure.

For proper and efficient operation of the gasoline storage tank it is necessary to provide three gasoline reservoirs placed below the floor level of the wash room of assembly shop to ensure a free run-off of the used gasoline.

One of the gasoline reservoirs must be under working pressure of the inert gas and its gasoline is fed to the shop.

The second reservoir is connected to the run-off system and used gasoline is drained into it.

The third gasoline reservoir must be filled with used gasoline where it remains in quiescent state to settle the dirt and shavings which were not trapped by the filters with which each tank is provided.

During the work process the designation of each reservoir continues to change. When the first reservoir is emptied it is switched to receive run-off gasoline while the settling reservoir is now used for delivery of gasoline to the shop, etc.

Fig. 74 shows an open-type vat which is not equipped for centralized delivery of gasoline. At a certain height above the bottom of the vat there is a screen (aluminum perforated sheet), on which the part being washed is placed.

After washing, the used gasoline passes through the screen to the bottom of the vat from which it is pumped into a tank adjacent to the vat. To prevent gasoline vapors the vat has side channels through which a fan drives the vapor to the outside.

Gasoline for washing of the parts is conveyed through a flexible hose which is provided with a special nozzle (Fig. 75). The nozzle consists of case 1, push button 2, release spring 6, pusher 3 and shut-off valve 4. When finger pushed the button 2, the taper of its shaft presses out the pusher to the right, thus causing its end to thrust against valve 4 and to shift it from its seat. At this moment gasoline in the hose over the lengthwise channels of the valve 4 penetrates into the side channels (not shown in the drawing) of the case 1, and through nozzle tip 5 is directed to the part being washed under pressure of approximately 1.5 - 2.0 kg/cm^2.

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Outer and inner surfaces of the parts and oil and air channels are washed in the vat. Jet washing, in case of considerable accumulation of dirt, is sometimes accompanied by scrubbing with brushes, wire brushes, rags, etc. After washing, the parts are dried with compressed air or are wiped with clean lintless cloth.

Fig. 76 shows a closed type vat. Such vats are used for jet washing of parts with gasoline under pressure of 1.5 - 2.0 kg/cm^2. The vat has a gasoline tank 1 and such auxiliary equipment as: blast-proof electric motor 2 which is coupled to a pump 3 for delivery and pumping out of gasoline, filter 4 for purification of gasoline, screen 5 for draining of gasoline to the bottom of the vat, a valve 6 to empty the vat in emergency, cover 7 of the vat with a plexiglass window to observe the parts being washed, manometer 8 to maintain control over gasoline pressure during washing. To wash the part it is placed on the screen of the vat; gasoline is delivered over the pipeline 9 to the nozzles 10, through which it is directed as a jet at the part. After washing, the parts are dried with an air jet.

In a number of cases pulverized spray washing is used in the assembly shops which ensures good quality washing. Pulverized spray washing is done in closed compartments with top and side air exhausts. The part is placed on a pivot disc of the compartment and is washed with a strong jet of pulverized gasoline under pressure of 2-3 kg/cm^2. Gasoline is pulverized with the help of a pulverizing gun activated by compressed air from the shop's system. Pulverized spray washing, as well as jet washing, is extremely convenient for washing parts with sharp edges (blades, etc.) since they eliminate the necessity of toughing sharp edges by hand. A shortcoming of pulverized washing lies in the fact that much gasoline is needed, since in washing gasoline atomizes, evaporates and is carried into the air. Besides, such vats must be provided with high-capacity exhaust system which would guarantee non-penetration of gasoline vapors into the wash room.

Parts with simple outlines (without depressions, pockets, etc.), with the exception of parts made of magnesium alloys, are washed in aqueous solutions in special washing machines. Washing in such machines is more convenient from the point of view of fire prevention and is more economical than washing with gasoline. Mechanical washing machines which are in widespread use at serial production plants may be of varied construction: single chambered, two chambered and three chambered. The parts are washed in them in aqueous solutions.

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In single-chamber machine, (Fig. 77) parts and assemblies, after washing, are dried with hot compressed air. The machine represents a cabinet with receiving and discharge compartments for the parts being washed. The parts are placed on a belt which moves through the inner recess of the machine and then, after washing, are automatically passed to the adjacent table.

Inside of the washing machine is a tank (at the bottom), out of which atomized solution heated to 70-80° C. is conveyed by a pump through special sprayers to the part being washed. The solution is heated by steam, which passes through a coil located in the vat. To have a simultaneous washing of the parts from all sides the sprayers are placed in the chamber at the top and sides. Solution used is drained through a screen and then through a filter, with the help of a pump, is again directed over pipes and through a sprayer at the part being washed. The speed of the conveyor of the washing machine is selected to ensure thorough washing of the part which lies on the conveyor belt.

Fig. 78 represents a two-chamber washing machine. In one chamber the parts are washed in aqueous solution while in the other in hot water. Two-chamber machine, like the single-chamber one, has coils for heating of aqueous solution and water, as well as a water pipe system with sprayers through which the liquid for washing of parts is directed. A general view of a two-chamber washing machine is shown on Fig. 79. When the parts and assemblies leave the chamber they are dried on the conveyor with hot air.

A three-chambered machine represented on Fig. 80, washes, rinses in hot water, and dries the parts. The parts are moved on a continuously moving conveyor. Aqueous solution and water are admitted from tanks through boilers in which they are heated to 80-90° C. After washing in water the parts are blown in the drying chamber with air heated to 80-90° C., under 2-3 atm pressure. The air is heated by steam. The speed of washing in this machine may be varied from 2 to 4 m/min.

Besides washing machines in which aqueous solution is used, there are special vats filled with solution, as for instance for removing carbon deposits from the parts. Such vat is filled with solution which is steam heated to 80-90° C, the steam passing through a coil in the vat. The parts are immersed into the vat for a specified time, after which they are scrubbed with brushes, washed in hot running water and then dried with compressed air.

All washing machines and special vats are provided with exhaust fans. The equipment of a washroom division must be provided strictly in accordance with fire prevention requirements. Thus, for instance, electric motors must be blast proof, the vats must be made of non-ferrous metals (usually aluminum sheeting). The wheels of transporting carts (if the floor is of concrete) are of rubber or non-ferrous metal, the surface of the cart on which parts are loaded are covered with wooden boards (made of hard wood) or aluminum sheet, etc.

From the point of view of sanitation and safety of workers the equipment of the room must also meet the established requirements. These requirements specify sufficient exhaust of gasoline vapors which generate as a result of evaporation and atomization of gasoline, and the vat of a design which would permit the worker to operate outside of the fume zone during washing.

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Aqueous solutions which are used in the washing machines have the following components: 0.2 soda, 0.1 - 0.2% potassium bichromate, while the remainder, up to 100%, - water. Soda or bichromate is sometimes substituted with liquid glass. To prepare the solution the vat of the washing machine chamber is filled with water heated to 70-80° C. by steam passing through a coil. Simultaneously, the required composition of soda and bichromate is dissolved in a pail of hot water after which this solution is poured into the vat of the washing machine; to stir the solution the pump of the machine is switched on. After stirring, the solution is analyzed for overall alkalinity and for corrosive ability. For that purpose a drop of the solution is placed on the surface of a dressed and gasoline degreased plate of perlite iron; after drying the drop should not leave a spot. In case of unsatisfactory results of the analysis, lacking components are added to the solution.

Solution for removal of carbon deposits off fire tubes of combustion chambers is composed of 20% caustic soda and 80% water. To prepare this solution, the necessary amount of water is poured into the vat which is then heated to 70-80° C. with steam which passes through a coil in the vat; this is followed by an addition of caustic soda. After stirring, the solution is tested in the chemical laboratory.

The parts should be washed in washing machines and vats only after the tests of the solution were adjudged satisfactory.

Depending upon on their outlines, designation, construction, material, etc., the parts are subjected to various types of washing.

Such parts as power take-off housings, drive gear cases, support boxes, etc., of rather complex shapes of their inner recesses and which have oil and air channels, are washed not only with a jet of gasoline, but are also cleaned at the same time with plain and wire brushes, rags, etc., and then are blown with compressed air.

Inner recesses of oil lines, filters, plugs, ball and roller bearings, are washed in gasoline with special care; after washing, ball bearings are places in a vat filled with solution of 6% MK oil or MC oil dissolved in gasoline or are oiled and packed in special chlorvinyl sheaths to protect them from dust.

Parts made of rubberized material (for instance, oil seals), are not washed in gasoline to prevent their corrosion or swelling, but are wiped with rags lightly moistened with gasoline and then wiped dry.

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Parts pertaining to electrical equipment also are not washed in gasoline to avoid damage to individual parts which are covered with varnish, for instance, or made of materials which may be harmed by gasoline. Thus, for example, inner part of tachometer generator are rubbed with a brush slightly moistened in gasoline. The outer part of this component is cleaned with the shaft pointing to "up". To avoid damage to electrodes the flanges of igniter and fuel plugs are rubbed with rags lightly moistened in gasoline. Generators and similar parts are cleaned in the same way.

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Fuel manifold is subjected to an especially careful washing followed by flushing. The semicircular rings of the manifold are first washed in an open vat, and then the assembled manifold is flushed with gasoline in a closed vat (Fig. 81). Manifold of an engine with centrifugal compressor is fastened to a special device and placed in a closed vat, where the idling tubing is flushed for 3 minutes under pressure of 1.5 - 2.0 kg/cm^2, followed by flushing of the main gas line; in both cases flushing is done in two stages - preliminary and final.

Manifold hoses are also flushed with gasoline. As in the case of the manifolds preliminary and final flushings are done under gasoline pressure of 1.5 - 2.0 kg/cm^2, each flushing lasting 1-2 minutes. Other washing requirements are the same for hoses as in the case of the manifold.

Engine parts such as: body of the compressor truss, bearing housings, etc., are washed in washing machines. Before washing is started the machine is tested by idling. Large parts are arranged on supports (Fig. 82) before their placement on the conveyor belt of the machine, while small parts are placed in special containers, (Fig. 83), with perforated bottoms and sides, through the holes of which the solution is drained into a drip pan or into the tank of the washing vat.

Fire tubes of combustion chambers, after final testing of the engine, are cleaned off carbon deposits in a vat filled with alkaline solution. For that purpose the tube assembly is immersed into the vat with heated solution where it remains for about an hour. Following this the tubes are cleaned with a special brush to remove the scale which was loosened in the vat, then are washed with water and blown with compressed air.

One of the important requirements to be adhered to during washing with aqueous solutions is the maintenance of the proper concentration of the component parts of the solution. Quantitative deviation from the required concentration of the component parts results in the loss of washing and anticorrosion properties.

Washing for the purpose of de-preservation is done when the parts to be assembled are received from storage. This operation is done with gasoline, aqueous solutions and oil.

The process of washing with gasoline and aqueous solutions of the parts being removed from storage is similar to usual washing. Fuel manifolds, fuel hoses and fuel plugs are cleansed of lu- STAT bricants by flushing in gasoline under 1.5-2-0 kg/cm^2 pressure. The lubricant is removed in a vat filled with MK or MC oil which is heated to 60-70° C.; a brush is used to remove the lubricant. After the lubricant has been removed the parts are subjected to washing with a gasoline jet and blown with compressed air.

The quality of washing process of parts and assemblies is controlled visually.

Parts and assemblies are moved into and out of wash room in special containers (Fig. 84).

3. Marking of Parts

Engines produced by a plant, as a rule, are given their sequence numbers. The same number is marked on all major parts of the engine, including those which are subjected to individual matching. Besides, also marked are parts which require a strict fixation as to their mutual position in relation to each other in the assemblies of the engine.

Marking of the parts may be done mechanically, electrically or chemically.

Mechanical method is the simplest way of impact marking of parts (Fig. 85). However, this method has a considerable shortcoming which lies in the fact that strong hammer blows may result in deformation of thin-walled parts. This defect may be eliminated when special devices are used which permit marking with equal force (calibrated spring).

Electrical method of marking is quite widespread. For that purpose an electric etching apparatus - electrograph (Fig. 86) - is used. This device consists of a single-phase step-down transformer which is connected by means of a cord with a plug to the lighting network. One end of the secondary winding 2 of the transformer is connected to a copper plate 3, while the other end, through a brass handle 4, is connected to a tungsten tip 5.

In electrographic marking, the part is placed on a copper plate 3, thus including it in the circuit of the secondary winding; and the necessary mark is made with a tungsten tip (Fig. 87).

Electrograph may be used with primary voltage of 120, 220 and 380 v; this apparatus will consume no more than 0.5 kw. With the primary winding voltage of 120 v, the voltage of the secondary winding is 1.5 v with corresponding current capacities of 3.3 and 234 amp.

Chemical and acid marking is done on parts made of steel or copper alloys.

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Marking is done with stamps provided with rubber tips with thin lines, outlining letters or numerals. Felt pads placed in tightly closing containers (Fig. 88) are used for application of solution on the letters or numerals.

For marking steel parts (except high alloy) a liquid compound of the following composition is used:

copper sulfate	100 g
silver nitrate	10 g
oxalic acid	2 g
sulphuric acid of 1.84 specific gravity.	5 cm^3
water	1 liter

For the parts made of copper alloys:

copper sulfate	100 g
silver nitrate	10 g
nitric acid of 1.4 specific gravity.....	8 cm^3
acetone	50 cm^3
water	1 liter

For marking of parts made of tempered steel, a solution composed of 30% acetic acid, 10% nitric acid, 5% denatured alcohol and 55% water is used. A 5% solution of hydrochloric and nitric acids is used for marking bronze parts.

Places to be marked are cleaned with gasoline and lime to remove grease. After the mark is made acid is allowed to stand for 1-2 minutes until the marks appear, after which the remaining acid is removed from the surface with filter paper and the imprint is neutralized with a 10% solution of calcined soda. Besides, to prevent corrosion, the place where the mark was made is lubricated with alkaline compound, wiped dry and covered with a thin layer of industrial vaseline.

4. Assembly of Basic Units of Air Parts of the Engine

Assembly of Centrifugal Compressor Rotor

The rotor of a centrifugal compressor (Fig. 89) is assembled in two stages -- preliminary and final. During the preliminary stage of assembly the parts are matched, fitted together and marked, after which such parts as the impeller rotor of the compressor, rotating guide vanes and cooling impeller blades are sent to be anodized.

Final assembly of the compressor rotor is performed after the parts are anodized; at this time additional fitting operations are no longer permitted.

Preliminary Assembly of the Centrifugal Compressor Rotor

Due to the fact that the fit tolerance in assembly of the com- STAT pressor rotor is more rigid than the sum of tolerances of the mating parts, the assembly is done by the method of matching of the parts. For that purpose, the forward and the rear flanges of the shafts are measured for their thickness as are the seats for the inner race of the front ballbearing, cooling impeller, splined driven hub, inner race of the center ball bearing, rotating guide vanes and impeller; the corresponding seats of the above parts are measured in the same manner to ensure required fits and tightness (Fig. 90).

After matching of the parts the forward and rear shafts of the rotor compressor are assembled. Retaining ring is installed in the forward shaft (Fig. 90, a) which limits the axial shifting of the coupling shaft to the accessory power take-off housing after which the plug is pressed in. To press in the plug the shaft is heated to 70-80°C in an electric cabinet for 10-15 min.

After matching of the driven splined hub with the splines, a tie bolt and retaining ring are inserted into the rear shaft (Fig. 90, b). When the hub is installed, its inner diameter projections are matched with the grooves of the tie bolt. After its fastening to the shaft with a tie bolt the play of the hub (Fig. 91) in respect to the diameter of the journal of the shaft is checked, for the purpose of which the shaft is placed on prisms. Allowable play is up to 0.03 mm. Too great a play is eliminated by selection of a hub with lesser clearance at its setting shoulder to maintain the coaxiality of the bushing and spherical tip of the shaft of the turbine rotor during further assembly.

The basic operation, after the matching and assembly of the shafts, is their installation in respect to their relation to the compressor impeller in such a way as to place it strictly perpendicular to the seating surfaces, thus achieving the least play of all the parts of this assembly. For this purpose the surfaces of the shaft flanges are coated with a thin layer of paint, after which the fit of the flange surfaces with the corresponding surfaces of the compressor impeller and guide vanes is tested. The fit may be considered normal if the paint imprint is no less than 80%. If the fit is unsatisfactory the shafts are substituted (matched) or the surfaces of compressor impeller and guide vanes are slightly scraped.

Previous to testing play of the shafts of the compressor rotor together with the compressor impeller 16 block studs are installed for mounting of shafts and guide vanes. The operation of stud installation into the compressor impeller is an important one and requires great care. Threads of studs and holes must be absolutely clean. The necessary average diameter fit (in this case approximately 0.02 - 0.06 mm) is obtained by selecting studs which fit the holes.

Before inserting the stud its thread is greased. After insertion of the studs their perpendicularity to the surfaces of compressor impeller is tested.

After the accuracy of stud installation is tested the play of the shafts is tested simultaneously with the compressor impeller. For that purpose the shafts are placed on the compressor impelle STAT (dummy shims are inserted in place of guide vanes) and are tightened with nuts with application of 19 kgm torque. Compressor impeller thus assembled is installed on prisms using supports A and Б (Fig. 92). The play is tested at the points В, Г, Д, Е, Ж, З and И. Inadmissible play is eliminated by shifting the shafts along their axes with consideration of the place where the greatest play occurs.

The assembly of the compressor impeller with its guide vanes is done by matching.

Matching of guide vanes to impeller blades consists in elimination of the so called overhanging (Fig. 93), i.e. failure on the part of the end planes to coincide. In this case overhanging is permitted to 0.15 mm on the working side of the blade and to 0.5 mm (approximately) on the reverse side. The same fit is achieved on the outer contour of the hubs of guide vanes and of the impeller at the place of their division, also with a specified tolerance. In matching of blades, to achieve proper mating of their ends in the final joining, the guide vane, at the expense of a certain clearance in the studs, is moved toward the back of the blades (front shaft of the impeller) and toward the trough of the blades (rear shaft). This is done with consideration of the fact that in the final fastening of the guide vanes to the impeller they may shift in the direction of tightening of the nuts.

To lessen the unbalance of the assembly of the compressor rotor, which is later subjected to dynamic balancing, the guide vanes, the compressor impeller and the cooling impeller are balanced statically on prisms.

These parts are anodized after static balancing. After anodization all flaws in the metal such as cracks, porosity, and hair cracks, and which were not aparent before are sharply revealed. Consequently, after anodization, the parts are subjected to a careful visual examination to reveal possible defects.

Final assembly of the compressor rotor. The final fitting of rotor compressor assembly consists of the following. In fitting of the shafts with rotating guide vanes to the impeller, the vanes are shifted in the necessary direction before they are tightened. Preliminary tightening (setting) of the vanes is done with the help of a calibrated wrench (Fig. 94) using 17 kgm torque, followed by final tightening with the same wrench using 19 kgm torque. The degree of nut tightness may be also determined according to stud extraction. For that purpose the vane holding nuts are screwed in until they tough the surfaces of the washers; an indicator which is used to affix the initial position of the stud (for instance, 0) is placed (in sequence) on the end of the stud. Thus, the extraction of studs is tested at the moment of tightening of the nuts according to the reading of the indicator hand; it may be equal to 0.15 - 0.16 mm. In case of unconformity of the nut slits with the stud openings, for the cotter pins the washers are selected according to their thickness.

The fit of the matched vanes to the impeller in the final tightening of the nuts must ensure the required clearance and tightness (Fig. 95) at the face surfaces of the vanes and impeller blades, as well as at their hubs.

After the inspection of the relative spacing of the blades, cooler impeller, ball bearing and driven splined coupling are installed on the rear shaft. The inner ring of the roller bearing is installed on the front shaft. The compressor rotor thus assembled (Fig. 96) is again tested for the play of the compressor at its diameter, play of its blades, play of the cooler impeller and of the sphere of the driven splined coupling. The end play of the cooler impeller is eliminated, when necessary, by selection of adjusting rings 1 which have a lesser degree of wall thickness difference. This is followed by cotter-pinning of the vane mounting nuts to the impeller.

With this ends the assembly of the compressor rotor, which is further subjected to dynamic balancing previous to the general assembly of the engine.

Assembly of the Rotor of the Axial-Flow Compressor

Assembly of the rotor (Fig. 97) consists of the preliminary and final assembly. It includes the following basic operations:

- assembly of rotor discs with selection and matching of the blades;
- joining of the first stage disc with the front shaft;
- joining of the disc of the 8th stage with the rear shaft;
- final assembly of the compressor rotor.

Assembly of discs includes selection and fitting of blades 1 into special slots in the discs 2, which have dovetail form (Fig. 98). Previous to installation of the blades, the quality of the slots is checked with a go gage (Fig. 99), after which the blades are matched to fit these slots and matched according to their weight to achieve a decrease of the disbalance of the discs. In the entire assembly the allowable difference in weight of the blades is up to 5 g, while 0.5 g weight difference of two blades installed in diametrically opposite direction is permitted.

Blades thus matched are installed into the slots of the discs with light blows of a rubber hammer. In order to determine the accuracy of installation of the blades in their slots, an indicator equipped fixture (Fig. 100) is used to test the lateral play of the blades, for the purpose of which a mandrel is inserted into the opening of each disc being tested. In case of inadmissible play the blades are substituted by means of matching. After testing of the blade play the disc is machined, i.e. the protruding shanks of the blades are ground flush with the face of the disc and the face of the blade to the necessary diameter of the disc. To prevent lengthwise shifting of the blades, holes are drilled and threaded for stops (Fig. 101 STAT d the stops, after their insertion in place, are safetied by pressing in the thread of the hole.

Each disc is subjected to static balancing after it has been assembled.

The assembly of the disc of the first stage (Fig. 102) consists of the disc itself 6, cone ring 10, and front shaft 1, which is press fitted into the disc and is attached to it with a nut 3 through a steel splined sleeve 4. The latter also serves to transmit the torque from the front disc to the front shaft of the rotor. Assembly of this component is done with the help of a device (Fig. 103) which represents a hollow cast housing 1, provided with a steel hub 2 with inner splines, designated for centering of the front shaft during the assembly and to keep the shaft from turning during the assembly. Stop bolt 3 of the hub ensures support for the flange of the forward shaft and its end plane.

For the assembly of the component, the front shaft is placed in the device in such a way as to have the splines of the shaft engage the splines of the steel hub 2, and the flange and the end surface of the shaft contact the stop bolt 3. Then cone ring 10 (see Fig. 102) is placed on the cone surface of the disc to safeguard the shaft against getting out of alignment with the disc and to ensure a complete contact of the circumference of the flange with the butt of the disc. After the ring is installed, the shaft is pressed into the disc and then a steel splined hub is placed over its splines; the hub is simultaneously pressed onto the protruding, precisely machined, key of the disc. Pins 5 are pressed into the holes drilled in the hub and the disc. The shaft is pulled tight to the disc by nut 3 with a special wrench with approximately 45 - 50 kgm torque.

The assembly of the disc of the eighth stage (Fig. 104) consists of a disc, shaft with a flange, with slots which fit the boss 9 on the disc. In this way the transmission of the torque from the rear shaft to the disc is realized through these bosses. From the disc of the eighth stage to the disc of the first stage the torque is transmitted by the bolts of the disc centering slots 2 of the discs of the intermediate stages.

The quality of the fit of the surfaces of the bosses of the discs to the slots in the shaft is checked by two gages (Fig. 105). The gage for testing the disc bosses consists of body 1, which has six tangentially placed lugs with precision machined and ground surfaces A. To test the quality of contact, surface A is thinly coated with paint (Prussian Blue), following this the gage, which is provided with a centering tooth, is inserted into the opening of the disc. Handle 2 turns the gage to the point of contact of the surfaces A with the teeth of the disc.

The gage used to test the paint adherence to the surfaces of the slots of the shaft flange represents a conic disc with six radially placed teeth, the lateral surfaces of which are precision machined. The disc of the gage has an aperture through which the gage is placed on the journal of the shaft. Surface A is covered with a light coat of paint after which the gage is placed on the journal ofthe shaft in such a way as to have the teeth enter the slots. Adherence of the surface is tested by turning the gage until surfaces A tough the surfaces of the slots. If the gage turns with difficulty, a wedge is driven into the space between the nonworking surfaces of the teeth of the disc and the slots, (Fig. 106). The paint imprint, is not permitted to be less than 85% of the surface as it is tested by both gages. Clearance between the surfaces being tested and the gage should not be greater than 0.03 mm (this clearance is tested by a feeler gage).

For the assembly of the disc of the eighth stage it is possible to utilize the same device as in the case of the assembly of the disc of the first stage. Conic ring 3, is placed over the conic surface of the disc (see Fig. 104) after which the shaft is pressed into the disc. After the installation of the steel spherical bearing 4, the lock nut 5 which fastens the shaft to the disc is tightened with application of approximately 45-50 kgm torque. The seal housing of the rear roller bearing rotor of the compressor 6 and the inner ring of the roller bearing 7, selected for the shaft according to the proper fit, are pressed onto the shaft. Nut 8 is placed on the thread of the shaft and the lock of the nut is installed.

The final assembly of the compressor rotor unit takes place after the assembly of the first and the eighth stages. The tie rod (see Fig. 102) of the rotor is fitted with snap rings 7, retaining ring 8 and seal rings 9, followed by installation of the disc of the first stage. Then the second, third and the remaining discs are placed on the positioning collar of the first. After the installation of the eighth disc the following are placed on the rod (Fig. 107): a rubber seal ring 2, retaining ring 3, snap ring 4, and the second retaining ring 5; while a nut 6 is screwed onto the thread of the rod. The rod which runs through the central holes of the discs and shafts, tightens them.

Before the nut is tightened finally, the rotor is placed on the device, and the nut 6 is tightened to the contact of its surface with the surface of the retaining ring. Following this, a device (Fig. 108) for measuring the elongation of the rod is placed on the rotor. This device consists of a clamp 1 made of steel tubing, to the front end of which are welded: a prism 2, and a strip 4 with a stop 5, while to the rear end are welded: a prism 3, and a retainer 6 with a screw 7. To measure the elongation ofthe rotor tie rod previous to tightening of the nut of the rod, the device is installed on the journal of the rotor shafts in such a way as to have the stop 5 of the strip 4 contact the end of the front shaft, and to have the clamp in a vertical position. Into the opening in the retainer 6 is inserted an indicator to the contact (with the initial tightness of 0.5 mm) of its leg with the hexagonal end of the tie rod of the compressor rotor, and then is tightened in the retainer with a STAT screw 7. The indicator's hand is set in the zero position after which the device is removed from the rotor.

After setting of the device, the tie rod of the rotor is tightened with a nut while at the same time, the elongation of the rod is periodically tested. The elongation is brought to the final figure of 1.6-1.8 mm (approximately) which corresponds to the tensile stress of the rod of about 2,000 kg.

Tightening of the rod assures rigidity of the entire construction and the possibility of torque transmission from disc to disc as a result of friction force in the retaining bosses of the positioning collars of the discs. The set of snap rings is installed to avoid overloading of the rod. The rings deform under the effect on the rod of considerable force as a result of thermal expansion of the rotor and stabilize the stress in the tie-rod.

The play of the faces H, surfaces M and K of the disc, as well as, the play of the front and rear shafts is tested after the nut has been tightened (Fig. 109). For that purpose the compressor rotor is placed on a device (Fig. 100). Diameters A and B serve as bases for testing. Inadmissible play of discs and shafts is eliminated by shifting them by a certain angle taking into account maximum play obtained in testing. Play at the sides H is not permitted to be greater than $\sim$ 0.12 mm, at the surface M - not greater than 0.1 mm, at the surface K - not greater than 0.1 mm, front shaft - not greater than 0.02 mm, and rear shaft - not more than 0.1 (approximately).

After satisfactory results as to the play of the rotor discs have been achieved, the relative position of the discs is fixed with the help of stop bolts (Fig. 110); for that purpose holes are drilled and threaded in the hubs of the discs using a device-a split ring with jig bushings which are placed over the hubs of the disc, this is followed by placement of lock washers, and tightening and safetying of the stop bolts. The rotor compressor thus assembled is dynamically balanced.

Assembly of Cases and Stators of Compressors and Mounting of Guide Vanes

Figure 111 represents case of a centrifugal compressor and stator δ of the engine of an axial-flow compressor.

The assembly of case 2 of centrifugal compressor includes the installation on it of trunnions 3, designed for attaching the entire engine to the airplane, case cover 4 and air adapters 1. Assembly of the case is done on a stand which serves also for the general assembly of the engine.

The stator of the axial-flow compressor consists of upper and lower halves (Fig. 111, b). The guide vanes are inserted into the seats located inside of the housing (Fig. 112).

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Stator assembly operation consists of installation of cone ring, guide vanes and other parts.

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The cone ring, prepared in half-finished state, is given its final shape in the housing, after which the cone halves are attached to it with the help of bolts with the observance of the required tolerances. Following this the assembly studs are inserted in place.

Previous to the installation of the guide vanes into the housing, adjusting washers, which ensure the required clearance between the surfaces of the lugs and the stator, housing, are selected, (Fig. 113); at the same time a test is conducted to ascertain that there is no contact between the curve of the lug and the flange of the housing. Following this the vane assembly is installed in its final stage and attached with nuts which are safetied with plate locks.

Assembly of Air Inlets

Air enters centrifugal compressor engine through screens 4, which are located on the front a and rear 5 truss assemblies (Fig. 114), and is directed into the guide vanes 2, which are composed of blades and two rings which form a cylindrical crown. Front inlet assembly is provided from the impeller side with a rear wall 1, which is connected with the front bearing housing. The rear inlet assembly has from the impeller side, a front wall 5 and a rear coverfaring 7. The trusses are connected with the compressor case by flanges. The rear truss 6, as well as the front frame 3, has a number of openings to direct the air toward the cooling impeller.

The assembly of the front inlet consists of the following. The housing of the front bearing (assembled earlier) is attached to the truss. During the joining operation of the casing it is necessary to take care that the air and oil pipes are properly placed. Then the guide vane assembly is installed in the truss in such a way as to have the position of the blades correspond to the airflow direction. This is followed by installation of the rear wall and protecting screen. Guide vane assembly is inserted into the framework of the rear inlet assembly, the front wall is attached to truss of the flange and to the rear coverfaring and the protecting screen is put in place.

The bolts which hold the screens are uniformly tightened in such a way as to have the distances between shoulders at the screens correspond to the required dimensions.

An air inlet assembly (Fig. 115) of an axial-flow compressor engine represents a combination of several sub-assemblies: diffuser 1, through which the air is directed to the compressor, annular oil 2 and gasoline 3, tanks, and a connecting flange 4.

Assembly of these sub-assemblies consists in welding together the housing walls; welding on and riveting of stiffening ribs, brackets and connecting pipes; installation of threaded slee STAT for the bolts and assembly of holes and covers for filling gasoline tanks. After the assembly of oil and gasoline tanks and pipes are tested hydraulically. Previous to the assembly of the inlet components the gasoline and oil tanks are washed carefully with gasoline.

The assembly of the inlet components starts with bolting the connecting wall to the front wall of the oil tank. Following this the gasoline tank is bolted to the connecting wall. After this the diffuser assembly is selected according to its mounting dimensions. If no suitable dimensions are found, the diffuser is fitted to the tank and bolted to the connecting flange.

Following their assembly, the fuel and oil systems of the inlet components are tested pneumatically under 0.15 kg/cm^2 pressure.

5. Assembly of the Main Components of the Engine Hot Parts

Assembly of Turbine Rotors

The assembly of turbine rotors consists of selection of blades and their installation in the disc slots; selection and matching of shafts to the discs and the final assembly of the rotor.

Fig. 116 represents a rotor of a centrifugal compressor engine. The blades of the rotor (Fig. 117) are selected according to their weight and the size of the clearance in the slots and must meet the following requirements: the difference in the weight of the blades (each pair), placed in the discs in diametrically opposite slots, is not permitted to exceed 0.2 g, while the weight difference of individual blades in the assembly should not exceed 10 g.

The blades selected according to their weight are placed in the disc slots after which tangential, radial and axial plays of the blades (Fig. 118) are tested by means of an indicator which is provided with an L-shaped tip. Tangential play A of the blades is tested in ББ direction at a distance of 5 mm from the end plane of the blades. Play A is permitted to be from 0.7 to 1.3 mm. Radial play Г is tested in BB direction and at the same time play Д between the shoulders of the blades is also tested. If this play is not great enough the shoulders are filed. Play Г is permitted to be 0.05 - 0.00 mm. Axial play E is tested in ЖЖ direction and is permitted to be 0.1 - 0.2 mm. Fig. 119 demonstrates the method of testing tangential and axial play.

In case of inadmissably great play of blades and clearances between the shoulders, other blades of the same weight are selected.

After the blades have been selected according to their weight and grooves they are marked in sequence with numbers corresponding to those marked earlier opposite each groove of the rotor disc.

Further operations with the blades are performed after the installation of the shaft on the rotor disc.

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Fig. 120 represents the shaft of a rotor of an axial-flow compressor engine. The seats in the grooves of the rotor disc (Fig. 121) are checked. Base surface A is tested first with paint imprints; impression thus obtained is not permitted to be less than 80%. In respect to this base surface, the parallelism of end planes Б and play of outside end planes of the disc B are tested with an outside measuring indicator.

The blades are selected according to their weight. Weight difference of the blades in the assembly must not exceed 1 g. With this difference in weight the blades may be placed in the disc in succession. If the difference in weight exceeds 1 g it is possible to utilize diametrical installation of blades of the same weight.

The blades selected according to their weight are inserted in place and the clearence Б between the end surfaces of the roots of two adjacent blades (Fig. 122) is tested; the contact of the blade root with the outer surface of the disc at A and B is also tested. At side A contact of the entire surface with no clearance is permitted, while on the other side a slight clearance is allowed. Inaccuracy in pitch, checked by a device (Fig. 123), should not exceed $\pm$ 1 mm of the nominal pitch.

The device consists of support 1, to which a scale 2 with three lines is attached. On the axle 3, between the support and cover 4 is indicator point 5, the initial position of which is affixed by means of a spring, placed in the seat of the support under the cover. This device is placed on the end planes of two adjacent blades until it is in contact with the cover of the device. When the pitch between the two blades is within the permitted limits the indicator point is located between two extreme lines of the scale. Besides, testing is also conducted of thepplay of the blades along plane Г (see Fig. 122) in relation to A and end play of Д plane in respect to plane E. If the root of the blade is too wide and does not fit the groove in the disc, the blade may replaced by another or else the width of several last blades may be reduced by grinding the root surfaces.

After all the blades have been inserted into the disc, holes are drilled in the disc for the joint pins which will reinforce the blades. These holes are drilled with the help of a jig bushing (Fig. 124) — a round steel plate (casing) 1 — with holes equal in number to the number of joint pin holes. The plate is centered as to the turbine shaft bore. As the holes are drilled, the disc blades of the rotor are pressed in their grooves with the help of strips. After drilling, the holes are reamed and broached to the required dimensions, then the joint pins are pressed into them and the pin ends are flattened on both sides.

Further operations with the blades are conducted after the shaft is connected to the disc.

Selection and matching of the shaft to the disc of the turbine rotor of the centrifugal compressor engine and the final aSTAT-bly (Fig. 125) consists of the following. The shaft is selected according to diameter A, so calculated as to ensure a fit of 0.01-0.04 mm. Then the shaft, previous to joining it with the disc, is heated in a thermostat to 110-120° for 15 minutes. In direct joining, the shaft is centered on splines in such a way as to have the bolt holes in the disc and the shaft coincide, this is followed by the insertion of the bolts. The bolts are tightened applying the torque of $5^{+0.5}$ kgm. The contact of the bolt heads with the ends of the flange, and the ends of the sleeve with the end of the shaft is tested with a feeler gage. The contact is considered to be normal if the feeler gage 0.03 mm thick cannot be inserted between the joined parts. The ovalness and the conicity of the Б diameter are also tested.

The assembled shaft with the disc is placed on prisms (Fig. 126 and 125) to test they play of surfaces Г, Д and E in relation to journals Б and В. The play in the surface Г is permitted up to 0.07 mm, surface E - 0.02 mm, and surface Д - 0.01 mm.

After the shaft is finally assembled with the disc, the disc is subjected to machining (gas labyrinth is bored and the blades are ground along their outer diameter). To bore the labyrinth a device is placed over the shaft splines, and immediately before drilling the play of surfaces Д, Б and Г is tested. A face chuck, which presses the blades against the disc is placed over the disc of the rotor, and the labyrinth is bored. To have a rigid fit of the blades, wooden wedges are inserted between them during machining. For the final inspection of the blades and grooves in the disc, and to remove the burrs, the blades are taken out of the disc.

Following the inspection, plates are inserted into the slots of each blade (Fig. 127) with the help of which the blades are locked in the disc; this is followed by the insertion of the blades in place according to their numbers. The second tab of the plate is bent first with a copper punch to the angle of 25-30° and after this is completely bent by means of a special device. Then the axial play E of blades in the difection ЖЖ (see Fig. 118) is tested. If the axial play is smaller than the specified it is recommended to strike lightly the lock of the blade with a hammer and aluminum punch. If the play is too great, additional bending of the plate is recommended. The plates must be in close contact with the surface of the disc. Ten-power magnifying glass is used to examine the bent plates for cracks or breaks.

The inner case of the roller bearing is selected with its tight fit on the hub equal to 0.000-0.01mm according to outer diameter Б of the hub (see Fig. 125). The case is heated in an oil tank to 60-80° C., pressed on the hub and safetied with a nut. To clean the spaces between the hub and the shaft they are flushed with heated oil in a special device under 2-4 kg/cm^2 pressure.

Figure 128 represents an axial-flow compressor engine turbine rotor assembly.

The shaft with the disc is centered with steel bushings 21.

Previous to assembly the bushing holes in the flanges of the shaft and disc are reamed. For that purpose the shaft is joined with the turbine disc and these holes reamed through a special jigg bushing. Then studs are inserted into the turbine disc, the bushings are pressed in and the disc is attached to the shaft with bolts which are safetyed with lock washers.

After the shaft is joined with the disc, it is machined, i.e. both end planes of the disc are ground, simultaneously with the protruding heads of the pins which hold the blades, then the blades are ground along their outer diameter, after which the edges are cleared of burrs.

The seal housing 11 is pressed on the shaft of the turbine rotor, adjusting ring 26 is installed, and the inner ring 10 of the roller bearing and spacer 6 are pressed onto the shaft. The seal housings and the inner roller bearing ring are heated in an electric arc furnace to 70-80° C., for 10-15 minutes before being pressed in.

The rotor is tested for blade play along the outer diameter of the side surface of the disc (at the blades) and the end of the shaft. The inner ring of the roller bearing and the ball bearing are used as bases for testing.

After its final assembly the turbine rotor is subjected to dynamic balancing.

Assembly of Turbine Inlet Ducts and Nozzles

Fig. 129 represents turbine inlet ducts of a centifugal compressor engine, the main parts of which are: casing 1, inner casing 6, cover 4, hot air ducts 3 and connecting flanges 2 and 5. The nozzle assembly (Fig. 130) is connected to the cover of the inlet ducts. The nozzle assembly consists of outer and inner rings, vanes, labyrinth packing and adjusting rings. The outer and inner rings have chamfered slots into which the blades are inserted (Fig. 131). The bevel angle of the slot of the outer ring is smaller in relation to its axis than the bevel angle of the slot of the inner ring. The blades have a variable cross section of a specific profile, and the thrust sockets are beveled to fit the slots of the outer and inner rings. The turbine inlet ducts and nozzles represent a single assembly.

Turbine inlet ducts and nozzles are assembled on a stand (Fig. 132) on which the casing is placed, connecting flanges are inserted into the holes of the casing and the air ducts are placed on the connecting flanges. After the ducts have been attached to the casing, the ovalness of the inner diameters of the connecting flanges is tested; ovalness is not permitted to exceed 0.1 mm.

A test drum device is placed over the housing of the turbine inlet ducts to test and to establish clearances; this is followed by testing the clearances (Fig. 133) between the air ducts and the inner casing wall, the latter must be within the limits of 1.6 - 3.4 mm; not greater than 0.22 mm between the connecting flanges and the turbine inlet ducts housing; and at least 0.8 mm between the air ducts (Fig. 134).

The cover of the housing is installed in such a way as to have the openings A on a single axis (Fig. 135), this is followed by installation of de-airator case on the cover.

Previous to the final installation of the guide ring, a test ring device is placed over the cover studs to check clearance Г between the air ducts and the ring. These clearances must be within the limits of 0.7 - 2.0 mm (see Fig. 133). After checking this clearance, the test ring is removed and in its place normal guide ring is installed. Clearances Б between the ends of the air ducts and inner shoulder of the guide ring must be within the limits of 1.9 - 3.1 mm and the distance B from the ends of the air ducts to the face of the inner casing must be within the limits of 6.5 - 8.1 mm. After tightening and safetying of all nuts, plugs, etc., the test casing is removed from the turbine inlet duct assembly and a normal casing is placed in its stead.

Nozzle inner ring 1 is inserted into the case slot 2 (see Fig. 135) and is attached to it, after which the blades are inserted in accordance with their numbers into the slots of the inner ring and outer ring 4 is installed on the guide ring 5 of the housing. The blade play is checked in the directions E and Д. The play in E direction is permitted within the limits of 0.07 - 0.3 mm, and 0.10 - 0.6 mm in direction Д. Fig. 136 represents a method of testing axial and radial plays in the vanes of the nozzle assembly. In case of divergences the required play is achieved by means of selection of vanes and their dressing. Then nozzle vane lock surfaces Ж (Fig. 137) are checked for overhanging or countersinking in relation to nozzle outer ring crosspieces. Overhanging is not permitted to be greater than 1.2 mm, while countersinking is not to exceed 0.8 mm.

To ensure correct flow of gas (velocity and direction) through the nozzle passages they are tested with the help of a set of indicators (Fig. 138). In case of deviations from the required standards, other vanes are selected. Nozzle passages (Fig. 139) are checked along several levels located at definite diameters. The width of opening A is taken as measuring distance in each passage, and for each of the openings - the height of each vane B. All the vanes of the nozzle assembly are divided into nine sectors, the dimensions of which are noted in tables specially prepared for that purpose. The area of the nozzle passages of the vanes of each sector is calculated separately, after which the total area of the nozzles is computed. The area of each sector is calculated according to formula

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$$F_{sec} = \frac{A_{av.} Б_{av.} \cdot 6}{100} \text{ cm}^2 ,$$

where F_{sec} - sector area to be determined;

$A_{av.}$ - average width of the opening;

$Б_{av.}$ - average height of the opening;

6 - number of vanes in sector;

100 - transference number mm^2 in cm^2.

The sum total area of the nozzle assembly is calculated according to formula

$$F_{sm} = F_1 - F_2 - F_3 - F_4, \ldots F_9$$

Where F_{sm} - total area;

F_1 - area of the first sector;

F_2 - area of second sector;

F_3 - area of third sector

F_4 - area of fourth sector;

....

F_9 - area of ninth sector.

Difference in the areas of the greatest and the smallest sector is not permitted to be greater than 2 cm^2.

To test the play in surface K in relation to Л (see Fig. 135) the nozzle is placed on a device (Fig. 140). The play is not permitted to be greatmr than 0.15 mm. After the assembly of the inlet ducts and the nozzles the clearance M is tested for the second time, as well as theplay of the vanes in the Г direction, which must be within the limits of 0.18 - 0.6 mm. Following this, the turbine housing is placed over the outer casing of the inlet ducts and nozzle assembly.

The nozzle (Fig. 141) of an axial-flow compressor engine represents a set of vanes installed circle-wise between outer and inner rings. The outer ring consists of a shroud and a band. Hollow welded vanes (Fig. 142), which form openings through which the gas is conveyed to the rotor blades, are fastened on the inner band with the help of plates and collars and may shift freely in the slots of the outer band when expanded due to temperature increases. In order to establish the necessary clearances the vanes are selected to fit the slots.

Assembly of Combustion Chambers and Combustion Chamber Blocks

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A combustion chamber (Fig. 143) of a centrifugal compressor engine is composed of the following major assemblies and parts: entry section, housing, flame tube and plugs, installed on the inlet ducts. All combustion chambers are interconnected by crossover tubes (Fig. 144).

The contacts of spherical surface of ring 1 (Fig. 143, б) are tested, previous to assembly of each chamber, with a device and the distance A between the tube and the combustion chamber housing is measured at eight points (Fig. 145).. This distance is maintained by means of matching of housings or fire tubes. The fire tube is inserted into the housing of the combustion chamber; a suspension cup is inserted into the flanges of the housing and fire tube, to secure their rigid attachment, while two chucks are inserted into the flanges of the crossover tube of the housing and into the hub of the suspension cup of the fire tube.

After the housings and the fire tubes have been connected, seal rings are inserted into the flange grooves of the housings. Fire tubes which are inserted into the housings of the chambers, are rigidly secured by suspension cups. Nuts are placed on crossover tubes after which they are inserted into theflange of the combustion chamber. This is followed by insertion into the chamber of secondary crossover tubes. To avoid buckling, the combustion chamber entry sections are screwed to the casings evenly.

The combustion chamber assembly of an axial-flow compressor engine consists of a nozzle inlet ducts and combustion chambers (Fig. 146) of welded construction. All combustion chambers are interconnected by corrugated crossover tubes. Each chamber is equipped with a fuel nozzle, three of the chambers have igniter plugs.

Combustion chamber shown on Fig. 147 is assembled separately, followed by final assembly as a unit. Since the parts of the chambers are made of thin metal plate and are welded, the assembly of the combustion chambers is conducted by matching of the parts.

The assembly of combustion chambers starts with matching of outer liner 2 and entry section 3 to the combustion chamber housing 1. Entry section and the outer liner must enter the housing tightly and without exertion of much force. The entry section is temporarily bolted to the housing. At the same time, the clearance between the flanges of crossover tubes and housings is tested, as well as the clearance between the mounting flanges of the fuel nozzle and the housing. If the size of these clearances is greater than specified, another entry section is selected. After matching of the parts of the chambers, mounting plugs, studs, screws and other parts are installed.

This is followed by the assembly of the combustion chamber as a block. For that purpose the nozzle inlet duct assembly is placed on a mounting stand and the chambers are installed. The re STAT ve position of the chambers and of the nozzle inlet duct assembly is tested by a device (Fig. 148), which is placed on the entry section of the combustion chamber housings. The chambers are attached on the nozzle inlet duct assembly with screws which are evenly tightened. The flanges of the combustion chamber housings must be in tight contact with the flanges of nozzle inlet duct assembly without skewing.

With the help of an angle plate, which is placed on the housing of crossover tubes, the angle between the flanges of these tubes is tested. To match the crossover tubes according to their length, each tube with its seal is attached with screws to one of the chambers, after which the clearance between the flange of the other end of the tube and the housing is tested. Should the clearnace be greater or smaller than specified, the tube is replaced with another. A tube thus selected is attached to the chambers and tightened with screws then thecontact of gaskets with the housing is tested. For added reliability theccontact of tubes may be tested with paint.

The assembly of the combustion chambers is ended with the installation of the studs, mounting plugs and otherpparts.

Assembly of Exhaust Cones

An exhaust cone of a centrifugal compressor engine and its parts is shown on Fig. 149.

Assembly of an exhaust cone consists of installation of the cone, tie rod mounting flange braces, laying of thermal insulation on the outer cone, installation of housings, bottom plate and exhaust cone.

The inner exhaust cone (Fig. 150) is attached to the cone assembly with tie rods which go through the rod braces and sockets (seats) located on the cone.

Aluminum foil thermal insulation (Fig. 151) is placed in a definite order, i.e. first one sheet is placed between the first and second reinforcing rings, then between the second andtthird and, finally, between third and fourth. Round 6 and long 5 spirals are placed on the first layer of thermal insulation, followed by laying of the second insulation layer. Asbestos material may be used in place of aluminum foil.

After the installation of the casings and clamp rings on the outer exhaust cone, the de-aerator housing is installed. Because theparts, expand in high temperature, tightening of clamp rings is done in a definite sequence. At first the clamp ring bolts are tightened to the limit, then the bolts of two clamp rings (second and fifth from the gas turbine) are released by one turn, and the remaining three - by two turns. The bottom is installed on the inner cone, and the exhaust nozzle is placed over the mounting flange.

Exhuast cone assembly of an axial-flow compressor engine with a variable cone (Fig. 152) is of welded construction.

The assembly of the exhaust cone consists in matching and placing together of the control mechanism parts, adjusting the co-axiality of the vertical shaft and splined sleeve, and in adjusting cone movement.

Fig. 153 shows the schematic of control mechanism of variable cone.

Fig. 154 represents bevel gear box assembly.

Into the support 3 of the bevel gear are installed: roller bearing 6, spacer hub of bearing 5, adjusting ring A and ball bearing 2; after which into the assembled support is inserted a shaft with a bevel gear 1, made integrally with the shaft, and it is connected to the housing. Then, bevel gear, into the inner splines of which are inserted vertical shaft, adjusting ring Б and ball bearing 11 are mounted in the housing, and the entire assembly is tightened with a nut.

The clearance between the teeth is determined with the help of adjusting rings A and Б. The contact of teeth and turning of the gears, which must be smooth and noiseless, are also tested.

To shift the rod with its cone along the axle of the exhaust cone, angle brackets with rollers are installed on the rear cone; similar rollers are installed on the brackets on the bevel gear assembly bracket.

Assembly of the exhaust cone starts with the installation of the rear cone and its attachment to the inner cone. The support bracket of the bevel gear assembly is attached to the same cone; the assembly is equipped with spur gear, sleeve and an adjusting ring. In case of co-axiality the vertical shaft must be able to enter the splines of the sleeve freely. If the axles fail to coincide, an adjusting ring of the required thickness is placed under the bracket.

The cone, which is being adjusted, with its rod is placed through the outlet of the exhaust cone assembly and is thrust in to the limit. After the installation of the cone, a shroud is placed on the rack of the rod, a thrust washer is installed and the nut is tightened. The cone must be set so that it could be pulled out to a specified length and must have a smooth movement; this is tested by pulling the variable cone in and out using cone control mechanism for that purpose.

The assembly is completed with the installation of the exhaust cone cover, under which an adjusting ring is placed, in order to maintain the required clearance between the turbine and the cover during the attachment of the cone assembly to the inner casing support.

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Assembly of Support and Casing of Axial-Flow Compressor Engine

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Figure 155 and 156 show casing and support.

The main operation in the support-casing unit (Fig. 157) assembly is that of establishing strict concentricity of the casing in relation to the support by means of rods 1 and 2.

For its assembly the support is placed on a stand which permits the placement of the assembly both in horizontal and vertical positions. Included in the immediate assembly of the support is the installation of plugs, studs, flanges and other parts.

Bracket 3, used to attach the rods, is placed on the support followed by placement of the casing over it and attaching it with bolts. To avoid skewing of the casing, tightening is done gradually and evenly. The rods are installed after the casing has been attached. The play of the inner ring of the casing is tested with the help of a device (Fig. 158), which consists of a body 1, flange 2 which is attached inside of the body of the hub 3 and which rotates freely on the pin of the flange, and a stem 4 with clamp 5. The body of the device is installed in place of the rear bearing of the turbine rotor. The steam of the indicator, which is inserted into the clamp, must touch the mounting shoulder on the inside wall of the casing. The rod, together with the indicator and the hub on the pin of the flange, is rotated around its axis; the play of the casing in relation to the support is measured at six points, located opposite the rods. Greater play than permitted is reduced by screwing or unscrewing of the rods.

6. Assembly of Accessory Drives and Couplings

Accessory units of the engines are put in motion by couplings and drives, the mechanisms of which in their turn are motivated by the gas turbine.

Accessory drive gear case (Fig. 159) of a centrifugal compression engine is located in the front part of the engine with the following units placed on it: fuel pumps, generator, tachometer, starter, oil pump housing, etc. The case is connected to the front shaft of the compressor through the assembly of the bevel drive gear and coupling.

The accessory drive power take-off housing (Fig. 160) of an axial flow compressor engine is a component part of the air flow system of the engine and is located between the air intake assembly and the compressor. Into it are placed thepower take-off assembly, spherical three-row bearing, oil pump and drives.

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On top of the accessory drive power take-off housing is located the accessory drive gear case interconnected by a drive shaft coupling. On the accessory drive gear case are located fuel pump, hydraulic pump, generator, de-aerator, and other accessories. On the air intake side, on the flange of the accessory drive power take-off housing is installed, the starter motor which is connected to the housing by a ratchet shaft. On the compressor side, the mechanism of the accessory drive power take-off housing is connected with the front shaft of the compressor by a coupling.

Assembly of Units and a General Assembly of Accessory Drive Gear Case of a Centrifugal Compressor Engine

Assembly of the case consists of three major stages:

- the assembly of drives to fuel pumps, tachometer generator starter and idle drive, oil pump case with filters;
- preliminary assembly of accessory drive gear case;
- final assembly.

Drives are composed of casings, geared shafts, bearings, spacer hubs, adjusting washers, and other parts.

Let us discuss the assembly of one of the drives (Fig. 161).

On the shaft of the bevel gear is placed one ball bearing 4 and together with the shaft it is pressed into the casing of the drive 1. This is followed by the placement of spacer hub 9 on the shaft and the second ball bearing is installed simultaneously in the casing and on the shaft. After this, retaining ring 2, lock washer 8 and nut 7 are installed. Turning of the gears must be smooth and noiseless. The rotation of the gears in relation to their axis is tested as to the play in surfaces A and Б with stationary gears and rotating flange. Permissible play of A and Б surfaces should not exceed 0.06 mm.

We will give another illustration of the assembly of one of the major units in the accessory drive gear case. Fig. 162 shows an oil pump drive assembly. Power is transmitted to the oil pump shaft through the lower drive of the pump.

Bevel gear 1 of the drive has inner splines 2 for meshing with the drive spur gear 3 of the oil pump. A steel hub for spur gear centering is pressed into the gear.

The drive shaft is installed on two ball bearings 4, between which a spacer hub is placed.

The lower bearing is mounted on the disc of the drive gear while the upper - on the disc of the rear shaft of the bevel gear.

Between the end of the bevel gear and the upper bearing a ring 6 is installed to adjust the clearance between the gear teeth. The outer rings of bearings are enclosed in steel cups 7 with flanges, which are pressed into the body 8 of the oil pump drive. The outer ring of the lower bearing is clamped by a spring ring 9.

The housing of the drive which represents a flanged cup is centered at the lower wall of the accessory drive gear case and is clamped by means of a flange between the housings of the oil pumps and the wall of the case.

The assembly of the drive is done in the following order. Ball bearing is pressed on the end shaft of the spur gear 3. Adjusting ring is placed on the shaft of the bevel gear and a second ball bearing is pressed on.

The spur gear is pressed into the housing of the drive to its contact with the flange. A retaining ring is inserted into the slot. On the end of the shaft of the spur gear is placed a spacer hub, after which the ball bearing together with the bevel gear, and connecting it with the splines of the shaft of the spur gear, are pressed into the housing. Lock and safetying washers are placed on the end of the shaft of the spur gear and the nut is tightened.

During the assembly the following are checked:

a) rotation of the shaft of the gear;

b) play of the bevel gears at the pitch circle in relation to centers on which the drive is mounted;

c) play of surface A in respect to centers.

If the play of the bevel gear at its pitch circle in respect to surface A does not correspond to the one required, it is recommended to do the following:

a) to disassemble the drive completely;

b) to test the play of the outer surface of the bearing cup in respect to the inner surface;

c) to test the play of surface A of the drive gear housing in respect to surface Б;

d) to test the play of the bevel gear at the pitch circle in respect to surface B.

The drive unit is again assembled out of matched parts and again tested at the centers.

The following operations are included in the preliminary assembly of the accessory drive gear case:

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1. Hydraulic testing of the oil passages of the case, conducted on a special fixture (Fig. 163); transformer oil, heated to 40-80° C. under 6 kg/cm² pressure is used for this purpose. In three minutes time there should remain no trace of oil on the outer surfaces which correspond to the passages in the case.

2. The assembly of the subassembly of the spur drive gear (Fig. 164) and testing of the clearance between the teeth of the sleeve and the pawls of the ratchet of the starter mechanism. On the shaft of the spur drive gear 25 are installed the following parts: breather sleeve 3, which rests on the roller bearing 14 and which is pressed into the cup 15 of the drive gear accessory case 13; driven bevel gear 29 of the starter, prepared as a single unit with the sleeve of ratchet mechanism, resting on two ball bearings 31 and kept in rigid position by spacer hub 30; and flange 18 of the ball bearing 24 of the drive spur gear.

In the ratchet mechanism (Fig. 165) are included, hub 1, to which thrust ring 2 is attached. Pins 3 with pawls 4, dowels 5 and springs 6 are mounted on the hub, after which the hub is inserted into the inner part of the sleeve 7 of the ratchet mechanism with splines 8. To test the clearance a between the teeth and each of the pawls, the pawls are lossened to the limit with the help of wedges; for that purpose the bevel driven gear with its sleeve is installed on a mandrel. With clearance C being zero the required clearance (a) must not be less than 0.3 mm.

3. Testing meshing of teeth of bevel and spur gears and side clearance between them.

4. Assembly of the oil pump case, which includes the installation of the oil pump (pressure and scavenge), pump drive, oil intake vent with a filter for filling the cashing with oil, one high pressure filter and two low pressure filters. After assembly, the case placed on a special installation is subjected to test run for 20-25 minutes.

5. Flushing of the accessory drive gear case with transformer oil with oil temperature of 70-80° C.

6. Disassembly of the case (partial) for inspection and preparation for the final assembly.

The final assembly of the accessory drive gear case consists in insertion into it of upper and lower drives, drive spur gear assembly, oil pump case, fuel pumps and other accessories and parts. Assembly is accompanied by inspection, measurements and notations in the rating plate of the case.

Assembly of Accessory Drives and Couplings of an Axial-Flow Compressor Engine

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Fig. 166 shows a bevel gear of accessory drive power take-off assembly which includes: the main assembly and drives from this assembly to the oil pump, to drive-gear box, to accessories and to the manual turning assembly.

Into the housing 1 of the assembly are pressed cage 20 with liner 19 of ball bearing of the drive gear 10, which are then tightened with nut 23. The inner ring of the roller bearing is pressed on the shaft of the drive gear 10, adjusting ring 22 is inserted into liner 19 and the assembled ball bearing is placed on the shaft of the gear. The inner splines of the ratchet 18, which is screwed into the end of the gear shaft 10, must coincide with the inner splines of the gear shaft; another ratchet is selected if they do not.

The outer ring of roller bearing is pressed into the cover 28. Before the cover is placed on the housing of the unit, distance A is measured from the end of the ratchet to the end of the housing; this distance must be within the required limits to ensure the necessary end clearance between the ratchets of the starter motor and the assembly. This distance may be altered by selection of adjusting ring 22.

Drive (Fig. 167) to the manual turning assembly consists of casing 1, gear 2, roller and ball bearings 3 and 4 and other parts. The outer ring of the roller bearing is pressed into casing 1; adjusting ring 6 is installed, spacer 7 and ball bearing which is tightened with nut 8, are also placed in casing. Inner race 9 of the roller bearing, spacer 10, and shaft stroke limiter, which is connected with the manual turning mechanism, are pressed on the shaft of the gear after which the spring ring is placed. The shaft of the gear is tightened with nut 11 and is safetied with special washers.

Drives to the accessory drive gear case and to the oil pump are of the same construction, but due to the fact that the outer diameter of the gearis greater than the inner diameter of the cases, their assembly is done in a different sequence. While during the assembly of the manual turning mechanism the case was pressed on the shaft of the gear, after the corresponding assembly of the parts of these drives, the shaft of the gear is pressed into the case.

The general assembly of the accessory drive gear case starts with the installation of the assembled spherical three-row ball bearing.

Further assembly of the case consists of installation of oil filter, oil pump and of the manual engine turning assembly.

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With the help of a device, which is installed in place of a shaft, the clearances between the edges of the apertures STAT the protective strainers of the oil pump and the device are checked. The turning of the oil pump, which must be smooth and without jamming, is also tested.

Pump shaft is inserted into the drive of the pump, the drive consisting of a cover with two ball bearings, after which the shaft passes through an opening in the pump and is connected with the drive, while the cover is connected with the surface of the pump body. Since the resesses of the oil filter and pump always contain oil, the surfaces of the cover and of the body must be fitted carefully.

Drive shaft 1 is inserted into the manual turning assembly drive (Fig. 168), after which ball bearing 2 with thrust ring 5 is pressed on the shaft on the outer side of the casing. Liner 3 is heated and placed over the ball bearing.

The assembly of the accessory drives consists of installing assembled drives with earlier matched gear clearances into the case.

Let us examine the assembly of the main drives of the case-drive shaft and generator (Fig. 169). The drive bevel gear 1 is manufactured as a single assembly with a hollow shaft (Fig. 169, a), which rests on two bearings - ball 2 and roller 3. Splines inside the shaft connect it with drive shaft 4 of the main drive assembly. To protect it from axial shifting the shaft is held rigid with positioning tube 5 inserted inside the gear shaft. During the assembly of the drive shaft of the accessory drive power take-off housing, the bearings are assembled first, followed by the assembly of the shafts, and finally the drive assembly in the accessory drive power take-off housing. Ball bearing with adjusting ring 14 is installed in the case 8. The outer race of the roller bearing is pressed into liner, is secured in it with spring ring 12 and then the liner is pressed into the accessory drive gear case. The inner race of the roller bearing is pressed on the shaft of the gear 1.

Roller bearings 3 together with the liner are pressed on the end of the gear shaft. This is followed by placement of spacer 5 inside of the shaft 1 and the screw 6 is tightened. In this state the drive shaft is placed in the accessory drive gear case. Cover 9 is installed after the gears have been adjusted. Spring ring 7 is installed during the process of general assembly after the installation of drive shaft 4 through an opening in the accessory drive shaft case 1.

With the drive bevel gear 1 of the shaft, is connected power take-off bevel gear 13 and its shaft which is provided with inner splines for its connection with the shaft of the generator. The assembly of the bevel gear drive or power take-off unit is done in the following manner. On the shaft of the bevel gear 1 of the drive (Fig. 169, δ) spur gear 2 is pressed on; it is locked on the end of shaft with dowel pin 3. All remaining spur gears of the drives obtain their power from gear 2.

Two bearings serve as supports for the gear -- front 4 roller bearing and rear 5 ball bearing. The outer race of the roller bearing is pressed into the steel liner after which the edg STAT of the race are pressed in. The bearing has no inner race -- the roller bearings run directly over the cemented end shaft of the spur gear. Into the liner 6 are placed adjusting ring 9 and a ball bearing, the outer race of which is fastened in the liner with a nut 10, and locked with a spring ring 11.

The liner 6 together with bearings is installed in housing 7 and is attached to it with screws 8, which are locked with binding wire. After this the housing is placed on the shaft of the bevel gear and is attached to it with nut 12. Nut 12 is not locked immediately, since in adjusting of the side clearance at the teeth of the bevel gears it may become necessary to disassemble the unit.

All the shafts of the assembly of the accessory drive must have axial clearances within the limits of 2 mm.

Adjustment of Meshing Action and of Backlash in Gear Teeth in the Accessory Drive Gear Case and Accessory Drive Power Take-off Housing

Kinematic schemas of accessory drive gear case and accessory drive power take-off housing of jet engines consist of a great number of gears, both spur and bevel. Complexity of assembly of these arrangements is due to the fact that in adjusting the meshing action and backlash it is necessary here to deal, in individual cases, not just with two gears, but with three and more (Fig. 170 and Fig. 171), which have to be installed and adjusted simultaneously.

All gears in both accessory drive power take-off housing and drive accessory gear case are tested with paint for proper meshing and the backlash between the teeth of bevel gears is adjusted. Meshing action testing with paint is done on the working side of the teeth as the drive gear is turned in the forward direction, i.e. in the direction of its rotation during the operation of the engine. The turning direction of the gears, as a rule, is indicated in the kinematic arrangement. To obtain a more clear imprint it is recommended to turn the gears, which are being tested, two or three times.

Adjustment of backlash between the teeth of bevel gears is done by altering the thickness of adjusting rings.

Adjustment of backlash between the teeth of spur gears is done by matching gears according to the thickness of the teeth and by proper selection of drive housings.

The backlash between the teeth is measured with a feeler gage or an indicator with a 0.01 mm precision in four points in three different positions of the gears (through 90° turn of the drive gear) on the working side of the teeth.

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Special devices are widely used for convenient and rapid measurements of backlash between the teeth of the gears. Fig. 172 shows a fixture for testing backlash between the drive gear and the gears in the accessory drive gear case. This device consists of a split cylinder, in the hollow of which dowel pin 5 is secured with a joint pin 6; and a hollow cone 3 which moves freely along the dowel pin inside of the cylinder. The threaded end of the dowel pin which prodrudes out of the cylinder, has a nut 2, while rod 4 with a plate 7 for installation of the leg of the indicator is attached to the cone. To test the backlash the cylinder of the device is inserted into the opening of the drive gear assembly. By turning the nut of the dowel pin the cone is moved inside of the cylinder and as it is shifted loosens the cylindrical fixture, thus attaching itself to the gear.

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Fig. 173 shows fixtures for testing backlash between the teeth of the spur gears in the accessory drive gear case of a centrifugal compressor engine; between the gear of fuel pump drive and drive bevel gear; between the teeth of drive and driven gears of the starter; and for testing the backlash between the teeth of the auxiliary gear and the fuel pump drive, and oil and fuel pump drives.

7. Assembly of Subassemblies of Main Bearings of the Engine

Assembly of Main Bearings of Centrifugal Compressor Engine

The engine under discussion has three assemblies of main bearings: front, center and rear, which support the compressor and the rotor of the turbine.

Assembly of the front bearing subassembly (Fig. 174) starts with measuring the seat of the main roller bearing and outer race of the roller bearing to determine the actual placement of the parts. If the measurements coincide with those given in the drawing, the bearing is installed in the housing, otherwise another bearing is selected.

After the selection of the bearing, the following are placed in the assembly of the housing of the front bearing: oil jet, oil inlet tubes and oil labyrinth seals.

After its assembly the entire unit is flushed with transformer oil under 3-4 atm pressure and 50-60° C. temperature.

Before the assembly of the center bearing (Fig. 175) its cover is matched according to the outer race of the ball bearing and the axial play of the ball bearing (Fig. 176) is measured.

Besides, measurements are also taken ofthe overhanging or countersinking of the outer race of the ball bearing in its seat. Upon the conclusion of these operations, the ball bearing is pressed into the seat with the help of a device (Fig. 177) and is fastened in it with a tightening washer (Fig. 175).

After the ball bearing has been installed, into the cover of the center bearing are inserted the parts of the oil jet (Fig. 175), which are covered on top with a cowl screwed to the studs of the STAT center bearing cover with two nuts.

The assembly of the rear bearing support (Fig. 178) consists in selection of the roller bearing, installation of oil jet and placement of oil labyrinths. Besides, a shroud and a deflecting ring are also installed. Oil labyrinths are selected in such a way as to be able to maintain the specified clearances between the shaft and the labyrinths.

Assembly of Main Bearings of Axial Flow Compressor Engine

In the design of the engine under consideration there are four assemblies of main bearings, of which two support the compressor rotor, and two serve as supports of the turbine rotor.

The assembly of the front subassembly of the compressor bearings (Fig. 179) is performed in the following way. Parts for a given assembly are selected first, for the purpose of which a micrometric measurement is taken of such parts as bearings, liners, spherical cone, spacers, etc.

The quality of contact of the selected spacer rings with the surface of the cover is tested by pouring in a mixture of oil and kerosene; no leaks are permitted.

For an even distribution of axial load on all three bearings during their assembly the bearing supports 6 are first pressed in a special press with a force equal to 1/3 of the actual axial load.

After the bearings have been pressed, three conic holes are drilled and reamed in the supports; conic dowels 11 are inserted into these holes rigidly fixing the position of the ball bearings in relation to the outer bearing support.

The rear assembly (Fig. 180) of the compressor rotor bearing is composed of the housing of the bearing 1, roller bearing 3, retaining ring 2 and flange 4.

Spherical housing with the assembled three-row bearing is installed in the accessory drive power take-off housing (Fig. 181). In the seat of the housing are installed springs 7, which press the bearing to the spherical body of the casing. Sealing rings 10 are placed on the journal of the bearing, after which cover 8, which attaches the bearing to the housing, is installed.

The subassembly is assembled on support 10 (Fig. 182). Seal 7 with rings 9 and the inner race 6 of the roller bearing are placed on the rear shaft of the rotor. The roller bearing is pressed into housing 2, the retaining ring 4 is installed, followed by pressing the housing with its bearings into a previously heated flange 3 and attached to it with nuts. The flange thus assembled is installed in the support by means of a centering shoulder 5 and is attached to the support. As the housing is being inserted into the flange, matching of oil draining holes is tested.

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Front and rear bearings (Fig. 183) are assembled in the support. In the assembly of the front bearing (Fig. 183, a) housing 1, which is attached with bolts 2, is placed into the support flange 14. Cover 4 is placed on the shoulder of the housing, after which a split radial thrust ball bearing attached with nut 5, which in turn is locked by means of a retaining ring 6, is inserted into the housing.

Seals 9 together with nut 13 are mounted on the turbine shaft after the turbine rotor has been installed in the support.

The rear assembly of the rotor roller bearing (Fig. 183, δ) is also assembled in the support. Steel liner 2 is pressed into the housing 2. Into the liner are placed outer race 3 of the roller bearing with separator and rollers; the outer race rests on one side on the supporting shoulder of the liner, and on the other side is held in place against axial displacement by six supports of cover 4.

Seals 8 with sealing rings and the inner race 5 of the roller bearing, located between the casing and shaft spacer 7, is pressed onto the shaft during its assembly. Cover 4 is made fast to the rear flange of the housing 1.

The oil channels of the assembled subassemblies are flushed with oil.

8. Assembly and Testing of Oil System Units

Fig. 184 represents an oil system of a centrifugal compressor engine. One of the main assemblies of this system is the oil pump casing 4, which is connected to the accessory drive gear case and which includes a pump with pressure 3 and scavenge 2 stages. Oil is poured into the casing to fill the oil system. Besides the pump, two strainer filters 7 and 8 are installed in the casing, which protect the pump stages from extraneous matter, and a high pressure filter 10 of slotted type for the oil which passes through the system under pressure. De-aerator tray 5 which removes air and gas from the oil is installed in the casing.

Oil in the box is pumped through filter screen into the intake channel of the oil pump, and then through a high pressure filter proceeds into oil distributing channel in the accessory drive gear case. This channel is connected with a relief valve which is calibrated to 3.5 kg/cm^2. Oil distributing channel is branched into three lines; one of them 13 feeds the jets which lubricate the center and rear bearings, and delivers oil for lubrication of connecting sleeve coupling of the shafts of the turbine rotor and compressor; the second line 1 feeds oil to the jet of the front bearing; while the third 14 feeds oil to the drive of the airplane auxiliary assembly and to two tubes which spray oil on the gears of the accessory drive gear case.

The scavenge stage extracts oil only from the housings of the center and rear bearings. From the front bearing the oil flows into the accessory drive gear case, and out of the case it i STAT poured into pump assembly housing. The scavenge stage of the pump sucks this oil through filter screen and delivers it through a system of channels into the pipe of de-aerator installed in the case, and from the pipe -- to the tray of de-aerator from which oil flows downward and reenters the main oil line.

Oil system of axial flow compressor engine does not differ radically from the one described above. This system, of a somewhat different design, includes an oil tank, oil pumps with pressure and scavenge stages, filters, de-aerator and other units.

Assembly of Oil Pumps

The pumps are designed for circulation of oil in the oil system of the engines. Fig. 185 shows the design of a pump with one pressure and one scavenge stage. Pump shown on Fig. 186 has two pressure and one scavenge stages. To draw off the oil from the housing of gas turbine of an axial flow compressor engine, a pump shown on Fig. 187, with two scavenge stages is used. All these pumps are of gear type.

Since the pump stages are processed together in the machine shops, it is necessary during matching and assembly of the pump parts to have the marks stamped on them correspond strictly. Pump parts, such as: shafts, gears, etc., are also marked after their final preparation.

The basic preparatory operation for final assembly of the pumps is the determination of the required side and radial clearances of the gears in the stages; backlash between the gear teeth, etc. The surfaces of the stages being joined must fit together tightly and must be strictly parallel to each other. To avoid skewing of the nut, fastenings of the stages must be tightened evenly. The pump parts must turn smoothly, without jamming or noise. Radial clearances of the drive and driven gears of the pressure and scavenge stages are set within the limits of 0.035 - 0.09 mm, axial clearance between the gears and surfaces of the stages - 0.02 - 0.07 mm, and the backlash between the teeth of the drive and driven gears - 0.24 - 0.32 mm.

Checking the assembly of the pumps is done with the help of an indicator depth gage which measures the depth of grooves in the stages, and feeler gage and indicator for measuring backlash between the teeth.

After their assembly the oil pumps are tested, the test consisting of the following four operations:

a) Test run of the pump after assembly;

b) Determination of discharge of the pressure stage of the pump; STAT

c) Determination of discharge of the scavenge stage of the pump;

d) Determination of discharge with vacuum in the pressure stage of the pump.

These operations are performed on a special installation, the diagram of which is represented in Fig. 188. Testing of the pumps is done with transformer oil at 75-80° C. temperature.

For the purpose of testing, the oil pump is installed in a housing made up of upper and lower halves; during the installation, the gear of the pump is meshed with the drive gear of the installation. To control the emergence of oil in the breather tube of the upper housing valve 23 and valve 17 are opened.

This is followed by opening of the valves 15 and 16, after which the engine is switched on. By means of a rheostat pump revolutions are adjusted to 700-800 RPM and the pump is operated for 2 minutes. Then at 1500-1600 RPM the test run is conducted for 3 minutes, finally, the number of revolutions is increased to 3100-3200 RPM and at that speed the operation is conducted for ten minutes. During all of these processes, the by-pass valves are opened to drain the oil into the service tank. With this the test run of the pump ends.

Then counter-pressure of 3 atm is created in the pressure stage of the pump with the help of a valve 15; this counter-pressure is controlled with a manometer 11, and then a three-way valve 18 is switched to a metering tank 3 with a simultaneous switching on of a stop-watch. After 3 minutes valve 18 is switched to service tank with a simultaneous stopping of the stop-watch. This is followed by evaluation of the discharge according to formula

$$V = Q \cdot 20,$$

where V - discharge of the pump during 1 hour;

Q - amount of oil in liters, which entered metering tank during 3 minutes;

20 - conversion coefficient to hourly discharge.

The discharge of the pressure stage must not be less than 600 lit./hr with 3,1000 - 3,200 RPM.

To transfer oil from metering tank 3 into the service tank, valve 21 is opened and then closed. This is followed by testing discharge of the scavenge stage of the pump in which counter-pressure of 1 atm is created and which is tested by manometer 13. To create counter-pressure, valve 16 is used. A three-way valve 19 is switched over to the metering tank 2 with simultaneous

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switching on of stop-watch. After 3 minutes, valve 19 is switched over to the service tank and at the same time the stop-watch is stopped. The discharge of the scavenge stage at 3,STAT-3,200 rev/min and at 1 atm counter pressure should not be less than 900 lit./hr.

Then, by means of a valve 17, 0.85 atm vacuum is created in the pressure stage, which is controlled with a vacuum meter 10. To test the discharge of the stage with vacuum, the same operations as the ones described above are conducted. The discharge with vacuum must be not less than 300 lit./hr. The discharge of the pressure stage with vacuum is calculated by the formula given above.

Assembly of Oil Filters

Assembly of filters requires absolute cleanliness and careful matching of parts. After their assembly the filters are flushed with oil.

High pressure filter (Fig. 189) consists of outer and inner filters. Previous to their installation into the liners, contact tightness of the flanges of the liners being connected (to avoid overflow of oil) is tested. Fig. 190 represents a filter of a different design. The body of the filter is composed of four filter elements, eight spacers and three partitions. Each screen disc in its turn is composed of two fine mesh outer screens and two coarse mesh inner screens. Surfaces of the discs and partitions must be in tight contact with each other, to avoid leakgge of oil.

Assembly of Relief Valves

Valve design is shown on Fig. 191 and Fig. 192. Overflow oil passed by the valve into any cavity is poured out through an opening in the seat of the valve.

During the valve assembly special attention is paid to their contact with their seats. For instance, a ball must be in contact with its seat along its entire circumference, the piston or the cup must be fitted to its seat until a complete contact is achieved.

Parallel position of the surfaces of the spring in its working position must guarantee true (without skewing) operation of the valves. The valve is tested for its hermetical properties with oil under certain pressure in a given period of time, and is calibrated to a specified pressure by means of a spring and an adjusting screw.

Assembly of Oil Jets

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Engine bearings are lubricated with oil which enters through jets. Jet housing (Fig. 193) is composed of two flanged parts which attach the jet with studs to the housing of a bearing. A brass bushing with shoulders at its ends is inserted into the housing and a screen filter is placed on it. A small rod with a spiral thread on its end is inserted into the bushing; due to this arrangement the oil is given a rotating motion and is sprayed, through a calibrated opening in the housing, onto the bearing being lubricated.

During the assembly of the jet, the clearances are tested between the brass bushing and the screen body and the jet. One part of the housing with its calibrating opening is installed in the seat of the part in which the jet is installed (labyrinth seal, front partition, etc.). Then into the housing of the jet is inserted the bushing with its screen and rod. The other part of this body (cap) is placed on the flange of the housing.

To determine the amount of oil which passes through the calibrated opening of the housing, the jet is operated on a special installation, diagramatic layout of which is shown on Fig. 194.

The jets being tested are inserted into the seats and then the adjusting valves 6, 7, 12, 13 and 14 are opened. Valve 8 must be closed after the electric motor of the pump is switched on. With the help of valves 6 and 7, the needed pressure is established which is controlled with manometer 9. When three jets are tested simultaneously, valves 12, 13 and 14 are opened to the limit. When one or two jets are being tested, unnecessary valves are shut.

When lever 11 is turned up a stop-watch is switched on. At the expiration of a definite period of time the lever is lowered and the stop-watch is switched off. By turning lever 17, the oil in the metering retort is poured into tank 2. Electric motor is switched off and valve 1 is closed.

Discharge of each jet is estimated according to formula

$$Q = \frac{V}{t} 60 \ l/hr,$$

Where Q - discharge in lit./hr;

V - measured volume of oil in liters;

t - time of measurement in minutes;

60 - coefficient for transfer into hourly discharge.

The required volume of oil used in test discharge run is assured by the selection of the diameter of the inlet opening of the jet.

Assembly of De-Aerators

Fig. 195 represents a de-aerator designed to extract the minuSTAT: air particles from the oil which is pressure pumped by centrifugal force of scavenge stages of the oil pumps into the oil tank of the engine.

The major parts of the de-aerator are: casing 1, centrifuge 2, shaft 3, ball bearing 5 and roller bearing 11. Because the shaft and the centrifuge rotate at a great speed, mounting of parts is performed with extreme care. Co-axiality of two openings for the roller and ball bearings is ensured by provision of tolerances as the casing is being produced in the machine shop.

Clearance A between the deflecting washers and the end plane of casing 1, as well as clearance Б between the end plane of the centrifuge 2 and washer 14, located on cover 4, are ensured by the selection of adjusting rings placed between the end of the inner race of the roller bearing, deflector washer 12 and sleeve 13 of the centrifuge.

For the assembly of de-aerator, matched adjusting rings and deflector washer are installed on the shaft and the inner race of the roller bearing, which is tightened with a nut, is pressed on. After the casing of the deaerator has been heated to 80° C., the outer race of the roller bearing is inserted into it. Into the outer casing is also placed the body of the ball bearing, assembled together with the shaft and the centrifuge.

After the de-aerator has been assembled, the rotation of the centrifuge, which must be smooth and without jamming, is tested. The assembly of the de-aerator is finished with drilling of holes for dowel 15, placement of the dowel and screw 6, the last is wire locked.

9. Assembly of Fuel System Units and Their Test Runs

The fuel system of an engine consists of fuel pumps, throttle valves, filters, fuel and starter nozzles, fuel distributors and other parts.

Figures 196 and 197 represent fuel diagrams of centrifugal and axial-flow compressor engines.

Since the systems operate under high fuel pressure, the assembly of the parts should be conducted with great precision and accuracy. Of great importance, from the point of view of fire prevention, is absolute hermetical sealing of the connections.

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Assembly of Fuel Pumps

Multiple plunger pump, cross section of which is shown on Fig. 196, has a rotor with seven plungers 5, which are pressed by springs 6 to the spherical surface of rocker arm 7, which can pivot on two pins along the vertical axis of the pump. The rotor is connected by shaft 2 with the pump drive installed in the accessory drive gear case.

Plungers and cylinders constitute the main parts of the pump. In grinding this pair as it is machined a clearance of ~ 0.003 - 0.005 is left. Fitting consists in grinding the surfaces of the plunger and cylinder with special grinding preparations such as ГОИ paste or grinding for 30 minutes with alundum abrasive powder followed by a 60 minute grinding with an addition of spindle oil. The ground surface of this pair must be of an even dull color. Besides, grinding of these parts produces the necessary clearance (0.008 - 0.012 mm). The quality of the surface and the clearance are tested, with micrometric measurement, and by hydraulic pressing.

After its assembly, the pump is tested on a special installation, the testing includes: test run, adjustment and checking its discharge.

Fuel pump (Fig. 198) of gear driven type has the following major parts: front cover of pump 6, pump body 7, two intermediate walls 8 and 20, pump cover 9, shafts 4, 19, driven and drive gears 11, 12 and seal which includes a cup 5 which is inserted into a steel cup housing 27, spring ring 14, rubber ring 26, and retainer cup 15.

During the assembly of the pump it is necessary to adhere to strict co-axiality of the outer ring of needle bearing 30, which is pressed into the front cover of the pump 6 and rear cover 9, and parallel relationship of the axes of the holes of these two parts.

Axial shifting of the shaft of the driven gear is achieved by selection of bronze thrust bearings 21, pressed into the pump body and cover, while shifting of the shaft of the drive gear is done by selection of lock washer 31. Gears 11, 12 are connected to the shafts by three balls 22, which sit in grooves made in the shafts and slits in the gears and which play the role of pins. The clearance between the shafts and inside diameter of gears is assured by proper selection of these parts. Clearance 0.02 - 0.04 mm between the gears and intermediate walls 8 and 20 is established by selection of gears and pump body 7 according to height.

To prevent fuel from entering accessory drive gear case through clearances, a seal - a rubber cup is placed on shaft 4; this cup must fit closely, but not too tightly, the journal of the shaft. At the same time ring 14 is so selected as to have the cup envelope the journal of the shaft along its entire diameter.

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To obtain rigid fit of the base of the body, cover and intermediate discs, tapered dowels 3 are installed and the entire assembly is joined with bolts 13.

Fig. 199 represents a starting fuel pump of gear driven type. The end clearance 0.015 - 0.04 mm between the bushings 7 and the gears is determined by selection of thickness of gasket 16, made of lead foil. The same requirements are observed when this pump is assembled as in the case of the assembly of the pump described earlier.

After their assembly, the pumps are test run on a special installation, the hermetical fit of all joints and seals is tested, and the discharge of the pumps is determined.

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Assembly of Fuel Filters

The design of one such filter is shown on Fig. 200. Filtering element here is a metal screen.

Assembly of the basic-fuel filter consists in the following. Two-sided screen discs are placed on body 3, between the discs, from the inner and outer sides, screen rims 6 are inserted to tighten them and shaped washers 7 are also inserted to add rigidity to the disc set. Clearance between the discs is maintained by proper selection of washers 9.

High-pressure fuel filter is also composed of screen discs but is provided with a relief valve. Both in the first and in the second case, bolt nuts which hold together the set of disc should not be over-tightened to avoid their deformation. Fig. 201 represents a low-pressure filter with a felt filtering element.

It is very important to maintain cleanliness, during the assembly of the filter; the parts should be washed with extreme care. Filtering elements, after they have been washed in gasoline are dried in electric ovens for 10 minutes in 60-70° C. temperature.

For the purpose of testing the quality of assembly (hermetical sealing of the connections) and the discharge of the filters, a special installation has been devised which is shown on Fig. 202. Fuel temperature during filter testing must be 15-25° C. To achieve reliable filtering of the fuel, filter system includes filter 3 made of silk. After the pump has been connected with drive 4, pressure of 3-4 kg/cm^2 is created by proper manipulation of the valves in the main fuel line of the installation, then its air-tightness is tested and the pressure is reduced to 0.8 - 1.0 kg/cm^2 and its discharge, which should be 3,000 - 3,750 lit./hour, is tested.

Filtering elements and other parts located inside of the filters obstruct the passage of fuel. The difference in pressures at the intake and in the outlet (drop) is permitted at 20 - 30 mm mercury column (Hg).

For the purpose of washing, filters are flushed with fuel at 0.8 - 1.0 kg/cm^2 pressure for 12 - 15 min. Upon examination the filter of the installation must be absolutely clean, which would indicate that the operation of flushing is completed and that the filter is ready for operation.

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Assembly of Fuel Distributors

Fig. 196 shows a fuel distributor.

An irregularly shaped needle 32 of the distributor, which changes the cross section of the jet nozzle, through which the fuel flows to the main nozzles, must be matched very carefully according to the sleeve and the seat of the jet.

To avoid skewing of the needle, the surfaces of the springs must be strictly parallel to the surfaces to which they abut.

An important part of the stop-valve is its plunger, which shifts in a steel sleeve; one end of plunger is threaded with teeth which create a rack which is connected with a gear on the shaft of which the lever of the stop-valve is attached. Matching the plunger to the steel bushing by means of grinding this pair with grinding pastes (until an even opaque surface is obtained and the necessary clearances are reached) is the major operation. Meshing of the teeth of the cleat with the gear must be smooth and without catching.

Assembly of Throttle Valve and Compressor Pressure Limiter

Throttle valve (Fig. 203) serves as a means of engine control.

Assembly of the valve consists in screwing in of the connections 6 and 8, installation of idling jet and installation of a cap which closes this jet, assembly of control lever 5 and connecting of the plunger with the bushing. In meshing the teeth of the rack and pinion gear 7 the clearance is so selected as to allow smooth and free shifting of the plunger in the steel bushing. Good surface of the bushing and exact clearances between the plunger and bushing are achieved by grinding with grinding paste. After the assembly, the air tightness of the connections and the discharge of the valve are tested.

Compressor pressure limiter (Fig. 204) is oa a membrane type; it limits the pressure of the basic fuel which is delivered to the nozzles of the engine depending on the drop of air pressure before and beyond the compressor.

The assembly of the limiter consists of the following. Between the body 1 and the intermediate plate 3 gasket 10 is placed, while between the cover and the plate a membrane is inserted dividing the chamber under the cover in two: above and under the membrane. Plates 16 are attached to the membrane. A slide valve rests on one side of the membrane and a spring on the other side. The slide valve is installed in the body with a specified clearance. The engine compression is controlled with adjusting screw 7 or with the screw 9 of the ball bearing.

Assembly of Drain Valve

Drain valve (Fig. 205) is designed to drain fuel which drips from combustion chambers.

The main parts of the valve are: body, cover, valve and spring. At the places of its contact with the body the valve plate is covered with hermetic sealer. Then the valve together with its plate is placed on the studs of the draining valve and the cover is attached to the body. Then the connection is screwed into the cover, and the spring is installed, together with the disc and the retaining ring.

The valve is tested determining the moment of its closure and opening and the air tightness of the connection of the cover of the valve with its body is checked.

The valve is tested in a special testing stand shown on Fig. 206.

After a proper preparation of the stand the receiver valve is opened and air pressure of 1-2 kg/cm^2 is created, after which the valve is closed. Then, gradually opening the valve, the pressure at which valve closes (which must be 0.05-0.25 kg/cm^2), is determined with a manometer.

To test airtightness of the valve, the pressure is increased to 1 kg/cm^2 for three minutes. When the valve is closed pressure drop in the receiver is permitted to be no greater than 0.15 kg/cm^2. Attention is paid during testing to the appearance of air bubbles in the gasoline vat in which the valve hose is immersed. Pressure drop without formation of air bubbles indicates leakage of air along the line of cover joint in the body.

To test airtightness along the joint of the body and the cover, an air hose from cylinder 12 is connected to the drain valve and the valve is immersed in a gasoline tank. The pressure in the drain valve is increased gradually to 6 kg/cm^2. Airtightness of the connections is tested for 3-5 minutes. In the case of improper airtightness of the valve, it is tested for proper fit of the cap or the nuts which attach the cover to the body are tightened. When necessary, the valve is ground with ГОИ paste.

Assembly and Testing of Fuel and Starter Nozzles

Fuel nozzles (Figures 207 and 208) are designed for injection of fuel into the combustion chambers.

Preliminary assembly of a fuel nozzle (see Fig.207) consists of selection and fitting together of the parts being joined: atomizer 9, atomizer chamber 8, atomizer washer 7 and nozzle jet 6. Adjustment of these parts is done by grinding their surfaces with polishing pastes.

Final assembly of the nozzle consists of the following operations: Two fuel filters, springs and connecting pipes are installed in the flange opening for fuel admission. Locknut 13 is screwed on the inner casing 5 and retaining washer 14 is installed. Into cup 11 are inserted in sequence, nozzle jet 6, atomizer washer 7, atomizer chamber 8, atomizer 9 and spring 10, and then the cup 11 is inserted into the nozzle casing 12. This is followed by screwing the nozzle casing with the inserted cups on the inner nozzle body 5, tightening of locknut 13 and turning the edge of the retaining washer into the nut opening. During the process of testing, the nozzles, when it it necessary, are partially disassembled for the purpose of substitution of parts or their grinding.

Assembly of the starter nozzle (Fig. 209) involves installation into the body of the filter 5, spring and connecting pipe 3, atomizer 4, needle valve 2, solenoid and other parts. Needle valve and atomizer must be carefully fitted to their seats. In the process of testing, the starter nozzles when necessary are also partially disassembled.

After they have been assembled fuel and starter nozzles are tested with kerosene on special installations.

Main operations in testing fuel nozzles involve testing: discharge, atomization angle, uniformity of atomization, airtightness of connections and classification of the nozzles according to groups.

The discharge of the nozzles and igniters is tested in an installation diagramatic arrangement of which is shown on Fig. 210. The fuel in tank 1 is heated by a hot water coiltto the required temperature. Then with the help of an electric motor 11 and pump 3 the fuel, through a surge tank 4 and throttle valve 5, proceeds through a reductor (to retain constant pressure) to nozzle 6. Valve 12 is opened to test the discharge, after which fuel flows into metering tank 13.

Nozzle discharge is tested at 10 and 45 kg/cm^2 pressure. At 10 kg/cm^2 pressure fuel consumption must be within the limits of 41.5 - 43.0 liter/hour. In testing the discharge at 45 kg/cm^2 pressure, fuel consumption for fuel and starter nozzles must be:

group 0 .... 377 - 385 liter/hour
group A .... 392 - 400 liter/hour
group Б .... 410 - 418 liter/hour

In case of greater or smaller discharge, the nozzles are disassembled and the discharge is made to correspond to the required technical conditions by means of grinding or substituting individual parts.

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Atomization angle (Fig. 211) and the absence of the jet along the flame cone of the fuel being atomized is tested in two positions of the nozzle (in second position the nozzle is turned by 45° from the initial) with the fuel pressure of 45 and 10 kg/cm^2. In the first case the atomization angle in both positions must be 76° ± 5°, and at pressure of 10 kg/cm^2--75° ± 5°/

Uniformity of the atomization is tested, on the installation shown on Fig. 212, with fuel pressure of 10 and 45 kg/cm^2. Irregularity of the atomization should not exceed 26%. If this value is not maintained, parts are ground. Irregularity of the nozzle atomization is calculated by formula

$$\delta = \frac{q_{max} - q_{min}}{q_{average}} 100\%$$

where δ - variation factor in %;

q_{max} - greatest volume of fuel in one of the 12 retorts of the installation;

q_{min} - smallest volume of fuel in one of the 12 retorts of the installation;

$q_{average}$ - average volume of fuel (determined as the volume of fuel in all retorts, divided by 12).

Airtightness is tested on installation (Fig. 213) for 3 minutes with fuel pressure of 250 kg/cm^2. Leakage of fuel at places of connection and welding are absolutely prohibited; in cases of leakage the end planes of parts are ground. Tubes which show leakages at their welds are substituted.

Preservation of fuel nozzles after their washing and flushing with gasoline is done with MK-20 oil which is heated to 110°C, and which is passed through the nozzle previous to the appearance of oil in the atomizer opening.

Sparking of the plugs in the starter nozzles, airtightness of the fit of the needle of the electromagnetic valve to the seat of the atomizer bushing, as well as the discharge of the nozzles, are tested.

The electrode is installed in a special installation (Fig. 214) and a wire is connected to the shielding of the plug from a high voltage source. A pressure of 1.2 - 1.4 kg/cm^2 is created in the chamber. Installation for testing of sparking is switched on for not longer than 30 seconds. During testing the spark must appear at both side-electrodes, alternately, and without missing. The clearance between the side and central electrodes must be 1.3 - 2.0 mm. The difference between the clearances should not exceed 0.05 mm.

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For the purpose of testing sparking of the starter nozzle, fuel hose is connected to the connecting pipe of the igniter; wiring from the low-voltage source is connected to the solenoid of the electromagnetic valve; wiring from high-voltage source is connected to the shield of the igniter and the installation is switched on. With fuel pressure not greater than 0.7 kg/cm^2 the plug should ignite the fuel. At this pressure the flame should not go out and should be steady for not less than 10 seconds. Then the fuel pressure is increased to 1.2 kg/cm^2. At this pressure the flame also should not burn out and must be steady for not less than 20 seconds. Ignition is tested twice at a 2 minute interval. In case of faulty ignition the atomizer is replaced by another.

Airtightness of electromagnetic valve of the starter nozzle is tested on the installation at fuel pressure of 3 atm for three minutes. In case of fuel leakage through the opening of the atomizer, the valve is ground to fit the seat of the bushing.

To test the atomization angle the nozzle is installed in the seat of the device. Fuel hose is connected to the connecting pipe of the nozzle and wiring from the source of low-voltage is connected to the solenoid of the electromagnetic valve. Atomization angle, which should not be smaller than 30° is tested at first with fuel pressure of 0.5 kg/cm^2, and then with pressure up to 2 kg/cm^2. At this pressure atomization angle must be not greater than 80°, otherwise the atomizer is replaced by another.

The discharge of the starter nozzle is tested on the installation with fuel pressure of 0.5 kg/cm^2. From 60 to 75 cm^3 of fuel must pass through the nozzle in 60 seconds, and when fuel pressure is increased to 2.5 kg/cm^2, from 135 to 150 cm^3 in the same period of time. In the case of greater discharge the atomizer is substituted, in case of smaller discharge its side openings are ground down.

After its testing the nozzle is assembled with its igniter.

Shifting the nozzle, along the surface of the casing, determines the anular clearance between the body of the igniter plug and the cylindrical part of the atomizer nut (not less than 0.1 mm). To test its airtightness, the assembled nozzle is immersed in a tank filled with pure gasoline, and air pressure of 5-6 kg/cm^2 is created in the nozzle. Absence of air bubbles in the tank during three minutes will show that the connections are hermitically sealed. In case of air lekage through the connecting pipe of the nozzle the needle valve is ground to fit the seat of the bushing of the atomizer or the solenoid spring is replaced by another. If the air leaks at the place of contact of the nozzle with the body, it is necessary to scrape the surfaces of the parts being joined and to replace the packing.

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Preservation of the starter nozzles is done in the following way. The nozzle is placed in the installation, fuel hose is connected to the connecting pipe, and wiring from the source of low-voltage is connected to the solenoid of the electromagnetic valve. The current is switched into the solenoid of the electromagnetic valve and for ten seconds the igniter is flushed with pure gasoline after which the current is switched off. Then, in place of the gasoline hose, oil hose is connected to the connecting pipe. The current is switched on again and the nozzle body is filled with MK-20 oil, heated to 110°C, until it appears at the nozzle's opening. Then the nozzle is immersed in MC oil tank for its outer preservation, this oil is also heated to 110°C.

10. Hydraulic and Pneumatic Tests of Engine Connections

Airtightness of fuel, oil, air and gas systems is an essential condition necessary for reliable operation of engine assemblies on the whole.

Leakage of fuel and oil, pollution of the air with oil, infiltration of gas into air cavities, and other defects may impede the normal operation of the engines.

Airtightness of the assembled assemblies and connections in the engines is achieved by high-grade processing of the surfaces being joined, absence of nicks, scratches or burrs on the surfaces; proper placement and good quality of packing - rubber rings, gaskets, etc.

Airtightness of assemblies and engines is tested with the help of hydraulic and pneumatic tests on special installations and devices.

The fuel system of a centrifugal compressor engine operates at low and high pressures. Each assembly and subassembly of this system is tested for airtightness.

Hoses of the fuel manifold, as well as the connecting hoses of the pumps, throttle valve, distributor, servopiston, etc., are subjected to hydraulic tests with kerosene under 160 kg/cm^2 pressure for three minutes. The distributor of fuel manifold is tested with kerosene under 110 kg/cm^2 pressure for three minutes. The assembled manifold is placed for its testing in an installation and connected to a device (Fig. 215). Pressure of 60 kg/cm^2 is created in the manifold, at which for three minutes there should be no leakage of fuel in the connections.

After their assembly, fuel nozzles are hydraulically tested in a special installation (Fig.216). To the connecting hose of the line used during idling operation of the engine a kerosene hose of the installation is connected and the opening of the connecting hose of the line used during operation of the engine at high revolutions is closed. Before the test, air is pumped out of the main line of the installation through an opening in the nozzle, after which the opening of the nozzle is closed with a device. A pressure of 250 kg/cm^2 is created in the main line and the tests are conducted with kerosene for three minutes.

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The nozzles of the fuel system of an axial-flow compressor engine are tested with kerosene under 70 kg/cm2 pressure for two minutes.

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Fuel filters, stop-valve, throttle valve and other assemblies are hydraulically tested, discharge tested and are flushed immediately after their assembly.

Fuel system of a centrifugal compressor engine, both of low and high pressure are hydraulically tested in an assembled engine with the help of an installation shown on Fig. 217. Previous to the test, after the passages of the assemblies (stop-valve, throttle valve, etc.) have been opened, the air must be pumped out of the main line.

To test systems of low and high pressure the necessary pressure is created with the help of adjusting of valves 7 and 8 of the installation. Pressure for testing of low pressure is fixed at 1.7 - 2.0 kg/cm2 and at 60 kg/cm2 for high pressure.

Fuel system of an assembled axial-flow compressor engine is tested with a mixture of 97% gasoline and 3-4% MK oil; pipe lines of high pressure are tested at 80 atm pressure while those of low pressure at 2 atm.

For better visibility of connections of the systems kerosene is tinted with "sudan" paint.

The housings of front, center and rear bearings and other assemblies of a centrifugal compressor engine are tested hydraulically. Testing of housings is conducted on an installation (Fig. 218) for the purpose of determining the quality of the connections of the pipe lines and of the nozzles leading to the seals. For that purpose a solution of 65% of transformer oil and 35% of kerosene at 3.0 - 4.0 kg/cm2 pressure for 1-2 minutes is used.

Pipe lines are tested after the housing of the rear bearing has been connected to the housing of the center bearing and the tubes have been fastened to the intermediate connections. The cover of the center bearing with all entering parts is connected for its testing to the housing of the center bearing.

Pipe lines of the oil system, located on the outside of the centrifugal compressor engine, are tested with transformer oil in an installation (Fig. 219). In the assembled axial-flow compressor engine, besides the above described tests, the following are also tested: the condition of couplints between the accessory drive power take-off housing, and accessory drive gear case and other assemblies, starter drive and accessory drive power take-off housing, oil discharge box and the accessory drive power take-off housing and other connections; testing is done with air which is admitted into the inner housing under o.5 atm pressure during the time necessary for inspection. For a more convenient inspection butt joints are covered with a soap solution.

To prevent oil from penetrating into air recesses of the engine, seal rings and labyrinth seals are used.

Fig. 220 represents the assembly of a housing with seal rings. Contact of rings with the surface Б is tested by pouring a solution of oil and kerosene into the recesses of the assembly. To test the quality of the contact of the rings the shaft is turned on its axis by 1-1 1/2 turn and after one minute a test is conducted for leaks in A surface. If, during 10 minutes, when the shaft is turned there is no leakage, the contact of rings is good. Paint is also used to test the quality of ring contact.

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CHAPTER IV

FINAL ASSEMBLY OF ENGINES

1. ORGANIZATION OF ASSEMBLY IN THE ASSEMBLY SHOP

Assemblies and accessories can be put together either in the assembly shop or in the assembly departments of accessory and mechanical assembly shops; the final assembly of an engine, as a rule, is done only in the assembly shop. This is due to the fact that the technological process of the final assembly of an engine has its clearly defined assembly sequence without resorting to mechanical treatment or welding during the assembly.

An engine is put together in its final form from assemblies, accessories, and parts supplied to the assembly shop by accessory shops, supply plants, and mechanical-assembly shops or from assemblies put together directly in the assembly shop. Assemblies, accessories, and parts prepared by other shops and supply plants arrive in the assembly shop through the warehouse of finished parts and assemblies. On receiving parts and assemblies from the warehouse, the assembly shop checkers verify the matching of mating parts, and the presence of all the necessary technical documentation.

Before the assembly, all parts and a portion of assemblies undergo washing; a portion of assemblies undergo depreservation and flushing. During the washing particular attention is paid to the cleanliness of oil and fuel lines.

Thereupon technical control inspectors check the presence of acceptance marks, matching of mating parts, and conformance of data contained in technical documentation and testing certificates with technical conditions; they also inspect visually parts, assemblies, and accessories, ready for assembly, for minor damage (during transportation and washing). All minor defects noted by either the inspector or a worker are eliminated on the spot.

If, in the process of final assembly, it becomes necessary to select parts according to either dimension or weight, this operation is accomplished by the technical control inspector who puts on marks to show that the parts match and if necessary, the number of the engine. All instances of mounting on the engine individual parts and deviating from standards permitted by the chief plant inspector or the customer are recorded in appropriate documents; these are preserved in the engine file. The file also contains all technical documentation, records, forms, and other papers connected with the manufacturing and testing of parts, assemblies, and accessories from which the engine is put together.

Because of large dimensions and substantial weight of parts, final assembly work places ordinarily are set up in a straight line, following a strict sequence, so as to make it more convenient to move the object being assembled from one work place to another.

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2. ASSEMBLY OF ENGINES WITH CENTRIFUGAL COMPRESSORS

Inspection of coaxiality of supports is the preliminary operation preceding the final assembly of engines. Let us examine an engine with three bearing supports (Fig. 250) and let us investigate the checking process for coaxiality of these supports.

Discs with shaft cutouts are inserted into ID of tightly fitted support steel rings (Fig. 251). Clearance between the shaft OD and the disc ID must be the smallest possible (0.02 mm at the most). In order to obtain more correct results of checking for coaxiality, the engine is set up in vertical position, whereupon the shaft is inserted into the disc cutouts. The shaft shall pass through without jamming and rotate freely in the cutouts. An indicator is mounted on the journal.

If the engine has several supports, coaxiality is checked with the aid of the shaft which is alternately inserted into the disc cutouts located in the engine supports.

This is the way the checking is done, with the aid of an indicator, of the overall free play of bearing supports in relation to the shaft rotated in the discs. Tolerances for free play are determined depending on the diameter of the support (for example, free play of 0.04 mm at the most is permissible for diameter of 125 mm).

Greater free play of supports indicates incorrect position of parts in regard to each other; it is alleviated by either shifting or selecting proper parts. In the absence of locking elements (a bead, a bolt,) the parts are shifted along the generatrix at the expense of clearances between the holes and the pins with which the part is fastened. Parts with locking elements may only be properly selected.

Coaxiality of labyrinth seals is inspected after they had been installed according to clearances between them and the rotor shafts.

Fig. 252 illustrates devices for checking the mutual position of the seal and the outer bearing race with the aid of an indicator as well as with the aid of a disc and a shaft, which shall move smoothly and without jamming in the disc cutout in the case of coaxiality. In addition to the above methods, coaxiality of seals may be checked by devices used for checking coaxiality of bearing supports. The lack of coaxiality is alleviated by proper seals.

The order of checking coaxiality of two or four bearing supports does not differ in principle from checking coaxiality of three supports in engines with either centrifugal or axial flow compressors.

The final assembly of an engine with centrifugal compressor begins from the drive assembly (cf. Fig. 250) consisting of the following basic components: compressor casing 1, compressor rotor 2, front and rear truss rings 3 and 4, bearing housings-center 5 and rear 6, fan impeller 7, nozzle inlet ducts and nozzle 8, and turbine rotor 9.

Assembly of the drive is accompanied by inspection and, if needed, adjustment of the following axial and radial clearances and dimensions:

1. overall axial clearance between the compressor rotor and casing;
2. axial clearances between the compressor rotor and the conical portion of the casing and between the rotor and the casing cover;
3. distances between the turbine rotor coupling face and the rear bearing housing flange face;
4. axial clearance between the fan impeller and the rear wall (diffussor);
5. axial clearance between the nozzle labyrinth seal face and the turbine rotor disc as well as radial clearance between the seal crowns;
6. radial clearance of the turbine rotor in the bearing;
7. radial clearance between the turbine rotor blades and its casing;
8. axial clearance of compressor rotors and the turbine in the drive.

In order to adjust the overall axial clearance ΔA_1 (Fig. 253) between the rotor and the compressor casing, the latter is set up on an assembly stand and then:

a. the rear truss ring is lowered onto the casing with the aid of a sling (Fig. 254) and then turned 180°;
b. the compressor rotor is mounted with the aid of a fixture (Fig. 255);
c. the casing lid and the front truss ring are mounted on the compressor casing.

To determine the axial shifting of the rotor in the casing, a jack shown in Fig. 256 is attached to the flange of the front truss ring, and a fixture shown in Fig. 257 is attached to the rear truss ring; one of them serves the purpose of determining the clearance, the other -- for determining the shifting of the rotor along its axis.

Upon lifting the rotor with the fixture handle (Fig. 257) as far as it would go, reading of the axial shifting of the rotor is taken from the gage (Fig. 256); it will be the overall axial clearance $A_1 \approx$ 2.5 - 3 mm. Then the compressor rotor must be mounted in operating position, i.e., this clearance must be divided into ΔA_2 and ΔA_3 clearances (Fig. 258). For this purpose, the compressor casing is set up in horizontal position. A jack (Fig. 259) is attached to the front truss ring so as to prevent the rotor from turning; thereupon the casing is set up in vertical position (the front truss ring facing downward).

In order to check and, if need be, adjust these clearances, the following operations are performed:

a. a gasket (a seal), an adjusting ring, and a second gasket are placed on the flange studs of the center radial thrust bearing cover (Fig. 260);
b. the cover of the center bearing is placed on the rotor shaft;
c. the splined coupling is inserted into the shaft splines and, together with all parts, is tightened by a nut; thereupon a drive coupling is mounted onto the driven one;
d. the center bearing housing is mounted on the rear truss ring; in doing this, the cover is connected by studs with the inner lug of the bearing housing;
e. a jack (Fig. 261) is attached to the center bearing housing so that the gage leg would rest against the driven coupling end.

Clearances are checked as follows. After unscrewing the casing cover nuts of the center bearing (cf. Fig. 260), the rotor will drop until reaching the casing cover. In this position of the rotor as determined by the gage, a clearance equal to the overall clearance ΔA_1 will be obtained between the rotor and the compressor casing cone section.

Then, as the center bearing cover nuts are uniformly tightened, the rotor will rise and assume a position corresponding to its operating condition, i.e., ΔA_2 clearance determined from gage reading will be obtained.

Thus, it is possible to calculate ΔA_3 clearance with the aid of ΔA_1 overall clearance and ΔA_2 clearance. While conducting this calculation, the axial play of the radial thrust bearing, equal to 0.6 mm, is taken into account.

ΔA_3 Clearance is calculated from the formula

$$\Delta A_3 = \Delta A_1 - \Delta A_2 - \Delta_4$$

where ΔA_2 - clearance between the casing cover and the rotor;
ΔA_1 - overall rotor clearance in the compressor casing;
ΔA_3 - clearance between the compressor cone section and the rotor;
Δ_4 - axial play of the bearing found upon measuring.

An example:

$$\Delta A_1 = 3.0 \text{ mm};$$
$$\Delta A_2 = 1.7 \text{ mm};$$
$$\Delta_4 = 0.6 \text{ mm};$$
$$\Delta A_3 = 3 - 1.7 - 0.6 = 0.7 \text{ mm}.$$

If needed, the desired clearances may be adjusted by selecting a proper thickness of the adjusting ring found under the center radial thrust bearing cover. The thickness of the adjusting ring is selected so that ΔA_2 and ΔA_3 clearances are assured within the desired tolerances.

Turbine rotor is secured in regard to the compressor assembly, particularly in regard to the compressor rotor, by a bearing which must be mounted so that the position of bearing rollers would coincide strictly with the inner race of this bearing mounted on the turbine rotor shaft (Fig. 262).

In order to determine this position, $\triangle B_1$ distance is checked between the turbine rotor coupling end and the rear bearing housing flange face. For this purpose, the rear bearing housing is mounted on the center bearing housing. With the aid of a lifting fixture (Fig. 263), the turbine rotor is inserted into the rear bearing housing and engaged with both the driven and the drive couplings, after which. $\triangle B_1$ distance is checked with the aid of the gage (Fig. 264).

The required distance is obtained by selecting the thickness of the adjusting ring under the cover of the center radial thrust bearing. When substituting this ring for another (according to thickness), it is necessary to maintain $\triangle A_2$ clearance between the compressor casing cover and the rotor, for which purpose the adjusting ring under the radial thrust bearing (Fig. 258) is also replaced. If the adjusting ring of the center bearing cover is of greater thickness, the adjusting ring under the bearing is correspondingly selected to be one size thinner, and inversely; thus, $\triangle A_3$ clearance is also maintained.

After checking $\triangle B_1$ distance, the turbine rotor is disengaged and taken out of the casing; the rear bearing housing is taken off.

While assembly operations are in progress, free play of the spherical surface of the driven splined coupling is checked. For this purpose, there are installed on the back support: the fan impeller assembly together with the impeller mounted on the rotor shaft, the center bearing cover, and the driven splined coupling attached to the shaft by a tightening bolt. After placing the gaskets on the cover, the casing is mounted on the rear truss ring instead of the center bearing housing. Free play of the spherical surface is checked at a distance of 2 mm from the surface of joining (Fig. 260) with the aid of a gage mounted on the housing surface. During the check, the compressor rotor is turned 360°. The permissible free play (up to 0.03 mm) must provide for a normal connection between the sphere of the drive splined coupling and the spherical turbine rotor tip. After checking the free play, these parts are taken off for further checking of clearances and assembly.

Fig. 265 shows the impeller assembly consisting of the following basic parts: impeller to be mounted on the real compressor rotor shaft, fan front cover, and fan rear wall (diffuser).

When mounting the fan on the rear compressor rotor shaft, it is necessary to check and adjust $\triangle A_4$ clearance between the fan impeller and the front cover face, and $\triangle A_5$ clearance between the impeller and the rear wall surface.

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In doing this, a device preventing the compressor rotor from turning is mounted on the front truss ring while the rear truss ring receives the front cover of the fan impeller. The impeller fan is mounted on the rear compressor rotor shaft splines with the aid of a check and locked with a nut (Fig. 266). A_5 distance, measured by a depth gage, determines the position of the impeller in relation to the front cover plane without the adjusting ring.

Thereupon the impeller is taken off by means of a puller (Fig. 267) to install the adjusting ring. The impeller is then mounted on the aft shaft splines and locked with a nut. Distance A_6 is then measured to determine the position of the impeller with the adjusting ring on in regard to the face of the front cover.

Consequently, ΔA_4 clearance between the fan impeller and the front cover is adjusted by selecting a proper thickness of the adjusting ring and calculating it from the formula

$$\Delta A_4 = \Delta A_2 + (A_6 - A_5),$$

where ΔA_4 ----- clearance between the compressor casing cover and the compressor rotor:
ΔA_6 ----- distance between the fan impeller front cover face and the impeller tip after installing the adjusting ring;
ΔA_5 ----- distance between the front cover face and the impeller tip without the adjusting ring.

For example, $\Delta A_2 = 0.7$ mm, $A_6 = 20$ mm, $A_5 = 19$ mm.

Clearance, $\Delta A_4 = 20 - 19 + 0.7 = 1.7$ mm.

For determining ΔA_5 clearance by means of a depth gage, A_7 distance is measured in the fan rear wall, i.e., from the wall surface to the fan front cover surface.

ΔA_5 clearance to be determined is calculated from the formula

$$\Delta A_5 = A_7 - A_6 - \Delta A_2 - \Delta_4,$$

where A_7 - distance between the rear wall plane and the front cover plane;
A_6 - distance between the front cover plane and ring impeller tip after mounting the adjustment;
ΔA_2 - clearance between the compressor casing cover and the compressor rotor;
Δ_4 - axial clearance in the radial thrust bearing selected after measuring.

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For example, A_7 = 22.5 mm; A_6 = 20 mm; ΔA_2 = 0.7 mm; Δ_4 = 0.6 mm; ΔA_5 = 22.5 - 20 - 0.7 - 0.6 = 1.2. ΔA_5 clearance is adjusted by a proper selection of thickness of the fan rear wall and the adjusting ring.

The technological process of the engine drive air system assembly consists of the following operations and is accompanied by a check and adjustment of tolerances desired:

1. joining the rear truss ring and the compressor casing;
2. placing the rotor into the casing;
3. mounting the cover on the casing;
4. joining the front truss ring, which includes the front roller bearing housing and the compressor casing;
5. adjusting the fan impeller front cover and mounting the fan impeller on the rotor shaft;
6. connecting the front cover and the fan impeller rear wall (diffuser);
7. mounting the radial thrust ball bearing cover on the shaft;
8. joining the center bearing housing with the rear support and its inner lug with the ball bearing cover;
9. mounting the driven splined coupling in the rotor rear shaft.

Let us examine the further engine assembly process, i.e., assembly of its hot section consisting of the following basic components: rear bearing housing, ring and tube assembly, turbine rotor, and exhaust cone.

The rear bearing housing is mounted on the center bearing housing. Nuts, brace bushings, and sealing gaskets (Fig. 268) are placed on the ends of oil lines (both suction lines and pressure lines). In order to check the quality of joint seals, the assembly undergoes hydraulic testing using transformer oil under the pressure of 3-4 kg/cm^2. Leakage of oil in joints is absolutely not permissible.

Fig. 269 shows the labyrinth seal of the nozzle inlet ducting and the turbine rotor disc. It is needed to determine ΔB_2 clearance between the labyrinth seal face and the rotor disc as well as the radial clearance ΔB_3 between the labyrinth seal (teeth) and the turbine rotor disc. To do this, a lifting yoke (Fig. 270) is used to mount the nozzle inlet ducts on the rear bearing housing. The yoke is attached to the housing flange for positioning the turbine rotor. Then the adjusting ring and the labyrinth seal are mounted on the inner ring of the nozzle, after which eight lead check plates, 15-20 mm in length and 1.5-2.0 mm in thickness, are placed on the seal teeth along the circumference (Fig. 271).

Using this yoke, the turbine rotor is lowered into the rear bearing housing until it reaches the lead plates; then the rotor is secured by a screw on the yoke. Thereafter ΔB_2 clearance is checked at eight points which are uniformly located along the circumference, using a clearance gage inserted into the vane joints (Fig. 272). ΔB_3 clearance is determined from the thickness of imprint upon the lead plate. ΔB_2 and ΔB_3 clearances are obtained by selecting the thickness of adjustment ring or replacing the labyrinth seal.

Thus, assembly of the hot section of the engine consists of the following operations:

1. joining the rear and center bearing housings;
2. mounting the ring and tube assembly on the rear bearing housing;
3. installing the rotor in the rear bearing housing and joining the rotor shaft with the compressor rotor shaft;
4. attaching the turbine casing to the nozzle diaphragm flange.

Following the drive assembly, the radial clearance of the turbine rotor in the roller bearing is checked with the aid of a special gage.

This gage (Fig. 273) consists of a clamp with indicator 1 and flange sleeve 2. Flange sleeve 2 is attached to the turbine rear flange by three screws while clamp 1 is attached to the turbine casing. The indicator measuring pin is mounted on the sleeve contact ring; then the magnitude of the turbine radial clearance in the roller bearing is determined by pushing the turbine rotor behind the sleeve pivot bolt in two opposite directions.

Radial clearance between the turbine rotor blades and the casing (Fig. 274) is checked by turning the rotor 30°. If the desired clearance (~ 1.7 - 2.0 mm) is not obtained, a proper turbine casing is selected.

Axial clearance of rotors in the drive (0.6 - 0.7 mm) is checked with the aid of a jack (Fig. 256). When checking, the jack is mounted on the front casing while the splined coupling is locked.

Rotors shall turn smoothly, easily, and noiselessly. Before proceeding to the further assembly of the drive, a control inspection is carried out, in the course of which check is made of the presence of all parts, closure of all openings by dampers and hoods, presence of all papers, etc.

Assembly of engines with centrifugal compressors calls now for mounting on the drive the fuel manifold, oil lines, combustion chambers, drain system parts, spray nozzles, gearbox, their accessories and piping, exhaust cone, ignition assembly, and other parts and components.

Before mounting combustion chambers on the drive, the threading of crossover pipe nuts (Fig. 275) is greased with graphite-containing lubricant consisting of 50% scale graphite and 50% MS oil* One side of the copper-asbestos gasket disc is greased with BU paste.

* Analyst' Note: Light, selectively refined motor oil.

After mounting the chambers with spherical rings in their proper places, the nuts on bolts joining together the chamber intake and exhaust ducts are pretightened so that these rings would uniformly touch the pipes; the nuts on crossover pipes are likewise pretightened. Then the nuts on bolts and pipes are tightened as far as they would go. Clearance between the chamber shrouds - it must be at least 0.5 mm-is checked; then the fit of chamber shrouds in the nozzle diaphragm adapter flanges is also checked with a feeler (Fig. 276).

Taking into account expansion of parts in the combustion chamber under the effect of relatively high temperatures while the engine is in operation, the nuts on bolts connecting intake and air adapters (Fig. 277) are loosened so that it would be possible to turn them using a wrench with 0.4 kgm torque. Thereupon the bolt nuts are safetied with counternuts.

Before mounting the gearbox on the flange of the engine front truss ring, distance A (Fig. 278) is measured between box flange plane and the plane end under the roller bearing. This distance determines the axial shifting of the spring connecting the gearbox with the compressor rotor front shaft. The lack of the necessary clearance may result in spring "thrust". The moment the box is joined to the truss ring, particular attention shall be paid to the connection of air and oil lines; it must be absolutely airtight.

Before the final joining of the exhaust cone to the turbine casing, clearance between the turbine disc and the inside cone of the duct (Fig. 279) is checked according to formula

$$X = A - (B-C),$$

where X - clearance to be determined;

A - distance between jet cone attachment flange and the end of the inner cone;
B - distance between the end of the centering ring of the turbine casing and the exhaust cone attachment flange;
C - distance between the end of the turbine casing centering ring and the turbine disc with a radius of 237 - 239 mm.

All these distances are measured to determine the clearance.

After mounting all the parts and assemblies on the drive, airtightness of fuel line connections is checked and the oil lines are flushed.

Before carrying out a hydraulic test on the stand, air is evacuated from fuel pumps and lines by flushing through and opening drain valves. Low pressure lines are tested under 1.5-2.0 kg/cm^2 pressure and high pressure lines, under 60 kg/cm^2 pressure. In either case leakage in the joints is absolutely intolerable, with the test lasting for 3 min. Fuel used for running the engine is also used for testing. The engine oil line is flushed with transformer oil for 3-4 min. at the pressure of 1.5 - 2.0 kg/cm^2 and oil temperature of 15-30°C. In this case (without turning the engine rotor), the oil passing through the front, center, and rear bearing spray nozzles would flow from the drain pipe and the orifice in the oil pump box. No oil inflow is permitted in the joints between parts and assemblies during the flushing.

The final inspection and preparation of the engine for testing stand (Fig. 280) consists of a check of the rotation of rotors, availability of all parts, dampers covering all external orofices, documentation, etc. However, external safetying of engine parts sent for acceptance tests may be omitted.

3. ASSEMBLY OF ENGINES WITH AXIAL-FLOW COMPRESSORS

Assembly of engines with axial flow compressors is also accompanied by inspection and, if needed, adjustment of radial, and other clearances, because their proper adjustment must provide for the desired interlinking of all parts and assemblies.

Let us examine the basic assembly processes for one of the engines of this type. Fig. 281 shows its individual parts, subassemblies, and assemblies. The compressor rotor must be positioned in the stator (Fig. 282) so as to provide for the following values.

Distance A between the first rotor disc and the gearbox flange plane determining the position of the rotor in regard to the box;

ΔA_1 clearance between the eighth disc and the support labyrinth;

ΔA_2 clearance between the splined rotor drive sleeve and the rear bearing nut, precluding a possibility of the sleeve's thrust on connecting the stator and the support.

Furthermore, radial clearances are inspected between the rotor blade tips and the corresponding surfaces in the stator as well as **axial** clearances between the rotor blades and guide vanes mounted in the stator.

ΔA_2 and ΔA_1 clearances are checked after connecting the stator with the gearbox and the support. To do this, the lower half of the stator is joined first and then removed after taking measurements; the upper half follows next. In order to avoid deformation of parts, a spreader (Fig. 283) is used. It is made of a pipe with two sectors welded onto it; they are employed to attach it with bolts to the gearbox and support flanges.

Distance A, which in the given case may amount to 54-54.4 mm, must be obtained as a result of maintaining precise tolerances during the machining of gearbox and disc flange planes. ΔA_1 clearance is adjusted by selecting the thickness of adjusting ring on the rotor front bearing, after a final tightening of the nut which secures the sleeve and the inside ring of this bearing; it measures 1.8 - 3.2 mm.

ΔA_2 clearance is adjusted by a proper selection of thickness of lock safetying the rear bearing nut.

Radial clearances between the blade tips and the corresponding surfaces in the stator and axial clearances between the blades and the guide vanes are obtained basically as a result of machining the parts within the limits of tolerances indicated in the blueprints; they measure 1.3 mm (radial clearances) and from 1.3 to 5 mm (axial clearances) on the front shaft side and from 2.2 to 5 mm, on the rear shaft side.

To prevent in the process of putting together this assembly the deformation caused by a large number of joints, a strict sequence of operations is established. During the final mounting of the stator, the templet bolts joining together the stator halves are tightened in the following manner: the first bolt - from the left stator side; the second bolt - from the right side; the third bolt - from the right side; the fourth bolt - from the left side; and then all templet and ordinary bolts - from both sides. After the stator had been joined together, it is connected with the support, whereupon the gearbox is connected first with the upper stator half and then with the bottom one.

The suggested system of tightening this assembly when putting together engines of such type ensures normal operations without unnecessary strain on the parts.

The hot section of the engine (Fig. 281) is made of a support casing, a combustion chamber unit - tube and ring assembly - turbine rotor, and the exhaust cone.

The ring and tube assembly (Fig. 284) is mounted between the compressor and the gas turbine inside the support casing. Chamber orifices terminate in support air windows where they can freely expand due to thermal deformations. The ring and tube assembly (along the large ring) and the exhaust cone, are attached by an outer nozzle flange to the rear support casing flange (Fig. 285). The inner nozzle flange (Fig. 284) receives diaphragm 7, the nozzle ring (along the small shroud), the ring plate, and the turbine rotor shroud. The plate and the shroud have an outer and an inner flange. They are attached by an outer flange (Fig. 128) and distance bushes 13, together with the small part of the nozzle ring and the outside flange of the diaphragm, to the inner nozzle flange, using bolts 14; inner flanges together with the diaphragm are attached to the turbine rotor rear bearing casing, using bolts 27.

Air for cooling the front surface of the disc and the turbine rotor blades is supplied from the support air lines through pipes 18 and 19, welded to both the plate and the shroud.

Having been previously put together, the support assembly for mounting the ring and tube assembly is partially disassembled, i.e., the rear turbine rotor bearing is removed. After installing the component in a definite position with regard to the support, the rear bearing is reinstalled in the support; then the ring and tube assembly receive the nozzle ring plate, the nozzle ring, and the rotor shroud.

During the final assembly of the hot section of the engine, the following axial and radial clearances (Fig. 285) are checked and, if needed, adjusted:

$\Delta\delta_1$ between the nozzle ring flanges and the exhaust cone flange;

$\Delta\delta_2$ between the nozzle ring flange diameter and the rotor blade tips;

$\Delta\delta_3$ between the nozzle ring and the rotor disc surfaces

$\Delta\delta_4$ between the rotor shroud and the exhaust cone shroud.

$\Delta\delta_1$ and $\Delta\delta_2$ clearances are within tolerances established during the machining of interlinking parts.

$\Delta\delta_3$ and $\Delta\delta_4$ clearances are adjusted by selecting the thickness of adjusting ring 26 mounted on the rotor shaft between the inner roller bearing race and the seal housing (Fig. 128).

$\Delta\delta_5$ and $\Delta\delta_6$ clearances are adjusted by selecting the thickness of the adjusting ring under the exhaust cone shroud.

The final assembly of this unit now breaks down in to the following (Fig. 128). The rotor is inserted into its support and passed through the opening of the inner race of ball bearing 5. The gear teeth of the sleeve 4 must engage with the scavenger oil pump gear. Then a heated seal housing 3 is forced upon the shaft end, and nut 2 is tightened and safetied by lock 1. Rotor shaft splines receive a splined spring 28 connecting the turbine rotor with the compressor rotor.

To check the tightness of the turbine rotor casing seal, oil, preheated to 80-100°C, is poured into the assembled support cavity. The seal must not leak any oil on turning the rotor manually for 10 min.; otherwise the seal must be replaced.

This completes assembly of the hot section of the engine, which then is connected with the compressor rotor. After the connection, the rotor should turn smoothly and noiselessly. The exhaust cone is attached to the support casing flange.

The rest of the engine assembly is as follows (Fig. 281). Starter motor is connected to the central drive assembly flange, piping is led to it, and the motor dome is installed. Then the intake assembly (the diffussor) is attached to the box flange; the intake assembly is combined with the starter motor gasoline tank and the oil tank. Installation of this assembly is followed by connection of proper piping.

Accessory drive box is attached to the gearbox and connected, by means of a spring, to the main gear assembly. Landing gear pumps, basic fuel pumps, deaerator, tachometer generator transmitter, and generator RPM governor are mounted on the

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box. Exhaust cone operating gear, combustion chamber ignition plugs, and other accessories are mounted on the compressor stator.

After installing power lines, they are connected with oil and fuel lines as well as electric conductors and equipment. Gas control rod is adjusted for two extreme positions of the lever; RPM control handle on the instrument panel must reach the rests of adjustment screws "Stop" and "Full Gas."

To check the tightness of connection places for accessories, shrouds, etc., found on the outer contour of the engine, the assembled engine is air-tested at the pressure of 0.5 kg/cm^2 introduced into its inner cavity.

Fuel and oil lines in turn undergo hydraulic testing; no fuel and oil condensation, not to speak of leakage, is permitted under any circumstances. Thereupon the engine is flushed with oil under pressure.

Assembly of an engine with axial flow compressor (Fig. 286) ends with its visual inspection and check of the revolution of rotors and its preparation for shipment and acceptance tests; this is followed by the check of the presence of all engine parts and execution of technical documentation for the final engine assembly.

CHAPTER V

ENGINE DISMANTLING AND REASSEMBLY

1. ENGINE DISMANTLING AND TROUBLE FINDING

General Dismantling and Trouble-Finding Conditions

Following an acceptance test, every engine undergoes dismantling for the purpose of determining the condition of its parts and assemblies.

The process of engine dismantling and elimination of defects after the acceptance test consists of the following operations:

a. Disassembly of engines into assemblies and disassembly of assemblies;

b. washing of all parts and assemblies;

c. inspection of all parts and assemblies for the purpose of trouble finding;

d. elimination of defects or replacement of parts.

Engines are dismantled in the premises, equipped for that purpose and situated alongside with the washing department in the assembly shop so as to save time on transportation. Premises for dismantling must be equipped with hoisting devices (block and tackle lines) for taking the components off the engine. In the same premises there are placed stands with felt discs, vats with aqueous solution and water for cleaning from scale certain parts, such as turbine rotor blades, certain combustion chamber parts, etc., as well as air lines for drying of parts. Because of the presence of such vats, the premises are equipped with intake and exhaust ventilation. The floor in the premises has a track along which stands are moved with engines set upon them, making it possible to provide for appropriate order and sequence of dismantling.

Dismantling work places must be equipped with devices (puller chucks, etc.) and tools (open end, socket, and special wrenches). Tools selected for each operation are kept in special mobile boxes. Maintaining such an order is conducive to the application of more efficient methods and it improves dismantling standards.

To prevent oil and fuel from contaminating the floor upon discharge from pipe and accessory openings during the dismantling, catch basins are placed under the engine or the unit being dismantled. Special containers are provided for sorting, storing, and transportation of parts, assemblies, and accessories.

On receiving from the test station the engine in the dismantling shop, it is taken off the transport dolly and placed onto the dismantling stand. Parts, accessories, etc. are inspected visually and then cleaned off dust and oil.

During the disassembly of engines into components and disassembly of components, in order to avoid dents and scratches on the parts, one shall: use devices and tools which are prescribed by the shop process; use aluminum or wooden punches; carefully watch a correct attachment of pullers; drive out the parts smoothly, avoiding skewing. Before taking off parts and assemblies, one shall check whether all nuts and bolts are unscrewed and washers taken off.

Accessories received from another factory (fuel pumps, regulators, generators, electrical equipment) are not disassembled, as they undergo acceptance and control tests at the supply plant.

After dismantling, the parts are sorted into groups, i.e., parts in need of cleaning from scale and sealing materials and parts to go for immediate washing with soap and aqueous solution.

After cleaning and washing, engine parts and assemblies go to the control rack where they are placed in a strictly determined (permanent) order by assemblies.

Racks must be well illuminated. In addition to general illumination, portable low-voltage hand lamps are used when inspecting engine parts.

The control rack is supervised by the shop technical control department.

Technical control department personnel (control foremen and inspectors) thoroughly inspect parts and assemblies of every engine, note their defects, and enter them in special defect reports.

The trouble-finding process consists of visual inspection of parts and assemblies, using, if need be, optical instruments and carrying out control measurements and other checks.

A trouble-finding inspection is done with the goal of getting a clear picture of the condition of parts and determining their fitness for further operation. Simultaneously with the finding of defects, visual inspection, and measuring, a report on defects is drawn up and a measurement card filled out. The nature of defect, the method of elimination, and the conclusion about the inspection results is entered in the report, against every listed part and assembly. The report is filled in as follows:

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Part, assembly, and accessory	Defect	Conclusion
Rear truss ring	Dents on outer and inner strut surfaces	Dents of not more than 1 mm in depth to be dressed
	Scratches and tears on fitting straps	Dress
Front truss ring	A crack by the flange	Reject

This report, as well as the other documents (measurement cards, conclusions for individual parts, etc.), is the basic document for elimination of defects and provides the basis for replacement and order of parts.

Inspection of parts is done for each assembly in its entirety. While taking measurements, particular attention is paid to the cleanliness of surfaces of parts being measured. The extent of fitness of parts and the results of measurement are determined from fitness charts, technical conditions, and other documents.

The magnifying glass, the micrometer, indicators for inner and outer measurements, and others are the basic control instruments for inspection and measurement of parts.

Parts with defects which cannot be eliminated as well as the rejected parts must be replaced by new ones. In the case of rejection, some of the parts are replaced by new ones while the most important parts are replaced by ones which had previously passed acceptance tests on another engine. Tools and devices used in trouble shooting must provide for the required precision and cleanliness.

Work places for inspection for defects must be set off the places where the final assembly of components and engines takes place.

After elimination of defects and acceptance of parts and components, the technical control department personnel take up the assembly of components. The assembled components, together with corresponding documents, are set aside for the final assembly of the engine.

<u>Dismantling of Centrifugal Compressor Engines</u>

Dismantling of an engine with centrifugal compressor begins from taking off the exhaust cone. Then the following parts and components are taken off the engine in this sequence:

air intake collector;
electric lines;
fuel and oil lines;

accessories;
spray nozzles;
drain lines;
combustion chambers;
turbine rotor;
nozzle inlet ducts and rear bearing housing (Fig. 287);
fuel intake manifold;
center bearing housing (Fig. 288);
fan impeller;
front truss ring with the front bearing housing (the assembly) and cover (Fig. 289);
compressor rotor (Fig. 290);
rear truss ring;
combustion chamber air adapters off the compressor casing, whereafter the compressor casing is taken off the dolly;

Since certain parts operate at high temperatures, the following clearances are checked during the dismantling of engines: axial clearances between the turbine rotor disc and exhaust cone cover.

Radial clearance between the rotor blade tip and turbine casing and between the combustion chamber outer tube rings and nozzle orifices; and also between the turbine rotor and the rear bearing; and axial clearance of rotors in the drive.

Radial clearance between the blade tips and the casing is checked with a clearance feeler along the circumference. The gear box and the oil pump box are dismantled to check axial and radial clearances of ball and roller bearings, inspection of gear teeth, drives, and oil pumps (both scavenge and pressure pumps), oil filter shaft sleeves, and other parts. To do this, the oil pump box is taken off the gear box, as are the gears of the bevel drive gearwheel component of oil and fuel pumps, driving conical starter and tachometer wheel, and idle gear. Pumps, low and high pressure oil filters, and other parts are taken out of the oil pump box. Strippers are used for pushing out bearings, sockets, and other parts inserted in their seats. During dismantling one shall check the condition of adjusting rings with which axial clearances of shafts and engagement of gear teeth are set.

Before dismantling the gear box, the following clearances in the gear teeth are measured in the case of necessity:

a. driven and drive spur gears;
b. driven and drive starter gears;
c. driven and drive bevel gears;
d. driven bevel gear and idler drive gear;
e. driven bevel gear and oil pump and centrifuge gear;

When assembling the gearbox, following additional checks of axial clearances are made:

[redacted]

a. between the centrifuge and the deaerator cover;
b. between the centrifuge and the bearing housing;
c. between the oil deflector and the ball bearing housing.

Before dismantling the oil pumps, following checks are made:

a. clearances in the oil pump drive gears;
b. clearance in the oil pump gear teeth;
c. side and end clearances between the driven and the drive gears and the oil pump housings of all stages;
d. diametric clearance between the drive gear and the oil pump housing;
e. diametric clearance between the driven gear and the shaft of the driven oil pump gears.

However, if the engine design has been in production for a long time, checking operations are drastically curtailed, clearances are not checked, and a number of components are not disassembled.

The following fuel system components are disassembled: filter, nozzles, igniters, manifold, and drain valve. While dismantling the fuel filter, attention is paid to the condition of the filter element itself; after the dismantling, the filter is placed in a special container to prevent its contamination. Fuel nozzles and igniters are dismantled after acceptance tests only in extreme instances, i.e. if the spray nozzle has been clogged (according to test data) and it does not furnish the necessary atomization. To prevent dents, scratches, asf., spray nozzle parts are also placed in special containers. Rubber hose are taken off the fuel manifold for inspection of joints. The drain valve is dismantled for inspection of the valve, the disc, and the diaphragm.

Dismantling a combustion chamber consists of the following basic operations: taking off crossover tubes with union nuts, unscrewing cover and casing union nuts, removing lifting lug union bolts, and then taking out the flame tube out of the casing.

During the dismantling of combustion chambers, they receive protective covers from a close woven fabric to prevent damaging the casing paint. Flame tubes are cleaned from scale.

The turbine rotor disassembly includes taking the blades off its disc for inspection.

The nozzle and diaphragm are dismantled to inspect shrouds, inner and outer blades, and labyrinth seals of the nozzle casing and cover.

The front truss ring with the front roller bearing, the center ball bearing housing with the fan impeller parts, and the rear roller bearing housing are dismantled for inspection of bearings, races, rollers, separators, impeller, labyrinth seals, and other parts.

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Neither the front nor rear truss rings are dismantled after acceptance tests; only the nozzle diaphragm blades are.

The compressor rotor is dismantled only in the case of serious defects, such as deep dents on buckets, the impeller itself, or the shaft, or intolerable "overhanging" (shifting) of buckets in relation to impeller blades.

Combustion chamber air adapters are taken off the compressor casing for inspection of swirlers.

Dismantling the exhaust cone consists of removal of the air preheating shroud, outer cone casings, bolt fairings, and other parts. The cone is dismantled for inspection of thermal insulation sheets or asbestos sheets (depending on the design).

Components are dismantled essentially with the aid of devices used in their assembly, with the exception of certain special pullers and other equipment.

Dismantled parts of components are placed in appropriate containers and brought to the washing department.

Dismantling of Axial Flow Compressor Engines

Instruments and accessories are taken off the outside of the engine first; then pipes and accessory controls are disconnected; and then the exhaust cone nozzle control rods and nozzle controls are also disconnected.

After disengaging the tachometer generator drive, the tachometer generator, deaerator, fuel pump, RPM governor, gearbox, gasoline pump, high pressure filter, and fuel filter are taken off the gearbox.

Thereupon oil and gasoline tanks (together with their intake assembly -- the diffuser) are taken off.

In order to take off the starter motor, the cable is pulled out and the motor dome attachment screw is removed. After pulling the ring off the cable, the dome is taken out. Before taking the starter motor off the gearbox, ignition and gasoline lines are disconnected.

While taking the main drive assembly off the gearbox, one takes off first the oil pump drive, removes the pump spring, takes off the oil spillbox, and takes out the manual drive spring with its ball bearing as well as the gearbox spring.

Thereupon the distribution panel and electrical equipment are taken off, including thermocouple conductors and thermocouples, plug casings, elbows with spark plug wires, etc. The panel with ignition coils and wires is taken off the compressor stator; spark plugs, spark plug preheater and thermocouple transmitter are removed from combustion chambers.

To take the compressor rotor out of the stator, nuts on bolts joining the upper and lower stator halves are unscrewed. After the compressor rotor front shaft nut has been unscrewed, the bolts attaching the stator to the support and the gearbox are also unscrewed. In doing this, both the horizontal and the vertical surge tanks are taken off. Before proceeding to the following operation, the compressor rotor is suspended on a hoist. Then the gearbox is taken off by a puller (Fig. 291), which is mounted with its flange 1 on the studs connecting gearbox joint planes and the main drive assembly, whereupon the puller is secured with nuts. By rotating handle 3 of screw 2, the rest knob 4 is turned until it reaches the compressor rotor front shaft butt. The gearbox is taken off the rotor front shaft by turning the handle screw. Then the hot section is disconnected from the compressor rotor and the rotor rear shaft is disengaged from the rotor rear bearing in the support; this makes it possible to lift the rotor and place it on a special stand.

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To take off the compressor rotor and turbine rear bearing, the hot section is mounted on a stand, the nut is unscrewed, the compressor rotor rear bearing is removed from the support, the compressor rotor drive splined coupling and the nut lock are taken off the turbine rotor shaft, whereafter the nut is unscrewed off the turbine rotor shaft. Then the hot section is set up in vertical position and the turbine rotor is taken out of the support.

While proceeding with the further disassembly of the hot section, the turbine rotor shroud and the nozzle ring plate are taken off after removing the bolts on the nozzle flange and rear bearing. The nozzle ring is taken out of the support casing. The diaphragm is taken off the support, whereupon the turbine rotor rear bearing housing is pressed out of the support by a plug (Fig. 292). The plug is mounted on the rear face of the support so that disc 2 would rest with its holes against the support studs and disc 3, against the rear bearing studs. After securing the discs, the rear bearing is pressed out by turning handle 5. Then the combustion chamber crossover tubes and the spray nozzle feed lines are taken off.

The tube and nozzle assembly is taken out of the support casing by a plug (Fig. 293), which is set up so that flange 1 would rest against the support rear face and engage - with its centering ring in the seat under the turbine rotor bearing and with disc 2, in the nozzle flange under the diaphragm. After attaching the disc to the flange by rotating the screw handle, the tube and nozzle assembly is removed from the support. The support front bearing is pressed out by a plug (Fig. 294). Before employing the plug, sleeve 4 is taken off the shaft, whereupon the shaft journal with drum 7 is inserted in the support so that tha journal would pass through the front bearing holes and flange 1 would engage with its centering ring in the support seat under the rear bearing and rest with its two holes against the support rear face. After attaching the flange, sleeve 4 is mounted on the journal. The bearing is pressed out by turning handle 6.

To disassemble de-aerator, the drive shaft with its centrifuge and ball bearing housing is pressed out of its housing to permit inspection of the bearing, centrifuge, and shaft. Pressing out is accomplished with the aid of a plug (Fig. 295), housing 1 of which is mounted on the de-aerator flange and sleeve 3 is attached to the ball bearing housing.

During disassembly of the gearbox, bolts attaching the gears to the box are unscrewed first; then the generator idler, tachometer generator, RPM governor, fuel pump, and de-aerator drives are taken out. Drives are disassembled to inspect bearings and other parts.

The gear box is disassembled as follows. Before taking out the compressor rotor three-row front bearing, its cover is taken off; then the oil filter and oil pump are removed by a puller (Fig. 296). Prior to taking the pump off, both the drive and the spring are removed from the gearbox. The puller is mounted with the butt of its cup 1 on the gearbox flange; thereby rod 2 with hook 3 is inserted into the pump housing opening. The pump is taken out of the box seat by rotating handle 4 clockwise (that is, for screwing in). To disassemble the main drive component, it is necessary to take the spring out of the drive gearwheel, unscrew the nut, take off the rear bearing housing, and press out the drive gearwheel with the bearing, cup, and ratchet. It is also necessary to press the gearwheels out of the manual cranking accessory drive and oil pump drive after having unsaftied the locks and unscrewed the nuts off the shafts of these gears. To press out the manual cranking accessory drive springs and the bearing, a plug (Fig. 297) is used. The box is disassembled for inspection of gears, bearings, oil pump parts, springs, and other parts.

While disassembling the oil filter, the filter housing unit is unscrewed first; then the spring, the rubber ring, and the screen filter are taken out. To take the screens off the frame, the nut is unscrewed and the lock and flange are taken off. The filter is disassembled for inspection of screens, the spring, and the rubber ring.

To disassemble the fuel filter, the filter cover nuts are unscrewed and the cover with the screws is taken out, whereupon the anchor bolt nut is unscrewed. The screen truss cup and the spacers are taken off the frame. The frame and the anchor bolt are removed from the housing. The filter is disassembled for inspection of screens and other parts.

During disassembly of the combustion chamber assembly, the latter is taken off the nozzle diaphragm. From combustion chambers are removed spray nozzles, and then muffles and fore-chambers which are cleaned off scale. The muffles are removed from combustion chamber casing by a puller.

To disassemble the exhaust cone, the cover is taken off. After unscrewing nuts and taking off the rack slide block, the movable bullet is taken out of the cone. The cone is disassembled for inspection of the bullet and its operating gears.

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Washing Engine Parts and Assemblies After Dismantling

All engine parts undergo washing, with the exception of accessories and electrical equipment which cannot be disassembled and which are rubbed off by rags highly impregnated in gasoline. Depending on the design, parts are washed in open basins with gasoline jet (jet washing) or in washing machines using aqueous solutions. After washing, all parts are aerated and dried with pressure air.

Small engine parts are washed in containers provided with gasoline run-off holes of corresponding diameters (depending on dimensions of parts). Fuel and oil lines are washed under pressure of 4 kg/cm^2 for 5-8 min. to achieve better results.

Particular attention must be paid to washing of ball and roller bearings, spray nozzle parts, fuel and oil filters, and fuel manifolds and to prevention of dents and scratches on them. After washing in gasoline, ball bearings are again washed in gasoline containing 5% of either MK or MS oil to prevent corrosion; then they are wrapped in oil paper or placed in special canvas covers. Fuel manifolds are washed on a special stand under pressure.

After washing, parts and assemblies of each engine are moved to the trouble-shooting department for inspection.

Inspection of Parts and Correction of Defects

For inspection purposes, all engine parts may be subdivided into three following groups:

(a) rotating or friction parts;

(b) fixed parts with no friction;

(c) standardized parts (nuts, bolts, washers).

The first group is subject to inspection and, if needed, to measurement and checking with control equipment. The second group is subject to visual inspection and partially to measurement; finally the third group, to inspection only.

Let us dwell on types of defects which may be encountered during the inspection of jet engine parts and on the methods of their correction.

Nicks and dents. Nicks and dents can be caused by small foreign particles striking, during the engine operation on the test station, the surface of revolving parts through the safety screen. Impact of foreign particles, for example, against the blades, may cause formation not only of dents, but of cracks as well. Therefore, it is recommended to inspect carefully all nicks and dents using a magnifying glass. Foreign particles, can cause defects on guide blades, compressor rotor blades, its casing, air adapter swirlers, and other parts. Nicks and dents are removed by filing, scraping, or grinding with wetstone and then polishing with fine emery cloth.

Scratches. Reasons for scratches on friction surfaces of parts may be the following: burrs left during the assembly; adhesion of small foreign particles to greased parts; inadequate washing of parts (the presence of abrasives, etc.); contact of rotating parts with those fixed; etc. Small or deep scratches can occur on shafts, sleeves, bearing races, ball and roller bearings, components such as drive gearboxes and similar, surface of compressor rotor and turbine shafts as a result of contact of labyrinth seal crowns with the shaft surface, etc. Scratches on steel parts may be reworked completely or partially by hand, using fine emery cloth or polishing on the stand, provided that dimensions of the part permit it to take off a part of the material without affecting the tolerance during the interconnection of these parts. Scratches on bronze and aluminum parts are reworked by scraping and smoothing out. In this case, it is not recommended to use emery cloth.

Galling. Galling may be caused by the lack of coaxiality, inadequate fit of mating parts, free play exceeding tolerances, vibration of parts while the engine is in operation, etc. They can occur on spherical turbine rotor shaft tips, driven splined coupling, drive splined sleeve, springs, etc. Galling is reworked by buffing or polishing.

Cracks. Cracks on parts are caused by inadequate thermal treatment and great internal stresses, the effect of high temperatures (for example, flame tubes), vibration, etc. Cracks may appear on turbine rotor and nozzle diaphragm blades, about the flame tube openings, in the casing, adapter flanges and nozzle diaphragm cover (at joints, struts, etc.), asf. If cracks appear, rotor blades are rejected, while nozzle diaphragm blades are either reworked or rejected depending on the size of cracks. Casings and similar parts with cracks are rejected. The ends of cracks on flame tubes, the length of which is tolerable, are drilled.

Defects on Ball and Roller Bearings. Roller and ball bearings may have defects, such as discoloration, scratches, wear and tear of the race, weakening of cage rivets, and irridescence. The following can be the cause of these defects: unsatisfactory thermal treatment of parts, the lack of coaxiality between the bearings and mating parts, foreign particles on the race, inadequate setting of rivets, etc. Bearings in such instances ordinarily are rejected. Scratches being small, parts are polished, and the bearing is retained for further services. In the case of substantial increase in axial and radial clearances, bearings are rejected.

Wear and Tear of Gears. Greater wear and tear of gears may be caused by incorrectly adjusted end clearances and clearances between the teeth, skewing of teeth, etc. Gears with greater wear and tear are rejected.

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Burnouts. Burnouts of flame tubes, muffles, nozzle diaphragm blades, and other parts in the combustion system can be caused by abnormal atomization of fuel by spray nozzles (contamination, etc.) or faulty operation of the engine. Parts with burns are rejected.

Blade Shifting. Shifting of impeller blades in relation to compressor rotor blades (exceeding the tolerances) may be caused by inadequate tightening of the impeller and rotor. To correct this defect, rotor blades are taken off and replaced.

Metallization. Metallization of engaged and rotating parts - for example, labyrinth seals and compressor rotor and turbine shafts - may be caused by the lack of coaxiality between these parts. If the wear and tear of labyrinth seals is slight, their crowns are dressed, as is the metal on shaft journals. In the case of considerable metallization and substantial wear and tear, the parts are rejected.

Roughness. Rough spots appear on polished surfaces of blades, guide blades, compressor casing cover, casing itself, etc.; they are caused by large amounts of dust striking such parts and are removed by repeated polishing.

Wear of nuts, studs, and other parts is either remedied by dressing or the parts are replaced.

Rocking exceeding tolerance limits of turbine rotor blades (axial, tangential, and radial) is corrected by replacement of blades after checking the rock with a gage; this is also true of the rocking of guide blades (trusses), and combustion chamber air adapter swirlers after checking the rock visually.

During inspection of parts, one determines by measuring whether the openings are oval or conical; for example, in the turbine casings, the nozzle diaphragm and its cover, etc. Buckling and bulging of individual spots on the parts and of the whole parts (engine hot section) are checked visually or with the aid of master forms. Intolerable distortion of oval and conical shapes and other defects of parts found in the hot section may be caused by the effect of high temperatures upon them and great internal stresses. If buckling exceeds permissible limits, parts are rejected.

Inspection of parts, if needed, is accompanied by testing the parts and assemblies hydraulically, checking them on magnaflux or with fluorescent penetrants, microscopes, and other instruments.

Replacement of specific main assemblies and parts is done on their final rejection; in a number of instances it calls for additional testing of engines and their subsequent dismantling for inspection of replaced and interconnected parts. The assembly procedure for replacement parts is basically the same as in the case of the original assembly of components and engines as a whole.

Let us examine the reasons for replacement of parts and the technological summary of basic operations during the replacement.

Combustion chamber parts, such as casings, muffles, forechambers, flame tubes, etc., may be rejected because of cracks in flame tubes, forechambers and muffles or because of burnout indication, etc.

Replacement of parts in individual chambers of combustion unit (axial flow compressor engine) is followed by their fitting to assure the desired tolerances for clearance and tightness. After such an assembly, individual chambers are inserted into the unit where their position in relation to the nozzle diaphragm is checked with a gage.

Inlet ducts with large cracks are rejected. Replaced ducts are fitted to the particular spot so as to assure proper clearances in the nozzle diaphragm casing.

The turbine rotor casing is rejected in the case of distortion of its oval shape; another is selected so that clearances between the blade tips and the casing ID would correspond to the dimensions on the assembly blueprint.

Blades are rejected if they show cracks in the locks, sign of burnouts, weakening in the slots (axial flow compressor engine), etc. When replacing, blades are selected by roots and weight, after which they undergo machining (blades inserted in their discs are polished at the tips until reduced to the diameter of other blades left on the rotor).

If the rotor shaft is replaced, it is selected to fit the disc so as to ensure all the required tolerances. The roller bearing inner race, the shaft coupling, and other parts are selected to fit the shaft. After joining the shaft with a disc, the play of journals and rotor disc is checked. The contact of the spherical tip with the splined drive coupling sphere (in a centrifugal compressor engine) is also checked. The assembled rotor with all its parts (a balance assembly) undergoes dynamic balancing.

The nozzle diaphragm, which includes the casing, the [illegible] cover, and other parts, is rejected if it shows cracks by the window and flange openings. When replacing, these parts are selected so as to ensure tolerances with parts interconnected with the nozzle diaphragm.

Nozzle diaphragm and ring blades with cracks, signs of burnouts, deep dents, etc., can be rejected. Replacement blades are fitted to the inner and outer shroud slots; their passage cross sections are also measured.

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The following can justify the rejection of buckets and blades: a large number of dents which cannot be blended; shifting of buckets in relation to rotor blades; cracks on blades; weakening of their attachment in the seats (axial flow compressor engines), etc. In such instances, a new bucket is fitted to the rotor so as to provide for necessary tightness and interconnection of blade tips ("bow"). To replace compressor rotor blades in axial flow compressor engine, the entire rotor is disassembled and the rejected blades are replaced (selecting them by weight and disc slots). Then rotor discs are checked for free play and balanced statically. After rotor has been assembled, it undergoes dynamic balancing.

When replacing bearings, they are selected according to size to assure proper fit with interconnected parts, i.e. between ID of races in the housings and OD of roller bearing races, and ID of races and the rotor shaft diameter. Rotors with replaced bearings undergo dynamic balancing.

Replacement labyrinth seals are selected by size with the goal of providing for the desired diameter clearances between the shaft and couplings. After the selection, coaxiality of seals in relation to bearing supports is checked.

Replacement gears are selected according to dimensions of their seats and inner bearing races to assure the desired fit. To set axial clearances and teeth clearances with interconnected gears, adjusting rings are selected. Imprints on paint are used to check how the teeth mesh.

2. FINAL INSPECTION OF CENTRIFUGAL AND AXIAL FLOW COMPRESSOR ENGINES PRIOR TO CONTROL TESTS AND THEIR PRESERVATION

Final assembly of engines prior to control tests is one of the final stages, completing the production cycle of engine building at a factory. Engine testing is the concluding stage; it boils down to checking engine parameters and the quality of assembly.

After correction of defects and replacement of parts (if this was necessary), engine components are put together in the assembly shop and then passed along, together with appropriate documentation, for final assembly.

The technological process of the final assembly of engines prior to control tests is analogous to the assembly process prior to acceptance tests, with the exception of certain operations.

First, while engine parts and components are prepared for assembly, supplemental checking operations are carried out, such as balancing of compressor and turbine rotors, etc.

Second, all parts and accessories found not only inside the engine, but also on the outside, are safetied.

After completion of all operations, engines undergo visual inspection; turning of rotors is checked; then all openings in accessories and assembled engines are closed by special plugs; finally, all the prescribed papers are assembled and filled out (for components, accessories, etc.).

Thereupon, engines are taken to the test station for control tests, after which they are forwarded to the shipping department; here they undergo internal and external preservation and are packed.

Engine preservation is carried out after the final testing on the stand and before shipping them to the customer or the warehouse.

The preservation safeguarding all internal and external engine parts against corrosion is done in special premises; it breaks down into internal and external preservation of parts, preparation of engines for packing, and the packing.

Preservation of centrifugal compressor engines for two years is done as follows:

After completion of control tests, the inside cavity of the engine is blown by hot (120°C) air for 15 minutes through the orifice of the air adapter box.

The remaining fuel is removed from the piping with an electric pump. To preserve fuel and oil lines, either transformer or aviation oil is poured into the oil pump gearbox. To preserve the fuel system, up to 10 l of oil is pumped through the fuel system by rotating the engine.

External preservation of the engine is done in the shipping department.

In the case that the lacquer paint coating is damaged at some places, the latter are repainted, using a spray gun or a brush, and dried by an electric reflector lamp at not more than 70°C. The exhaust cone nozzle is preserved on the inside and outside by grease preheated to 60-70°C, using a spray gun. Cast iron parts with no protective coating are coated with grease, too. All engine parts from nonferrous metals with no protective coating (paint), as well as those zinc and cadmium-coated are greased with industrial vaseline with the addition of 4-6% cerosin, using a brush. All "dyurit" hose are rubbed off with a rag and then wrapped in oil paper.

To guard against the moisture effect, bags with silica gel are suspended in the inside hallow of the exhaust cone, adjacent to front and rear truss screens, and in other places.

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After closing all openings with plugs and after general inspection, the engine is wrapped in oil paper. On the engine base is laid a polyvinyl chloride sheet, the surface of which coming in contact with the engine is coated with thin coat of industrial vaseline. After the engine has been placed upon this base, it is wrapped into the sheet and the joints all around are glued together. Thereafter the air pressure in the space between the sheet and the engine is somewhat reduced through a pipe, using a vacuum pump; after this the sheet is pressed by atmospheric pressure against the outer contour of the engine. For humidity control, humidity indicators are suspended to the engine at definite places.

After the final inspection, the engine is covered with a container made from well dried lumber and sealed. Preservation of axial flow compressor engine for one year is done in the following manner.

The engine to be preserved is run after control tests at 2900-3000 RPM to drain oil from the oil tank and preserve the fuel system. To do this, the fuel system is switched to a mixture of 50% gasoline and 50% turbine oil and run through for 2 min. Then engine RPM's are reduced to 2000-2500, the fuel cock is closed, after which 0.8-1 kg of oil is introduced into the intake assembly diffuser by means of a pump and a special atomizer for the purpose of preservation of inner parts. After draining the starting fuel from the filter, the engine is taken off the stand and moved to the shipping department.

The oil tank which has been drained previously receives 10-12 l of aviation oil preheated to 60-70°C. For preservation of lubrication system and parts, the engine is rotated with a spring for 5-7 minutes. Then the remainder of oil in the tank is drained off. For internal preservation of the starter motor aviation oil is used; for external preservation, industrial vaseline preheated to 80-100°C.

External preservation of parts of axial flow compressor engine is done in the same manner as for a centrifugal compressor engine.

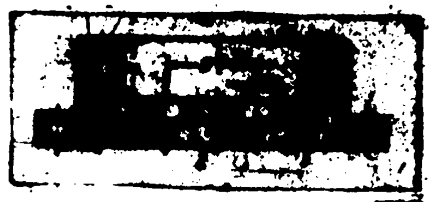

Fig. 1 — Machined assembly of [illegible] oil pump housing

1 — housing, 2 — bushings

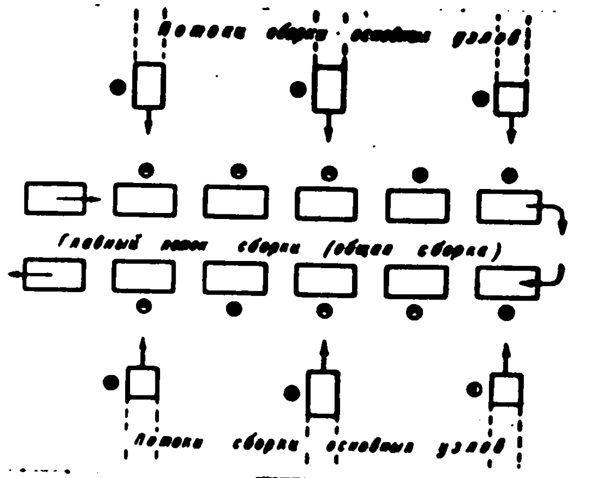

Fig. 2 — General flow sheet of movements of assemblies in the assembly shop.
Flow of assembly of basic units:

The main flow of assembly (general assembly)
Flow of assembly of basic units

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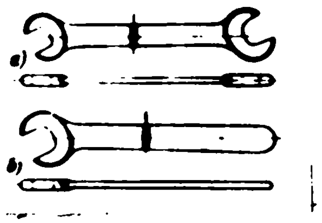

Fig. 3 — Open end wrenches

a — double ends
b — single end

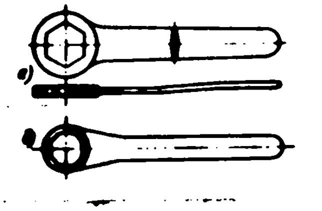

Fig. 4 — Box wrenches

a — 6-point end
b — 12-point end

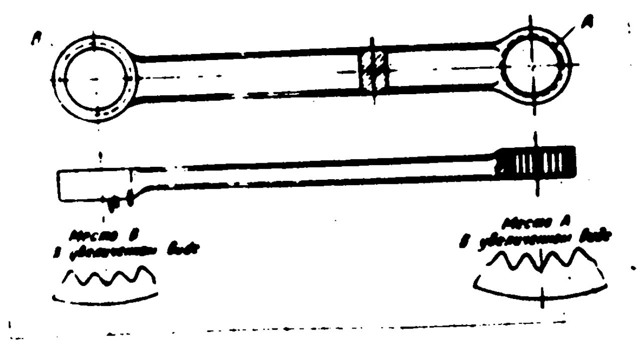

Fig. 5 — A box wrench for nuts with small triangular splines

point a magnified
point b magnified

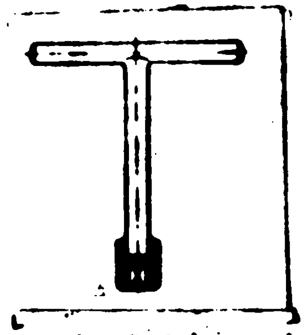

Fig. 6 – Socket wrench

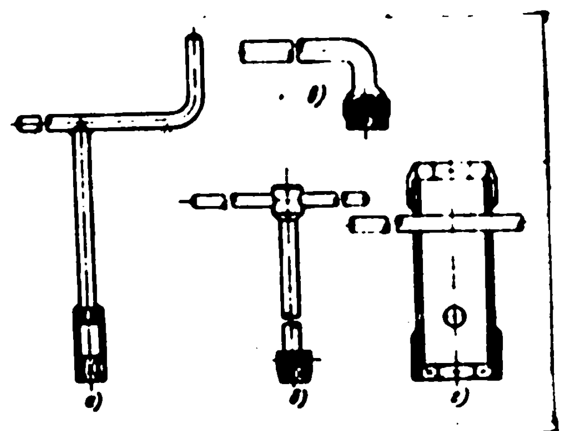

Fig. 7 – Design of socket wrenches

a – socket wrench with a special turning handle
b – socket wrench with insertable turning handle
c – end L-shaped socket wrench
d – tubular socket wrench

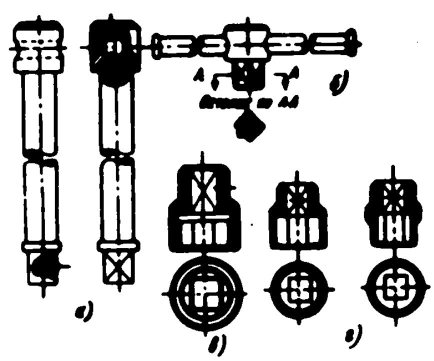

Fig. 8 – Socket wrenches with removable sockets

a – an arm of the wrench with removable turning handle
b – nonremovable turning handle
c – removable socket
d – welded removable socket

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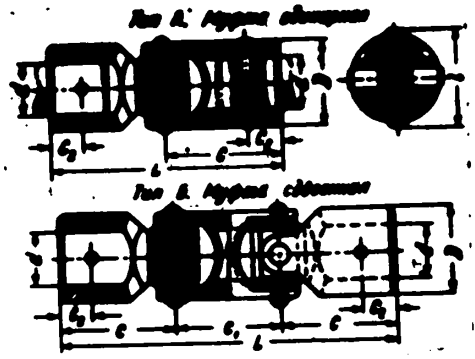

Type A. A Single Joint

Type B. A double Joint

Фиг. 9. Шарнирная проставка (муфта) ГОСТ 5147—49.

1 Номин. размер муфты	D	2 L Муфты типа А	типа Б	l номб. 4	C	C_1	C_2	5 Допускаемый крутящий момент в кгм
10	16	30	72	20	25	22	6	2,5
12	20	60	86	25	30	25	8	4,0
16	25	70	102	30	35	32	10	8,0
20	12	84	124	35	42	40	12	16,0

- Fig. 9 - A universal joint wrench GOST 5147-49.

1 - Nominal sides of the joint
2 - L Joint
3 - type type
4 - maximum
5 - permissible torque in kg

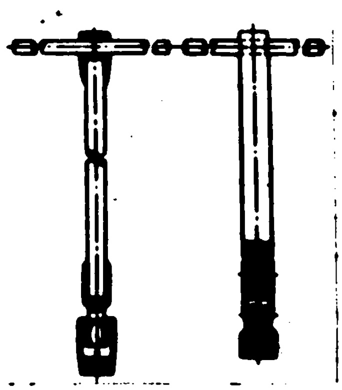

Fig. 10 - Universal Joint socket wrenches

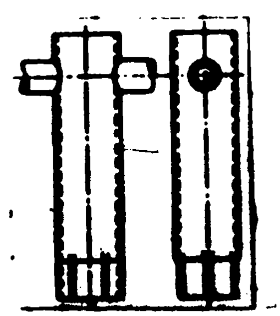

Fig. 11 - Socket wrench with outside hexagonal flats

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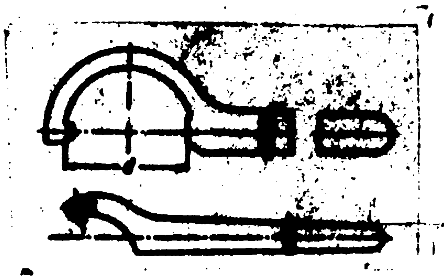

Fig. 12 – Spanners

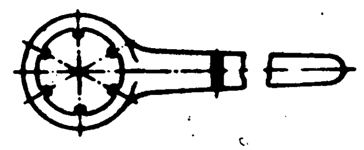

Fig. 13 – Splined box wrench

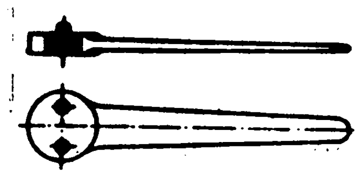

Fig. 14 – A rachet wrench

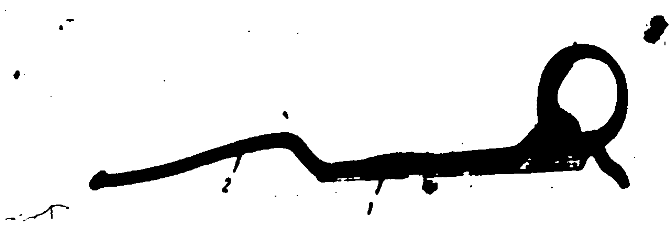

Fig. 15 – Strap wrench for round knurled nuts

1 – lever, 2 – strap

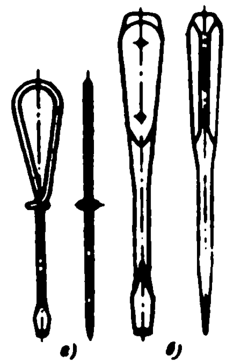

Fig. 16 – Screwdrivers

a – for small screws and
b – ordinary screwdriver

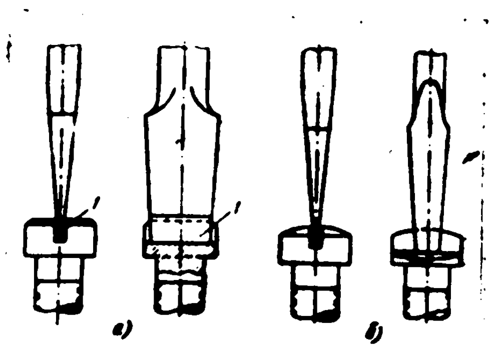

Fig. 17 – The tip of the blade and screwdriver

a – correct grinding – sides of the tip are parallel

b – wrong grinding – the sides of the tip are not parallel

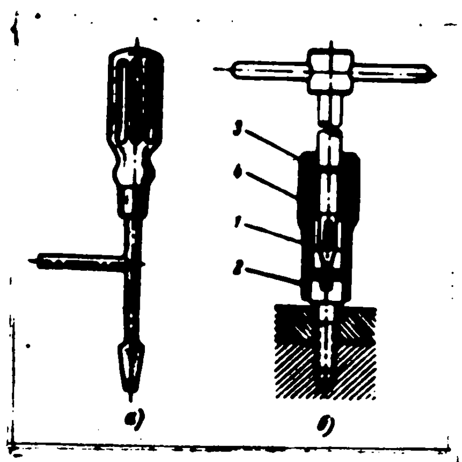

Fig. 18 – Special screwdrivers

a – a screwdriver with a turning handle,

b – a screwdriver with a guide.

1 – a screwdriver,
2 – a guide,
3 – blocking,
4 – spring

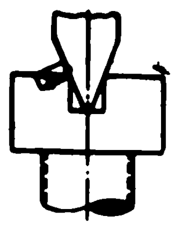

Fig. 19 – Forces acting upon the blade of the screwdriver

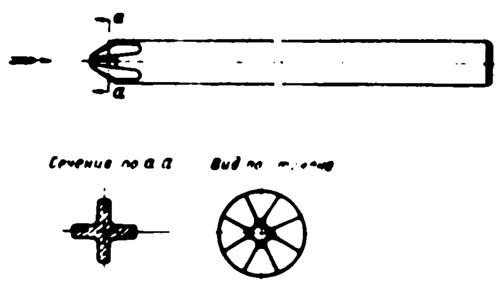

Fig. 20 – A screwdriver for screws with cross like slots in the head, Phillip's type

Cross section along A A   View along the arrow

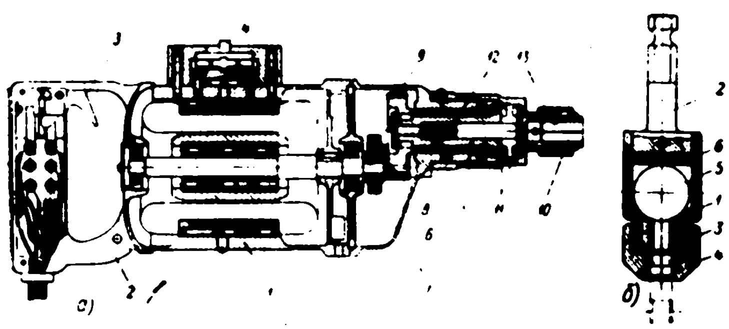

Fig. 21 – Electric wrench – a schematic drawing of electric wrench

1 – housing, 2 – handle, 3 – switch, 4 – rotation reversing slide,
5 – spindle, 6, 7, 8 – reducing gears, 9 – spindle gear,
10 – chuck, 11 – cam clutch, 12– spring, 13 – sleeve.

b – socket for studs for electric wrench
1 – housing, 2 – tail part of the socket, 3 – a movable nut,
4 – a lock nut, 5 – ball, 6 – a seat for the ball.

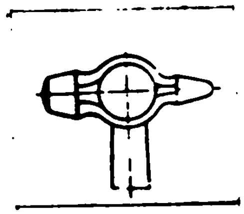

Fig. 22 - An ordinary machinists hammer.

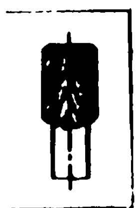

Fig. 23 - Method of spreading the handle of the hammer.

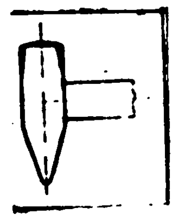

Fig. 24 - A light hammer

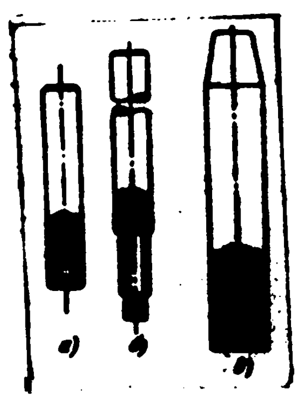

Fig. 25 - Punches
a - a punch with a pressed end tip,
b - a punch with an aligning tip
c - a punch with the tip with a lock pin.

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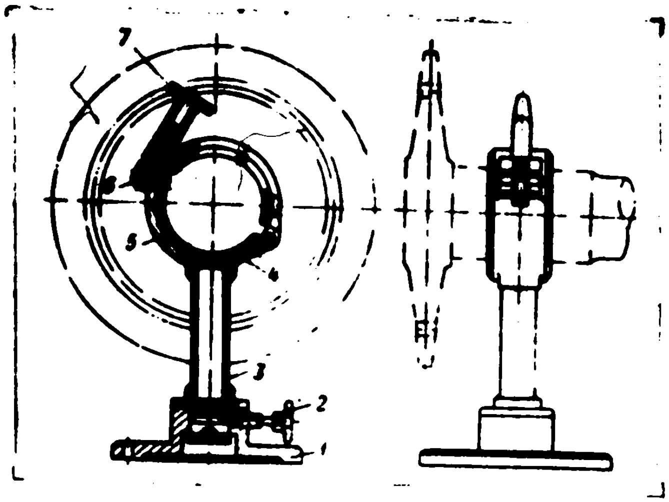

Fig. 26 – A device or clamp for holding shaft

1 – support plate
2 – fixed position lock
3 – support post
4 – collar
5 – insert or lining
6 – hinged screw
7 – lock nut

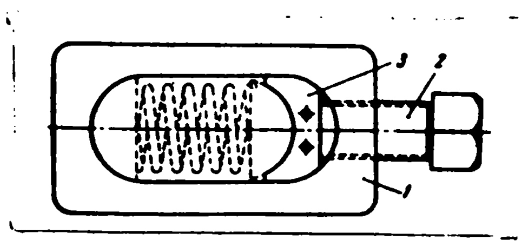

Fig. 27 – Screw clamp for inserting cylindrical springs in compressed state.

1 – housing
2 – screw
3 – movable block

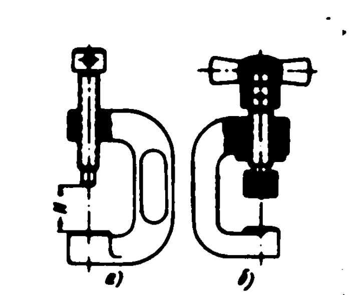

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Fig. 28 – Screw clamps

a – an ordinary screw clamp
b – a screw clamp with

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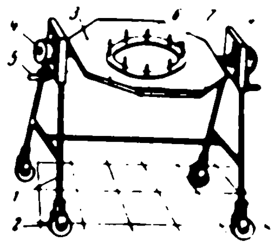

Fig. 29 - Movable assembly stand or cart for small assemblies.

1 - frame of the cart
2 - wheel
3 - turning plate
4 - bearings for holding the shaft to the plate
5 - fixed position lock
6 - studs for mounting the unit to be assembled on the plate
7 - lining

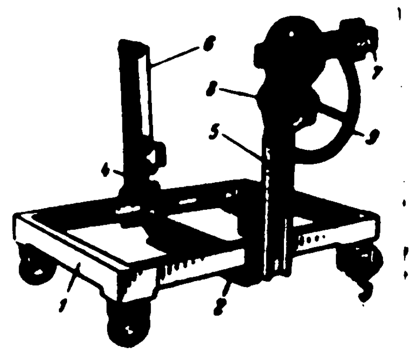

Fig. 30 - A cart for assembling the hot part and for general assembly of an axial flow compressor engine

1 - the frame of the cart
2 - cross member
3 - turning wheel
4 - vertical member for the movable lug
5 - vertical member for turning lug
6 - movable lug
7 - turning lug
8 - turning mechanism
9 - steering wheel of the turning mechanism

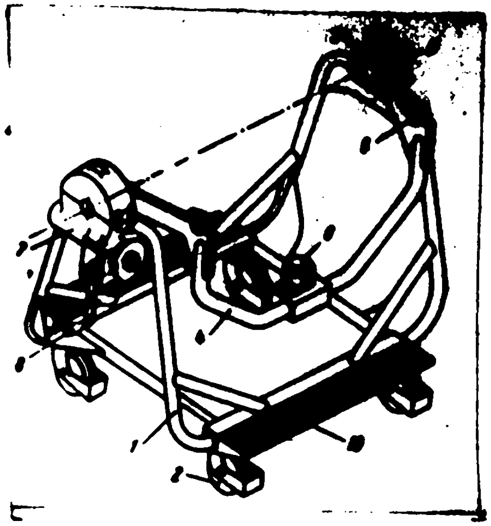

Fig. 31 - Cart for assembling compressor and for general assembly of engine with centrifugal compressor

1 - a frame of the cart
2 - turning wheel
3 - cradle bearing
4 - cradle
5 - an opening for the protruding lug of the engine
6 - support pin
7 - turning mechanism
8 - turning mechanism drive handle
9 - fixed position lock
10 - foot support

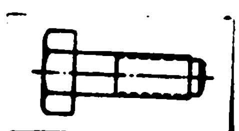

Fig. 32 - Push-out or squeeze-out bolt

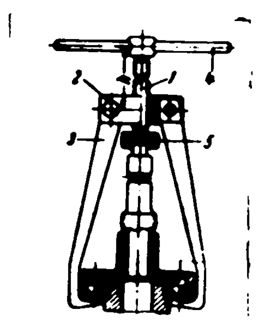

Fig. 33 - Screw puller

1 - screw
2 - cross member
3 - arm
4 - turning handle
5 - safety disc

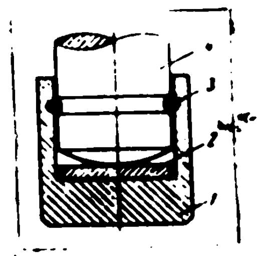

Fig. 34 - Safety tae of screw puller

1 - safety cap
2 - sheet
3 - pin
4 - the screw puller

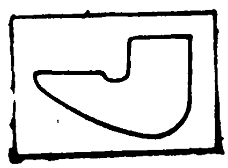

Fig. 35 - Jaw of the screw puller arm

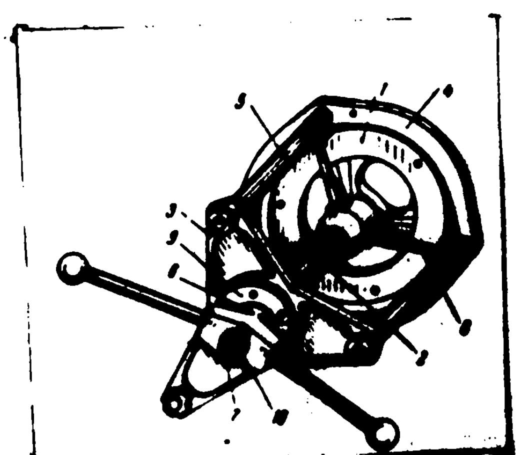

Fig. 36 - Puller for Pressing out the screws from the housing

1 - frame
2 - screw
3 - cover
4 - ring
5 - arm
6 - nuts
7 - pin
8 - spoke
9 - ring
10 - nut

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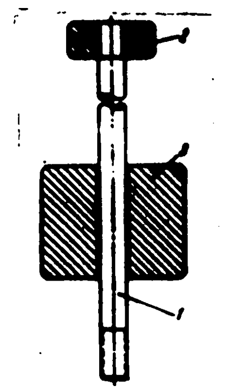

Fig. 37 - Impact puller

1 - rod
2 - the head of the rod
3 - steel cylinder

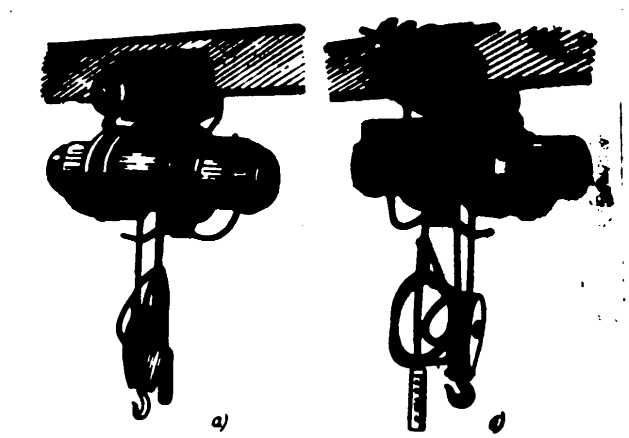

Fig. 38 - General view of electric hoist and trolley

a - view from the side of the electric motor
b - view from the side of the trolley

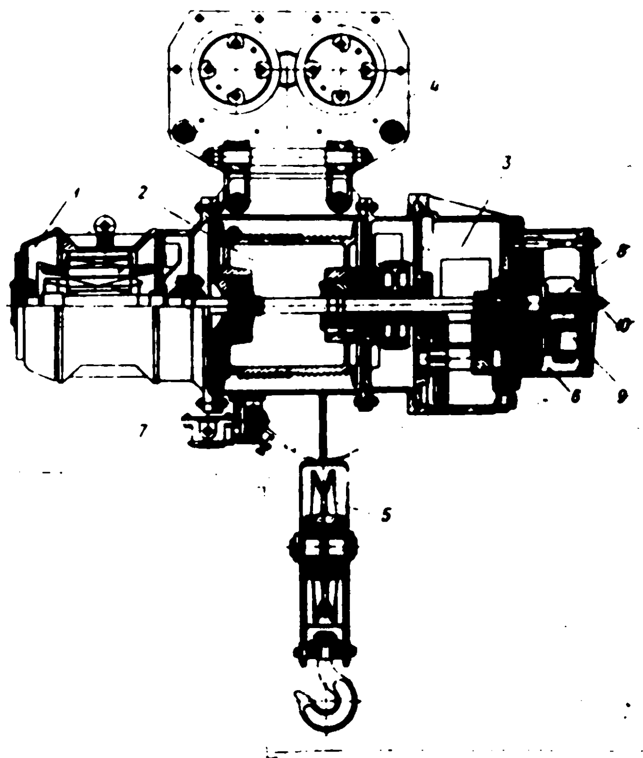

Fig. 39 - Longitudinal section of electric hoist with trolley of the TE-2 type

1 - electric motor of the hoisting mechanism
2 - cable drum
3 - reduction gears
4 - trolley
5 - hook pulley
6 - brake
7 - terminal switch
8 - brake springs
9 - brake electromagnets
10 - brake control screw

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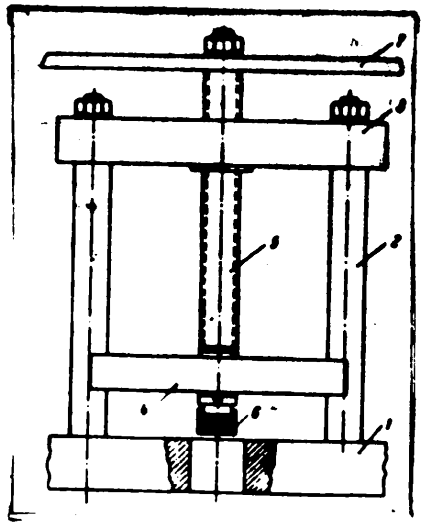

Fig. 40 - Screw press

1 - foundation plate
2 - guide
3 - stationary cross piece
4 - sliding cross piece
5 - main screw
6 - head
7 - hand drive flywheel

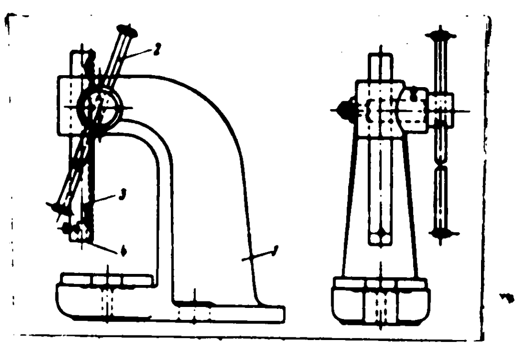

Fig. 41 - Rack press

1 - upright frame
2 - handle
3 - main rack
4 - arbor hole

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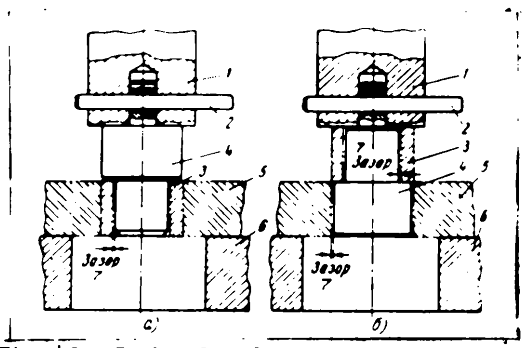

Fig. 42 - Device for placement of the hole of the part on the same axis with the main screw of the press

1 - press spindle
2 - chock
3 - bushing being pressed
4 - centering holder
5 - main part
6 - press table
7 - clearance

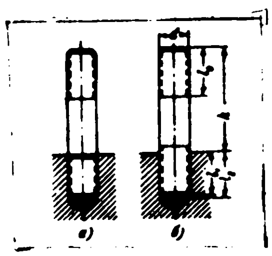

Fig. 43 - Stud

a - stud screwed in to its limit
b - stud screwed in to a specified depth

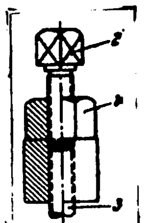

Fig. 44 - Tool post

1 - tool post holder
2 - clamp bolt
3 - stud which is being inserted

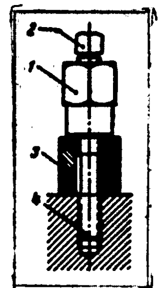

Fig. 45 - Screwing of the stud to a given height

1 - tool post casing
2 - tool post bolt
3 - ring-templet
4 - stud

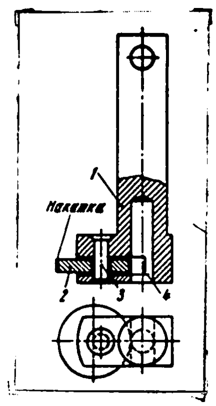

Fig. 46 - Stud wrench
1 - wrench handle
2 - reinforcing cam
3 - cam shaft
4 - hole for stud

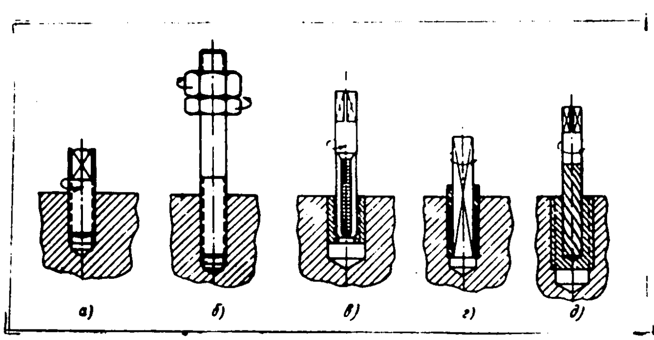

Fig. 47 - Methods of removal of broken studs

a - stud unscrewing with a wrench
b - stud unscrewing with two nuts
c - stud unscrewing with a tap
d - stud unscrewing with a four sided rod
e - stud unscrewing with an extractor

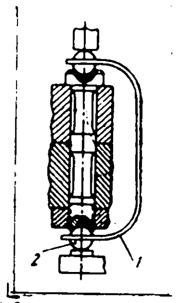

Fig. 48 - Device for precise measurement of bolt length

1 - spring clamp
2 - ball

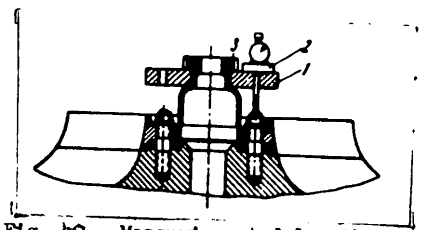

Fig. 49 - Measuring stud length during tightening

1 - ring with indicator openings
2 - indicator
3 - tightening nut

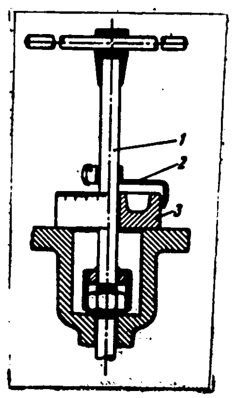

Fig. 50 - Tightening according to locking angle

1 - wrench
2 - indicator
3 - calibrated scale

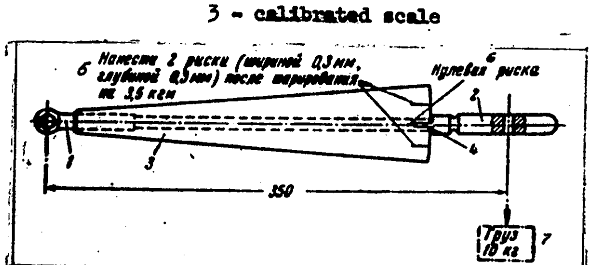

Fig. 51 - Dynamometric wrench (torque wrench)

1 - wrench head
2 - resilient rod
3 - scale
4 - indicator
5 - make two marks (0.3 mm wide, 0.3 mm deep) after calibrating to 3.5 kgm
6 - zero mark
7 - 10 kg weight

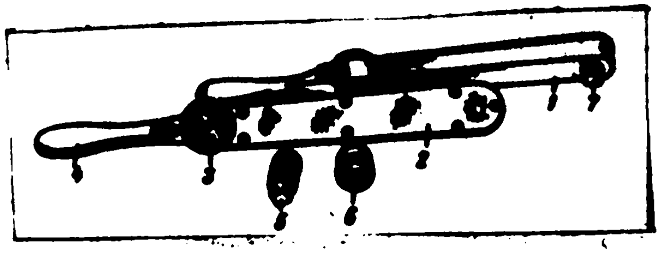

Fig. 52 - Dynamometric wrench

1 - wrench holder
2 - plate
3 - indicator
4 - wrench handle
5 - hinged joint
6 - detachable wrench head
7 - resilient rod of the wrench, connected with wrench head

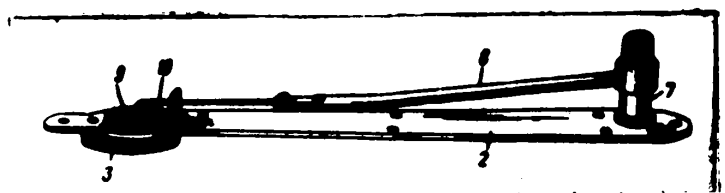

Fig. 53 - Mechanism of the dynamometric wrench

2 - plate
3 - indicator
7 - resilient rod
8 - transmission lever
9 - guide
10 - guide shaft

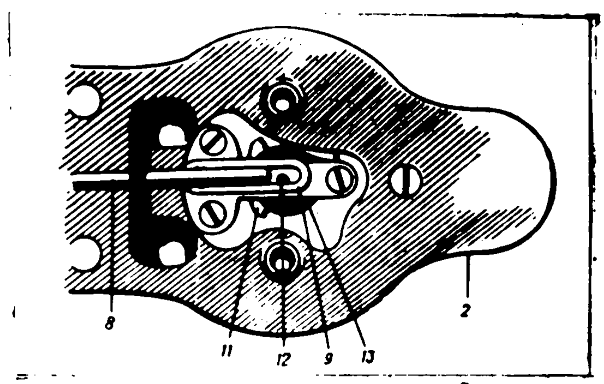

Fig. 54 - Mechanism of indicator of dynamometric wrench

1 - plate
8 - transmission lever
9 - guide
11 - toothed sector
12 - gear shaft and indicator hands
13 - spiral spring

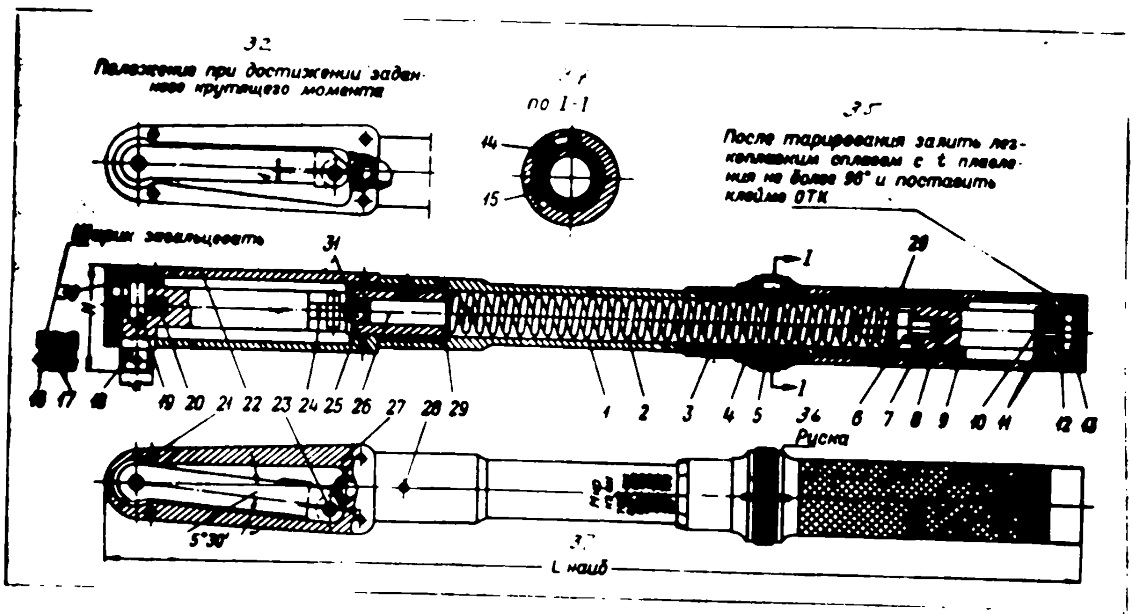

Fig. 55 - Spring limiting wrench

1 - holder
2 - spring
3 - handle
4 - thrust ring
5 - stop ring
6 - rod
7 - screw
8 - ball
9 - spring ring
10 - sleeve
11 - washer
12 - spring washer
13 - nut
14 - locator
15 - locator spring
16 - ball
17 - spring
18 - guide
19 - shaft
20 - ball bearing
21 - rivet
22 - cover
23 - shaft
24 - roller
25 - bushing
26 - plunger
27 - head cover
28 - screw
29 - washer
30 - ring
31 - ball

32 - Position when the required torque is reached
33 - Ball to be locked in
34 - At I-I
35 - After calibrating to be filled with easily melted alloy with melting t of no greater than 96°, and to be marked OTK
36 - Mark
37 - Greatest L

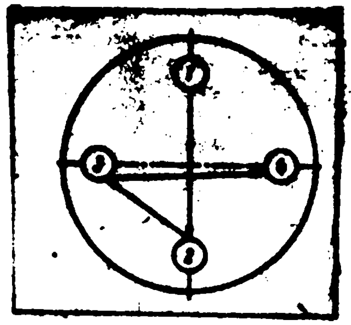

Fig. 56 - Sequence of tightening studs located on the circumference

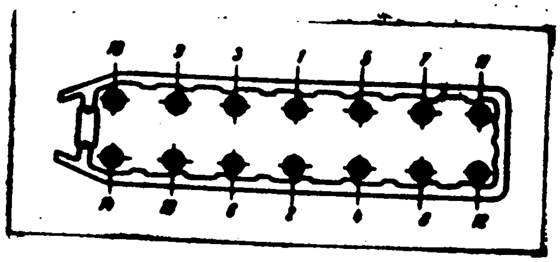

Fig. 57 - Sequence of tightening studs located in two rows

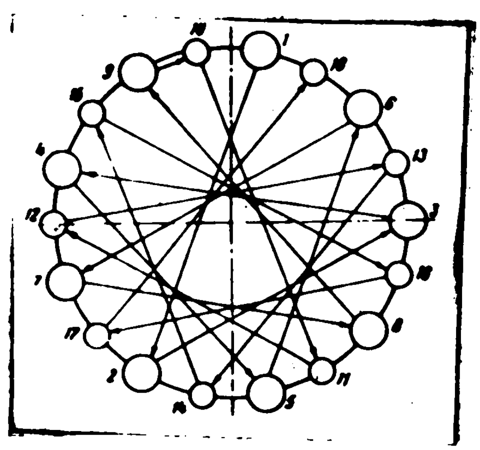

Fig. 58 - Sequence of tightening of bolts of a flange connections

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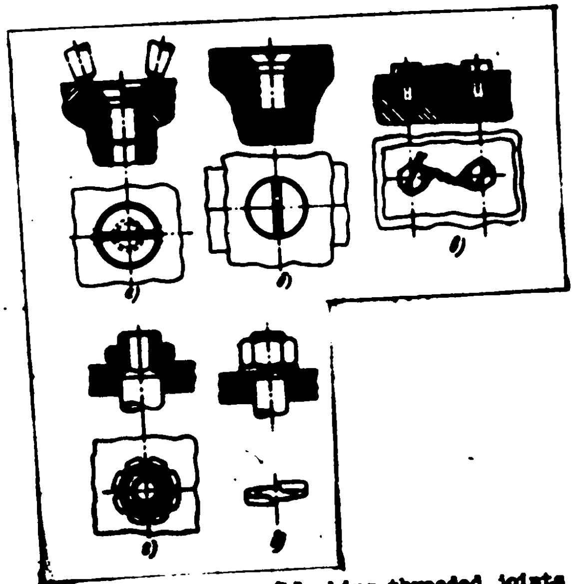

Fig. 59 - Methods of locking threaded joints

a - locking the screw head by means of a punch
b - locking the screw with a spring lock
c - wire locking of bolts
d - locking nut with a step washer
e - locking nut with a lockwasher

Fig. 60 - Locking with cotter pins

a - bending back cotter pin ends over the face of stud and nut
b - bending cotter pin ends around the nut

Fig. 61 - Locking with special locking devices

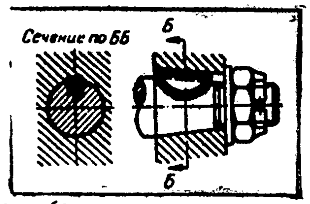

Fig. 62 - Sleeve joint connection

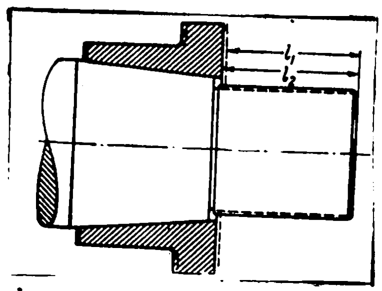

Fig. 63 - Determining tightness of sleeve connection

l_1 - distance between end of cold sleeve and end of shaft
l_2 - distance between end of heated sleeve and end of shaft

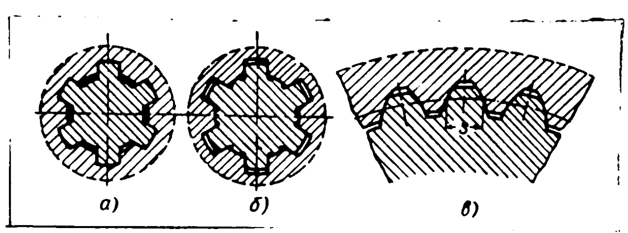

Fig. 64 - Types of spline joint centering

a - outside diameter centering
b - inside diameter centering
c - profile centering

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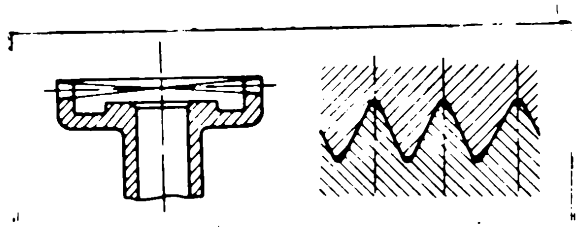

Fig. 65 – Joints made with help of end splines

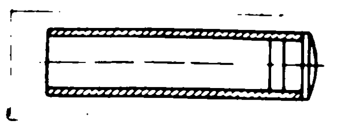

Fig. 66 – Tube device for press fitting of anti-friction bearings

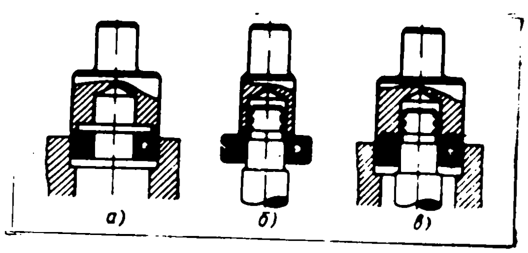

Fig. 67 – Fitting of a bearing

a – outer ring tightening
b – inner ring tightening
c – inner and outer rings tightening

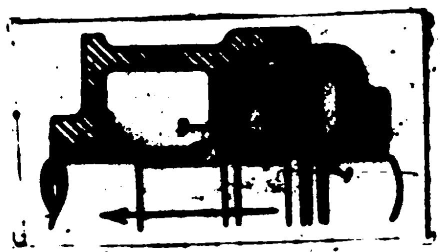

Fig. 68 – Assembly of ball thrust bearing

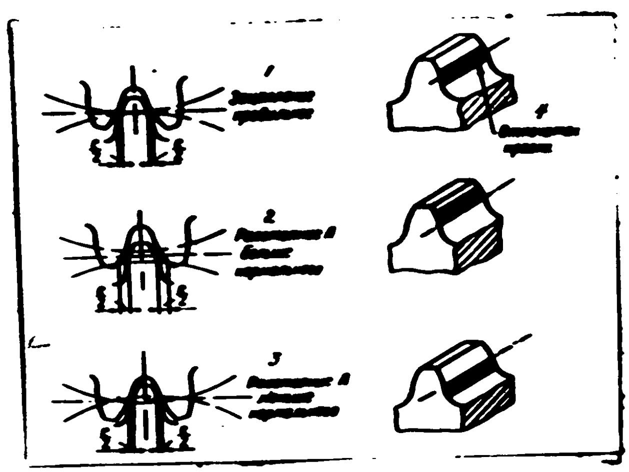

Fig. 69 – Imprints on teeth of spur gears

1 – True meshing
2 – distance A greater than normal
3 – distance A smaller than normal
4 – paint imprint

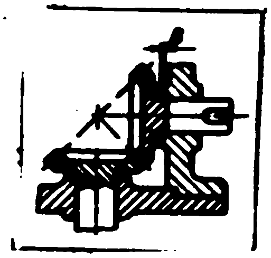

Fig. 70 – Regulating clearance between teeth of bevel gears by means of spacer rings

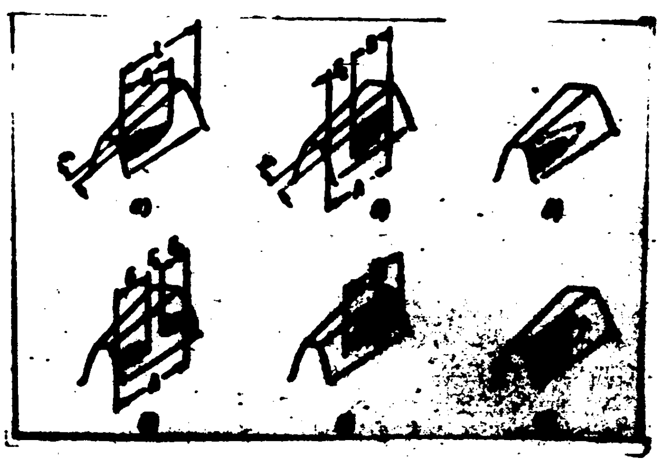

Fig. 71 – Types of [illegible] of bevel gears during [illegible]

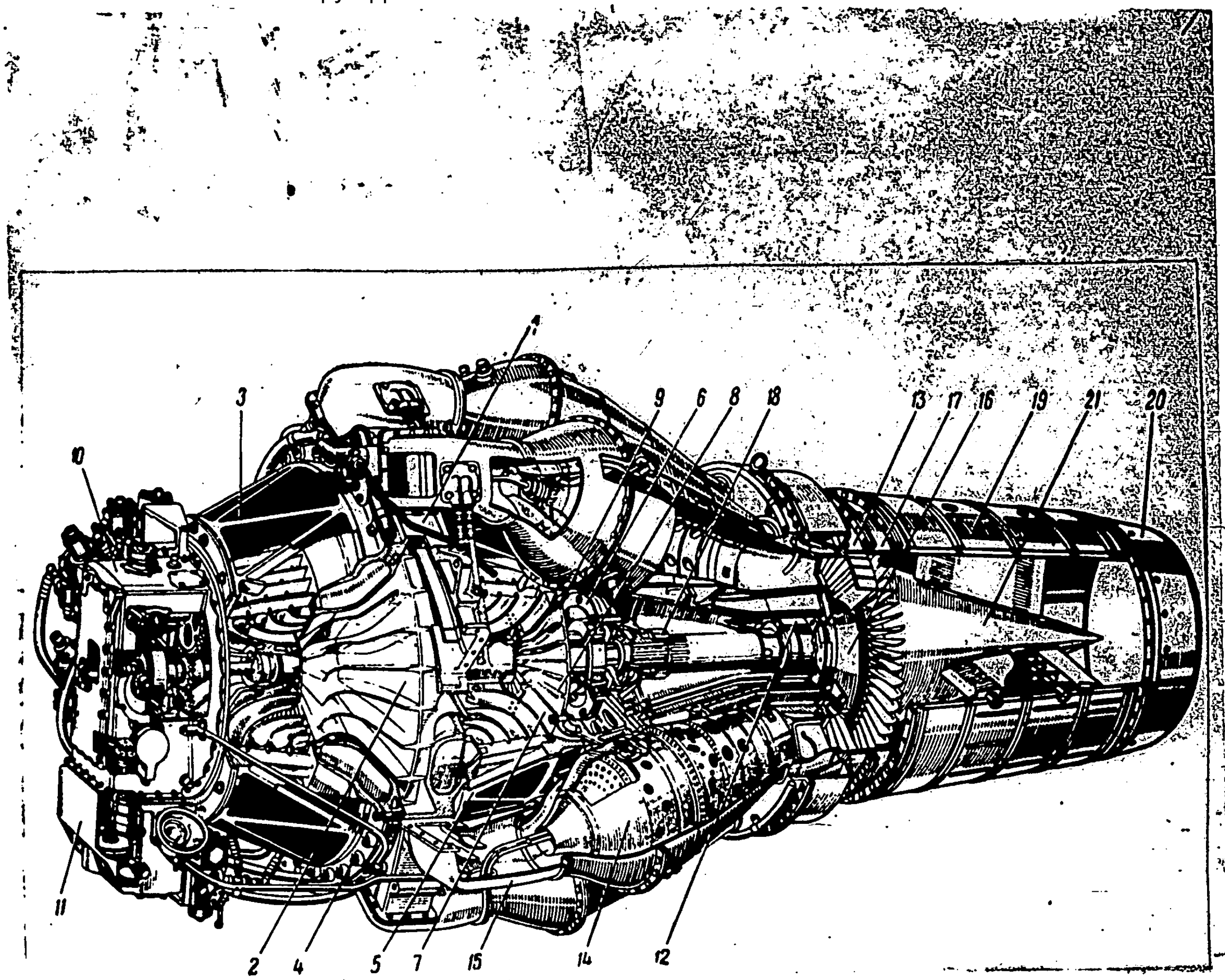

Fig. 72 - Cross Section of Centrifugal Compressor Jet Engine

1 - Compressor casing, 2 - Compressor rotor, 3 - Front ring truss with front roller bearing housing intake vane assembly, 4 - Compressor casing cover, 5 - Rear ring truss with intake vane assembly, 6 - Center radial thrust ball bearing housing, 7 - Impeller assembly front cover, 8 - Cooling impeller, 9 - Impeller rear wall (diffuser), 10 - Drive gear accessories case, 11 - Oil pump case, 12 - Rear roller bearing housing, 13 - Nozzle inlet ducts with nozzle diaphragm, 14 - Combustion chamber, 15 - Air adapter, 16 - Turbine rotor, 17 - Gas turbine shroud, 18 - Turbine rotor drive splined coupling hub, 19 - Exhaust cone outer shell, 20 - Outer exhaust hood, 21 - Inner exhaust cone.

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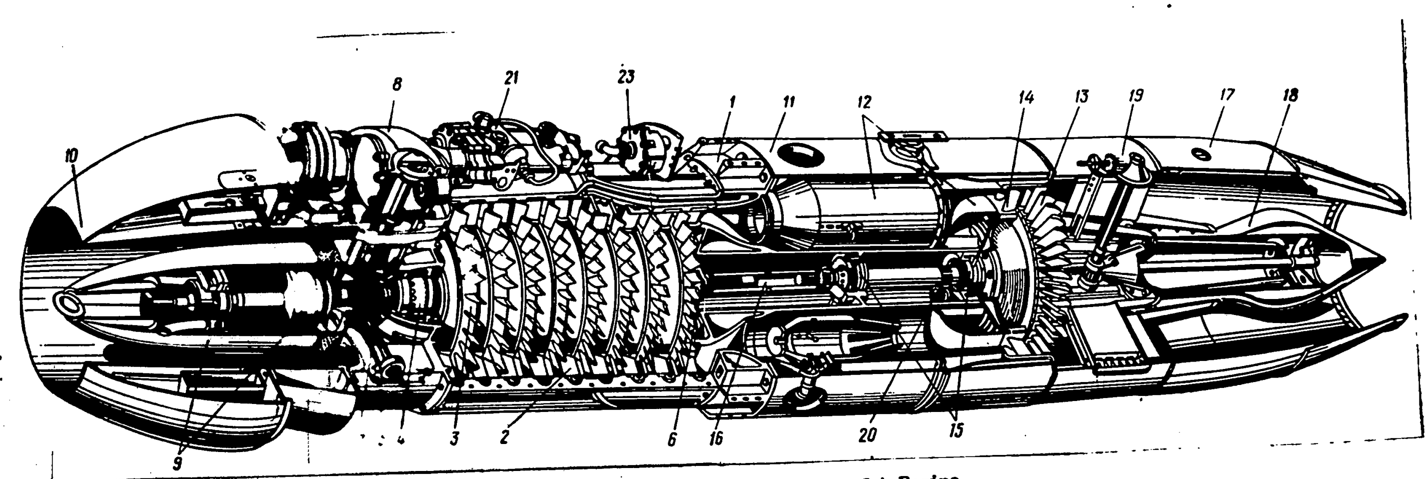

Fig. 73 - Cross Section of Axial Flow Compressor Jet Engine

1 - Support, 2 - Compressor stator with guide vanes, 3 - Compressor rotor, 4 - Three-row ball bearing, 5 - Accessories drive power take-off housing assembly, 6 - Roller bearing in its support, 7 - Coupling between rotor front shaft and power take-off housing, 8 - Accessories drive case, 9 - Starter motor and its faring, 10 - Air intake assembly, including diffuser and oil and gasoline tanks, 11 - Support housing, 12 - Combustion chamber assembly with nozzle inlet ducts, 13 - Turbine rotor, 14 - Nozzle, 15 - Roller and ball bearings in support - turbine rotor shaft supports, 16 - Splined coupling connecting compressor rotor and turbine shafts, 17 - Outer exhaust cone, 18 - Variable exhaust cone, 19 - Variable cone servo-mechanism, 20 - Oil scavenge pump drive gears, 21 - Engine rpm governor, 22 - Fuel pump, 23 - Fuel filter.

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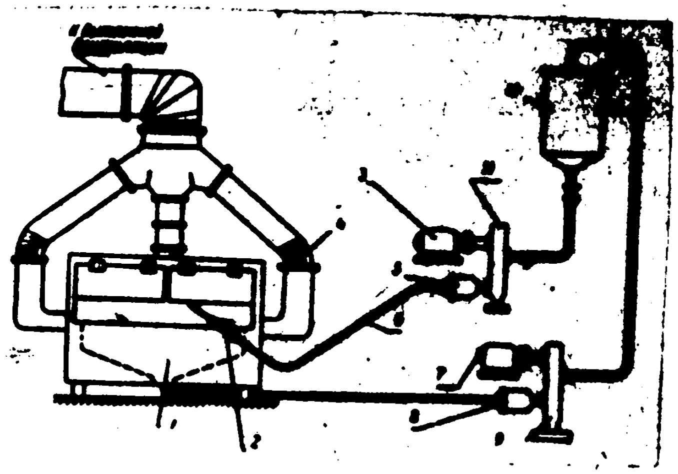

Fig. 74 - Open-Type Vat for Washing of Parts

1 - Vat, 2 - Nozzle, 3 - Electric motor, 4 - Gate valve, 5 and 8 - Filter, 6 - Flexible hose, 9 - Scavenge pump, 10 - Tank, 11 - Drive pump.

Inscription: To exhaust ventilation.

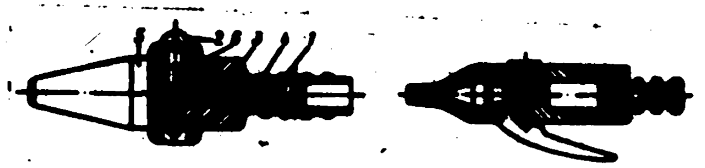

Fig. 75 - Nozzle Types for Washing of Parts

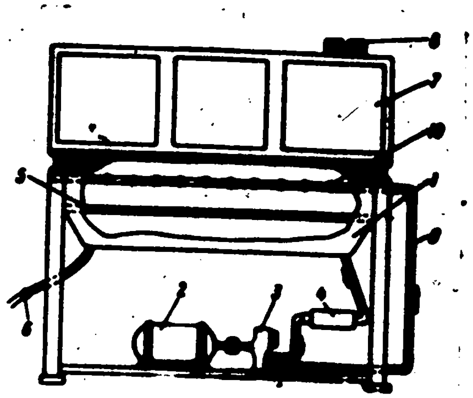

Fig. 76 - Closed-Type Vat for Washing of Parts

1 - Vat, 2 - Electric motor, 3 - Pump, 4 - Filter, 5 - Screen, 6 - Valve, 7 - Cover, 8 - Manometer, 9 - Pipeline, 10 - Spray nozzles.

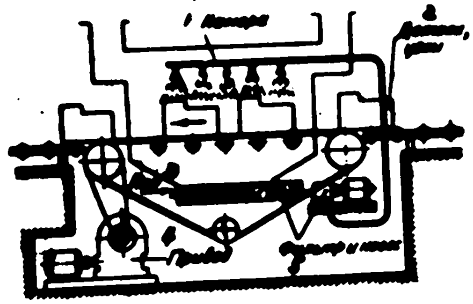

Fig. 77 - Schematic of Single-Chamber Washing Machine

1 - Chamber, 2 - Parts, assemblies, 3 - Steam, 4 - Drive, 5 - Filter and pump.

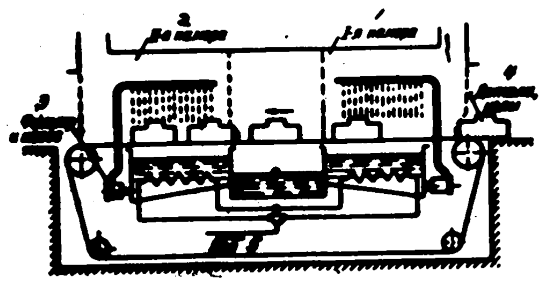

Fig. 78 - Schematic of Two-Chamber Washing Machine

1 - First chamber, 2 - Second chamber, 3 - Filter and pump, 4 - Parts, assemblies, 5 - Steam.

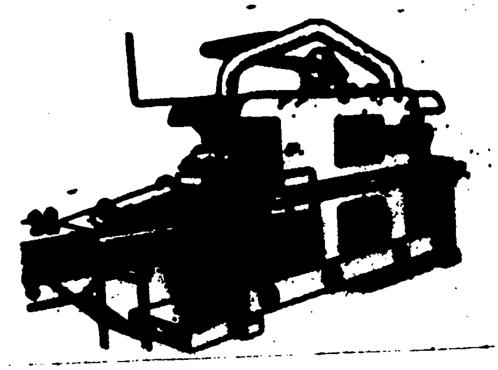

Fig. 79 - General View of Two-Chamber Washing Machine

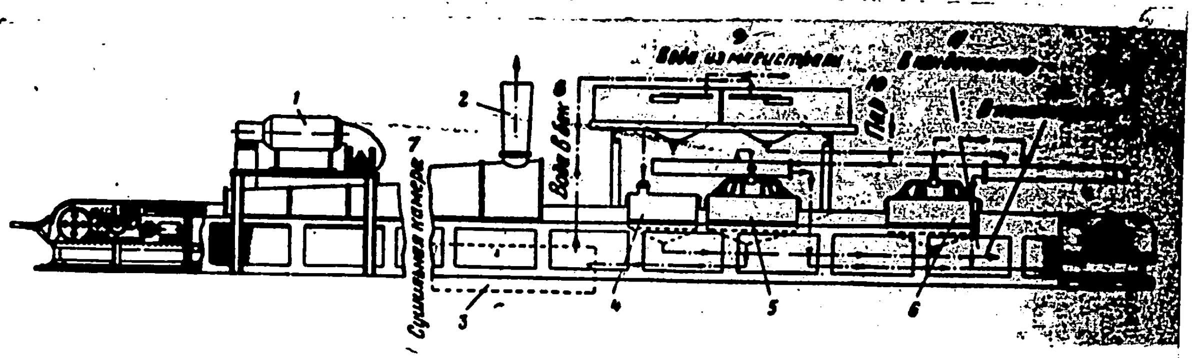

Fig. 80 - Schematic of Three-Chamber Washing Machine

1 - Electric heater, 2 - Air tube, 3 - Settling tank, 4 - Blow-off chamber, 5 - Second washing chamber, 6 - First washing chamber, 7 - Drying chamber, 8 - Water to tank, 9 - Water from the main, 10 - Steam, 11 - To condenser, 12 - To sewer.

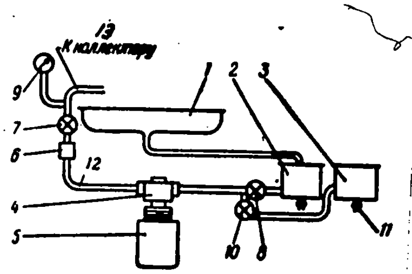

Fig. 81 - Schamatic of Installation for Flushing of Fuel Manifolds

1 - Vat under manifold, 2 - Vat for preliminary flushing, 3 - Vat for final flushing, 4 - Installation pump, 5 - Electric motor, 6 - Filter, 7 - Pressure regulating valve, 8 and 10 - Washing tank shut off valves, 9 - Installation manometer, 11 - Valve, 12 - Pipe, 13 - To manifold.

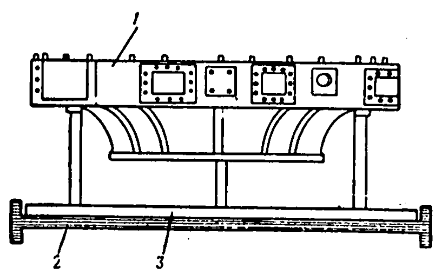

Fig. 82 - Stand for Parts in Washing Machine

1 - Compressor body, 2 - Conveyor belt, 3 - Stand.

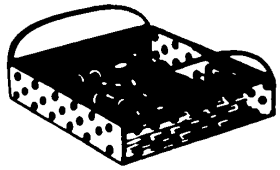

Fig. 83 - Container for Washing of Small Parts

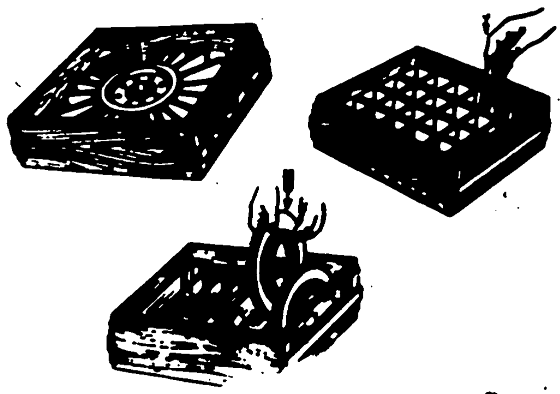

Fig. 84 - Container for Storing and Transporting of Parts

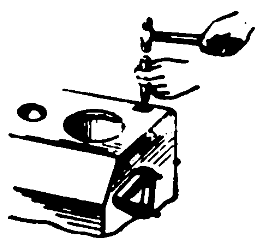

Fig. 85 - Impact Marking

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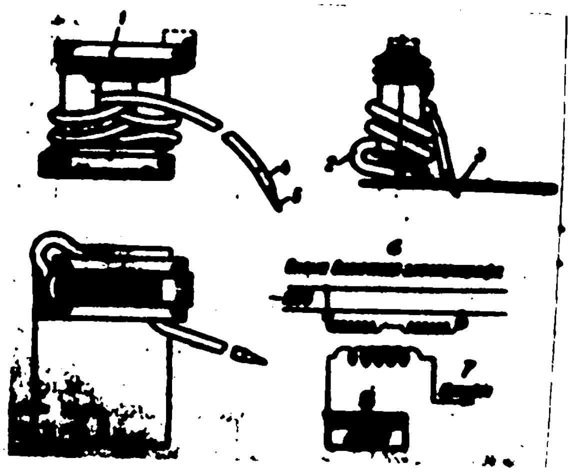

Fig. 86 - Electrograph

1 - Primary winding, 2 - Secondary winding, 3 - Copper plate,
4 - Handle, 5 - Tip, 6 - Electrograph switching diagram,
7 - Pin, 8 - Contact plate.

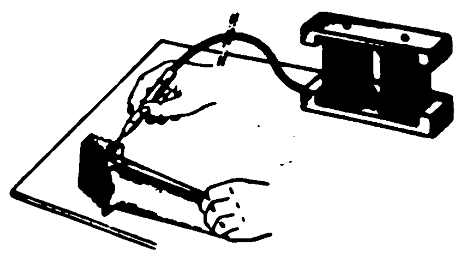

Fig. 87 - Electrographic Marking of Blades

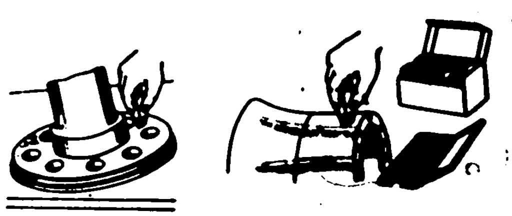

Fig. 88 - Chemical Marking of Parts

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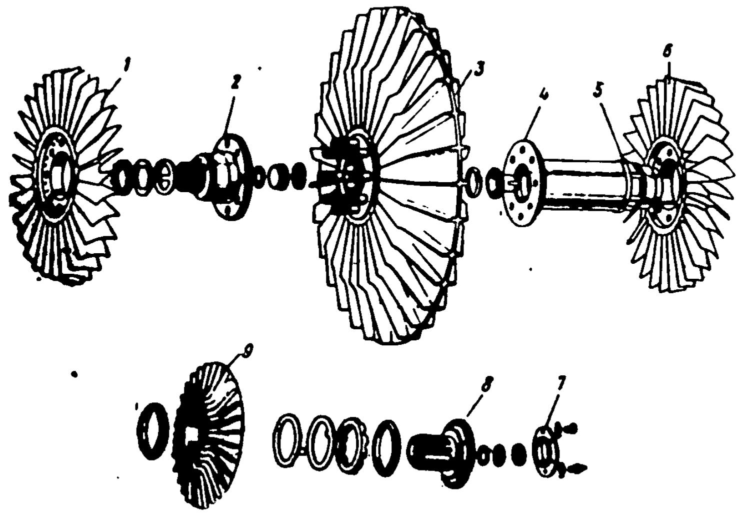

Fig. 89 - Centrifugal Compressor Rotor Parts

1 - Front rotating guide vanes, 2 - Front shaft, 3 - Impeller, 4 - Rear shaft, 5 - Shoulder, 6 - Rear rotating guide vanes, 7 - Sphere support cover, 8 - Splined driven coupling hub, 9 - Cooling impeller.

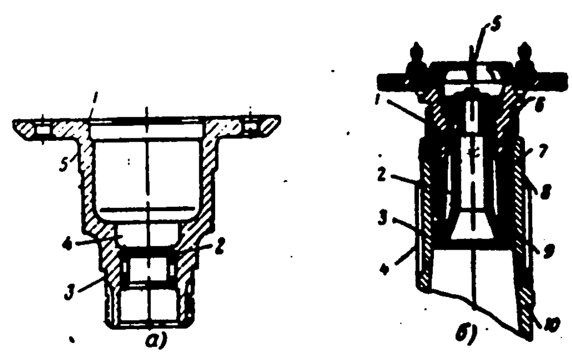

Fig. 90 - Front and Rear Compressor Rotor Shafts

a - Front shaft

1 - Impeller shoulder seat, 2 - Groove for retaining ring, 3 - Roller bearing seat, 4 - Place for plug, 5 - Guide vane assembly seat.

b - Rear shaft assembly

1 - Ball bearing seat, 2 - Bracket bolt, 3 - Retaining ring, 4 - Cooler impeller seat, 5 - Splined hub cover, 6 - Centering shoulder, 7 - Splined driven hub, 8 - Labyrinth seal shoulder, 9 - Hub centering shoulder, 10 - Rear shaft.

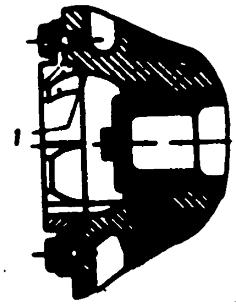

Fig. 91 - Testing Hemispheric Play

1 - Testing place

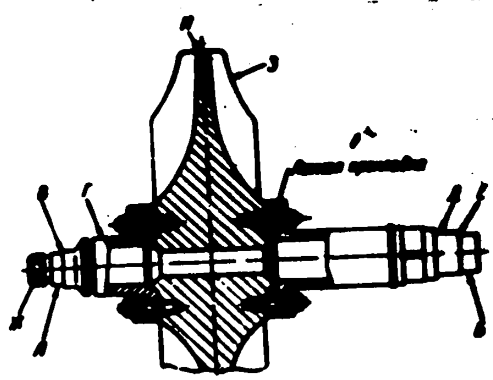

Fig. 92 - Places for Testing Compressor Rotor Shafts Play

1 - Dummy shim.

Fig. 93 - "Overhanging" of Rotating Guide Vanes 1 and Impeller Blades 2

3 - Overhanging of impeller blades, 4 - Overhanging of rotating guide vanes.

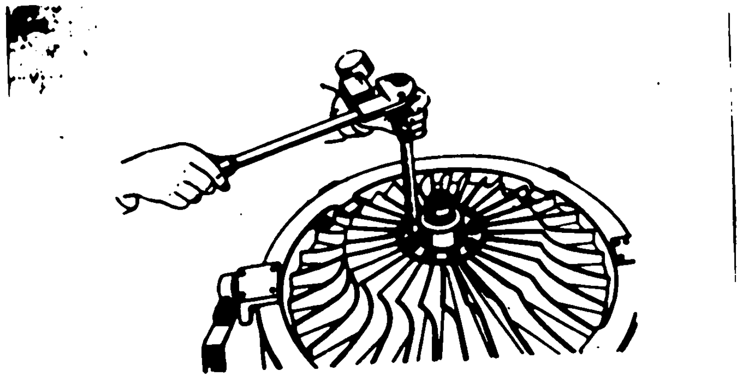

Fig. 94 - Tightening of Locknuts which attain Rotating Guide Vanes to the Impeller

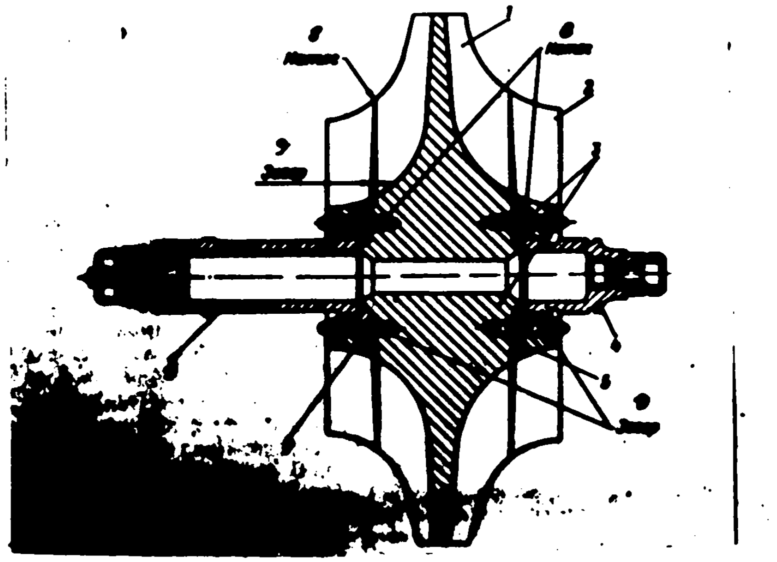

Fig. 95 - Clearances and Tight Fits in Compressor Rotor Assembly

1 - Impeller, 2 - Rotating guide vanes, 3 - Hubs of guide vanes and impeller, 4 - Front shaft, 5 - Front shaft flange, 6 - Rear shaft, 7 - Rear shaft flange, 8 - Tight fit, 9 - Clearance.

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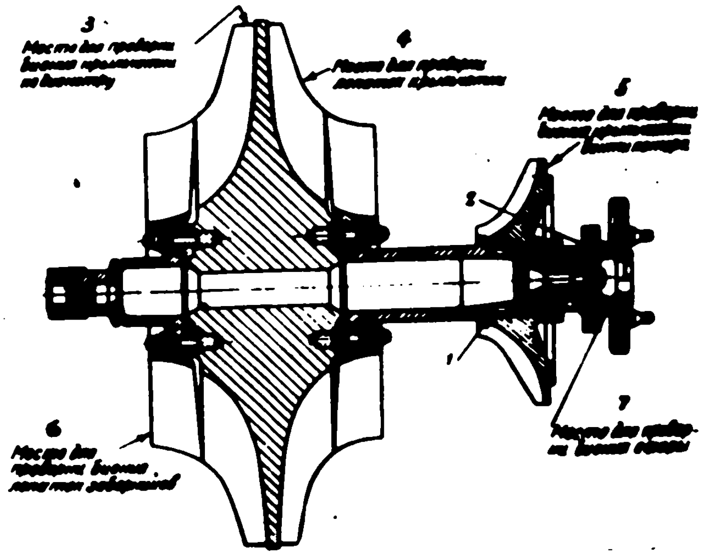

Fig. 96 - Assembled Compressor Rotor

1 and 2 - Adjusting rings, 3 - Place for testing impeller play along its diameter, 4 - Place for testing impeller blades, 5 - Place for testing cooling impeller blades play, 6 - Place for testing of rotating guide vanes play, 7 - Place for testing hemispheric play.

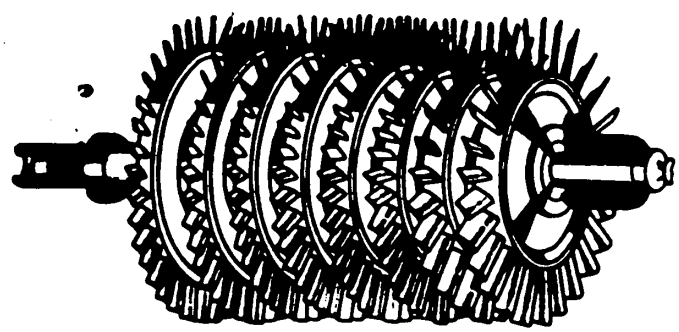

Fig. 97 - Axial-Flow Compressor Rotor

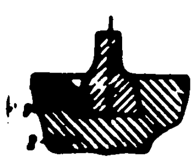

Fig. 98 - Mounting of Blade in Rotor Disc.

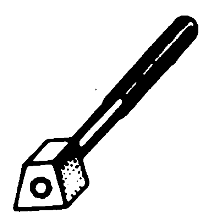

Fig. 99 - Gage for Checking of Slots in Rotor Disc.

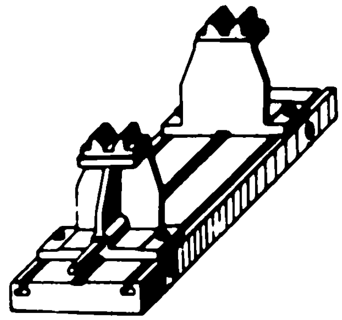

Fig. 100 - Compressor Rotor Play Testing Fixture.

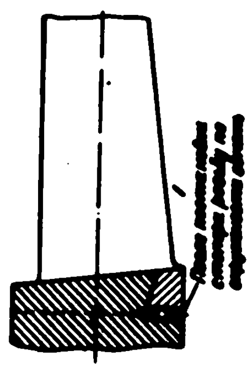

Fig. 101 - Blade Locking in Discs

1 - After lock installation the thread should be pressed in.

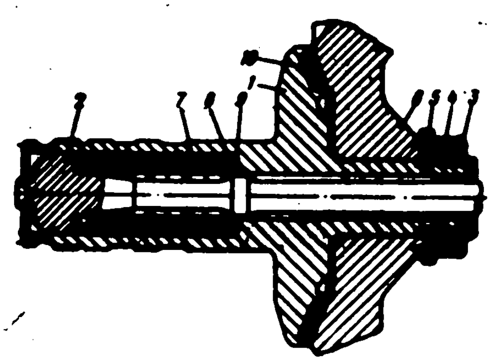

Fig. 102 - First Stage Disc Assembly

1 - Front rotor shaft, 2 - Tie rod, 3 - Nut, 4 - Splined sleeve, 5 - Slee lock pin, 6 - Rotor disc, 7 - Snap ring, 8 - Retaining ring, 9 - Rubber seal ring, 10 - Cone.

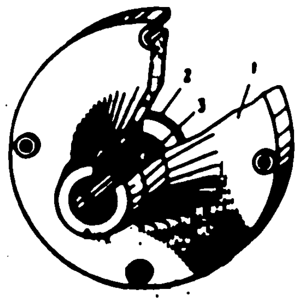

Fig. 103 - Device for Assembling Discs of First and Eighth Stages

1 - Housing, 2 - Hub, 3 - Bolt.

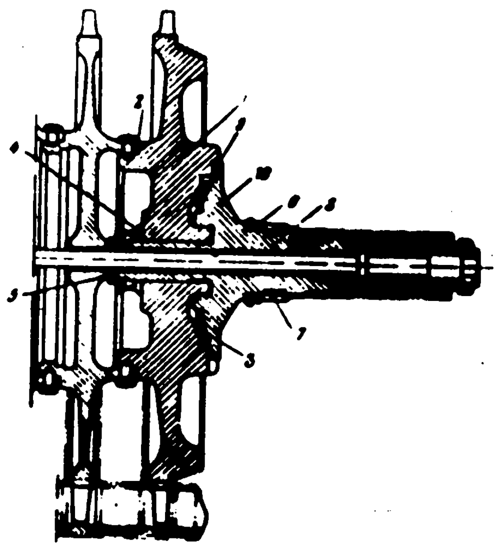

Fig. 104 - Eighth Stage Disc Assembly

1 - Disc, 2 - Disc positioning collar, 3 - Cone, 4 - Spherical bearing, 5 - Shaft locknut, 6 - Rear roller bearing seal housing, 7 - Inner ring of roller bearing, 8 - Roller bearing ring retaining nut, 9 - Disc boss, 10 - Rear rotor shaft.

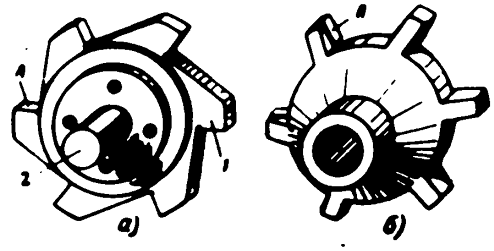

Fig. 105 - Checking Gages

a - For testing with paint the contact of 8th stage disc bosses,

b - For testing with paint the contact of surfaces of compressor rotor rear shaft.

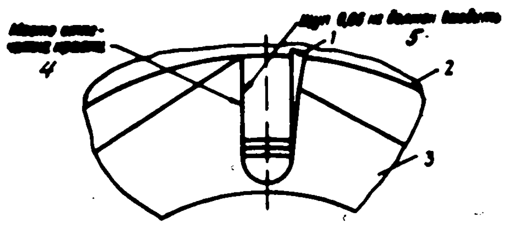

Fig. 106 - Testing Contact of Surfaces by Wedging

1 - Wedge, 2 - Second stage, 3 - Rotor rear shaft, 4 - Paint imprint, 5 - 0.03 feeler gage should not enter.

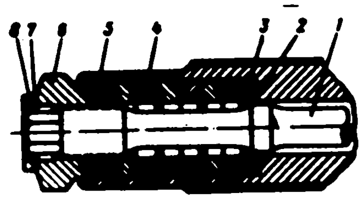

Fig. 107 - Compressor Rotor Rear Shaft Tie Rod Assembly

1 - Tie rod, 2 - Rubber seal ring, 3 and 5 - Retaining ring, 4 - Snap ring, 5 - Snap ring, 6 - Nut, 7 - Tie rod nut locking plate, 8 - Snap ring.

Fig. [illegible]

1 - Clamp, 2 and 3 - [illegible]

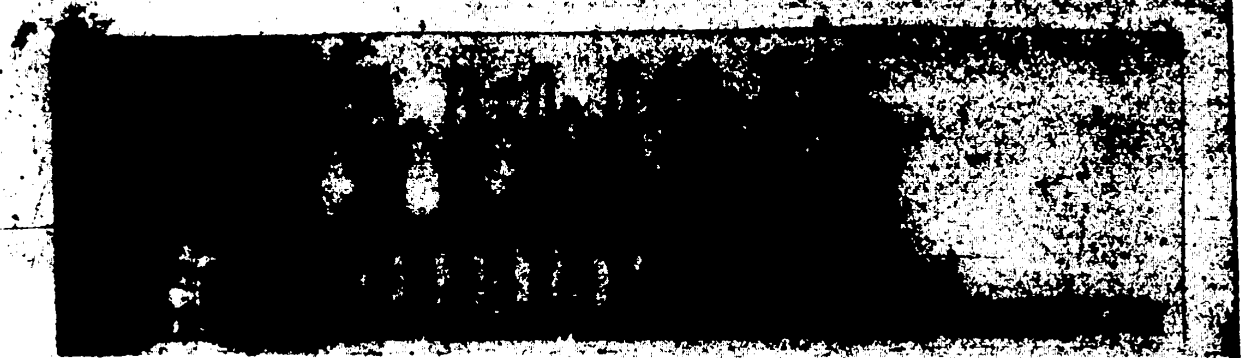

Fig. 109 - Compressor Rotor Assembled for Testing of [illegible]

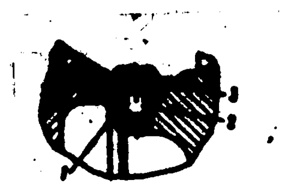

Fig. 110 - Mounting of Rotor Discs

1 - Centering shoulder of disc, 2 - Disc attaching bolt,
3 - Lock washer.

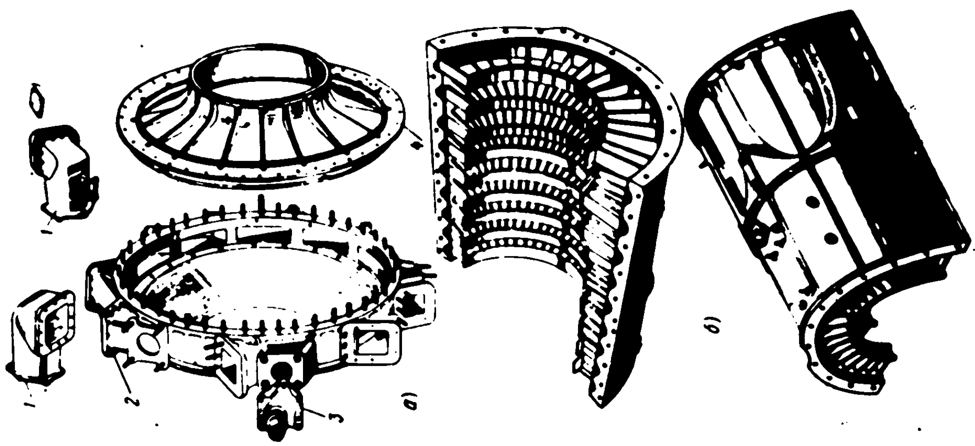

Fig. 111 - Compressor Parts

a - Centrifugal compressor housing with cover and air adapters,

b - Upper and lower housings or stator of axial flow compressor with guide vanes.

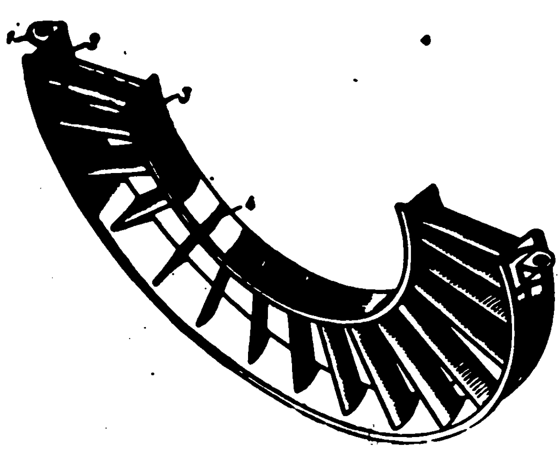

Fig. 112 - Lower Half of Stator Blade Assembly

1 - Lug, 2 - Outer shroud ring, 3 - Inner shroud ring, 4 - Stator blade.

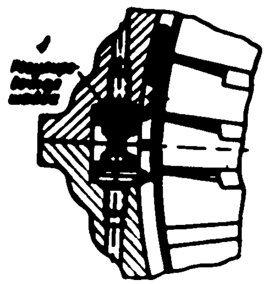

Fig. 113 - Mounting of Stator Blades

1 - Adjusting washer.

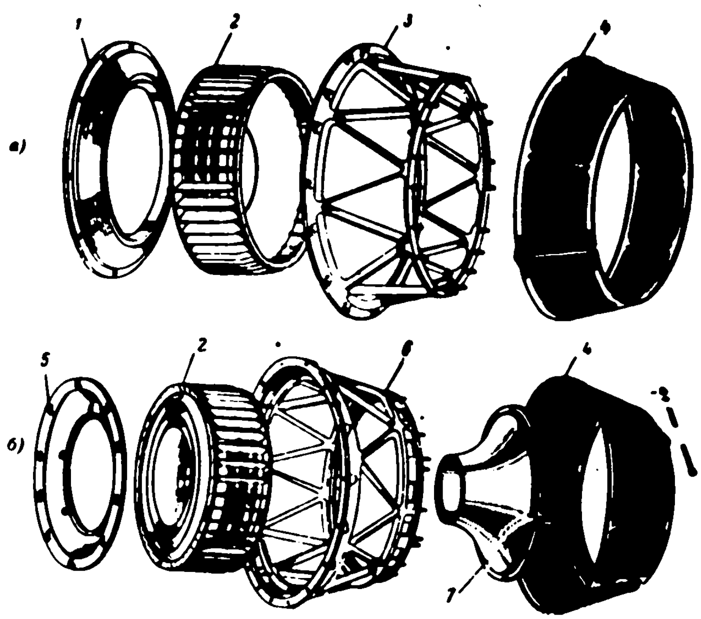

Fig. 114 - Front a and Rear b Truss Rings with Attaching Parts of a Centrifugal Compressor Engine.

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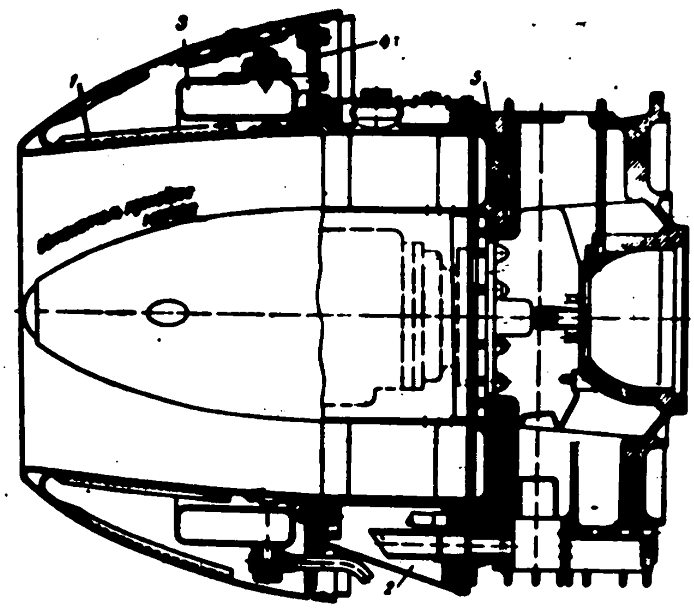

Fig. 115 - Axial Flow Compressor Engine Air Inlet Assembly

1 - Diffuser, 2 - Oil tank, 3 - Gasoline tank, 4 - Connecting flange, 5 - Accessory drive power take-off housing, 6 - Starter motor faring.

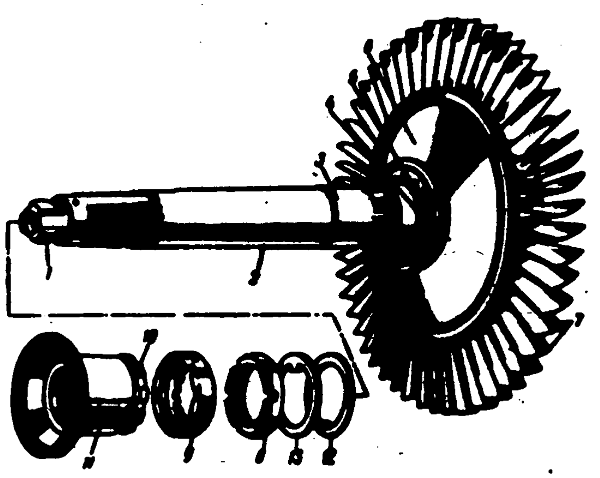

Fig. 116 - Centrifugal Compressor Engine Turbine Rotor

1 - Sphere support for compressor and turbine shafts coupling, 2 - Shaft, 3 - Sleeve, 4 - Balance plug, 5 - Bolt, 6 - Disc, 7 - Blades, 8 - Bearing cage, 9 - Retaining ring, 10 - Retaining ring lock bolt, 11 - Splined driven coupling hub, 12 - Adjusting ring, 13 - Lock washer.

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Fig. 117 - Blade

1 - Blade root with fir tree grooves 2 - Blade.

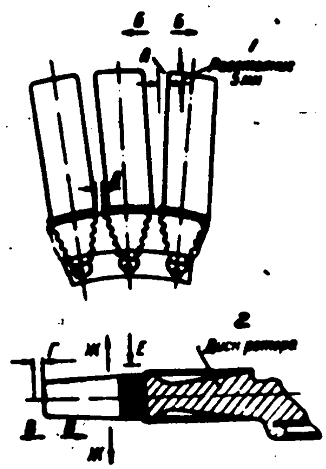

Fig. 118 - Directions of Testing for Looseness of Blades Installed in the Rotor Disc.

1 - Distance - 5 mm,

2 - Rotor disc.

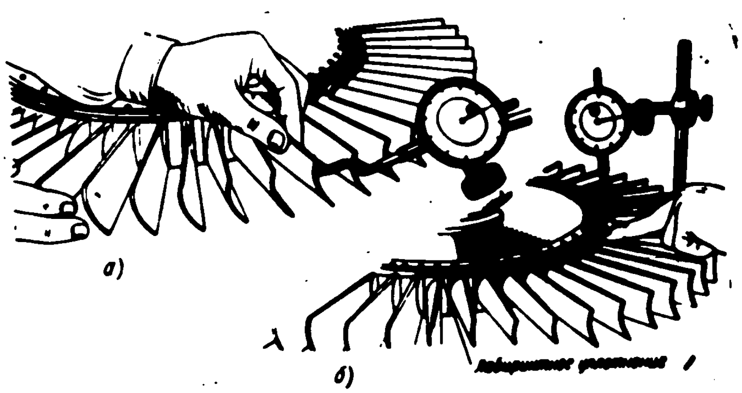

Fig. 119 - Checking Looseness of Blades

a - Tangential, b - Axial,

1 - Labyrinth seal.

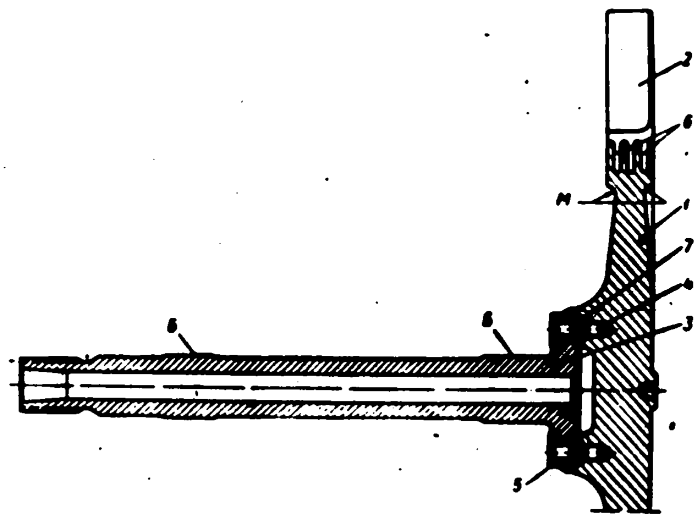

Fig. 120 - Turbine Rotor Shaft of Axial Flow Compressor Engine

1 - Rotor disc, 2 - Blades, 3 - Shaft, 4 - Stud, 5 - Stud nut, 6 - Disc slots, 7 - Bushing.

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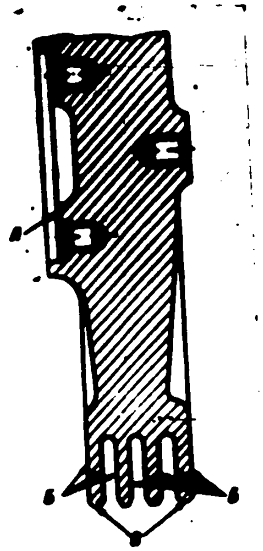

Fig. 121 - Checking of Basic Surface A and of Disc Slots.

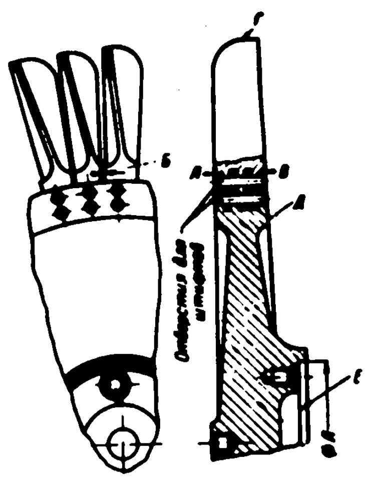

Fig. 122 - Checking Mounting of Blades on Rotor Disc

1 - Holes for Pins.

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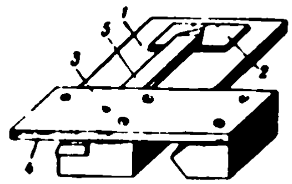
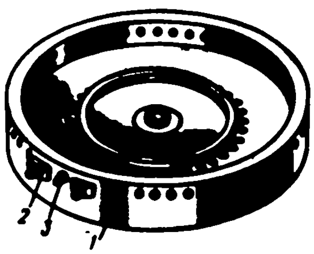


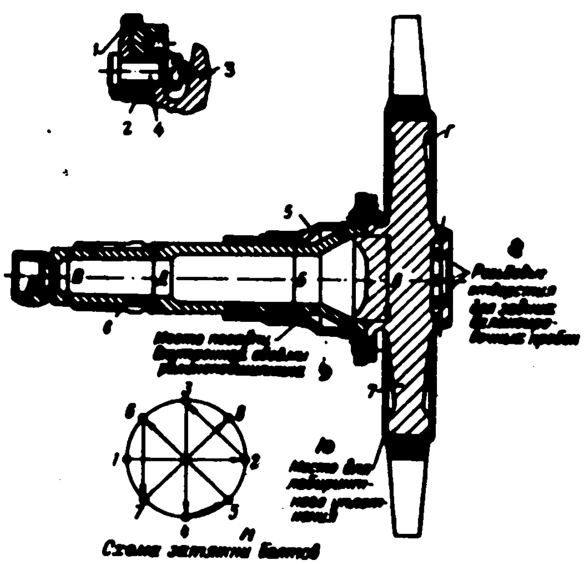
1 - Support,
2 - Scale,
3 - Axle,
4 - Cover,
5 - Indicator point.

Fig. 123 - Device for Checking Pitch of Blades



1 - Case,
2 - Plate,
3 - Plate attaching bolt.

Fig. 124 - Device for Tightening of Blades in Rotor Disc Slots during Drilling of Openings for Dowel Pin



1 - Coupling flange,
2 - Turbine shaft flange,
3 - Turbine disc flange,
4 - Bolt attaching shaft to turbine disc,
5 - Shaft sleeve,
6 - Hollow shaft,
7 - Turbine disc,
8 - Threaded holes for rear balance plugs,
9 - Place for installation of inner race of roller bearing,
10 - Place for labyrinth seal,
11 - Bolt tightening order.

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Fig. 125 - Centrifugal Compressor Engine Turbine RotorAssembly

Fig. 126 - Device for Testing-of-Play of Turbine Rotor Surfaces

1 - Plate,
2 and 3 - Prisms,
4 - Jaws,
5 - Bolt,
6 - Nut.

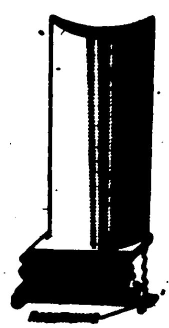

Fig. 127 - Rotor Blade Locking Plate

1 - Plate.

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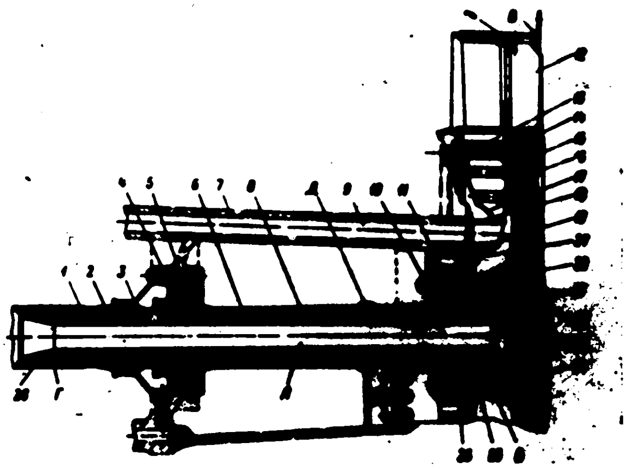

Fig. 128 - Axial Flow Compressor Engine Turbine Rotor Assembly

1 - Lock, 2 - Nut, 3 - Front ball-bearing seal case, 4 - Oil grooves to rear roller bearing, 5 - Inner race of front ball bearing, 6 - Spacer, 7 - Support, 8 - Rotor shaft, 9 - Air channel in support, 10 - Inner ring of the rear roller bearing, 11 - Rear roller-bearing seal housing, 12 - Rotor blade, 13 - Spacer, 14 - Bolt, 15 - Blade to disc attaching pin, 16 - Turbine casing, 17 - Nozzle assembly plate, 18 - Plate tube, 19 - Casing tube, 20 - Turbine rotor disc, 21 - Bushing, 22 - Nut, 23 - Threaded hole, 24 - Stud, 25 - Lock Washer, 26 - Adjusting ring, 27 - Bolt, 28 - Splined coupling, А - Turbine rotor, Б - Centering shoulder of rotor shaft, В - Nozzle diaphragm, Г - Rotor shaft splines, Д - Spacer teeth.

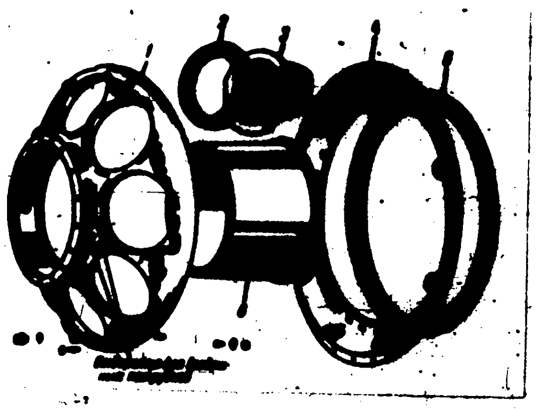

Fig. 129 - Centrifugal Compressor Engine Nozzle [illegible] Parts

1 - Openings for Mounting Air Inlet [illegible]

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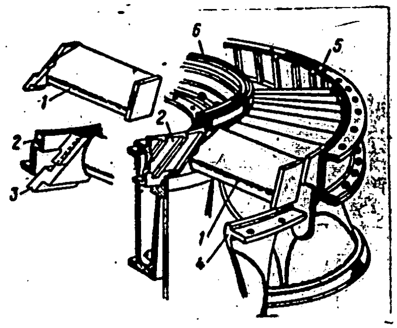

Fig. 130 - Nozzle

1 - Vane, 2 - Inner ring, 3 - Lock recess, 4 - Inlet ducts assembly cover, 5 - Outer ring, 6 - Labyrinth seal.

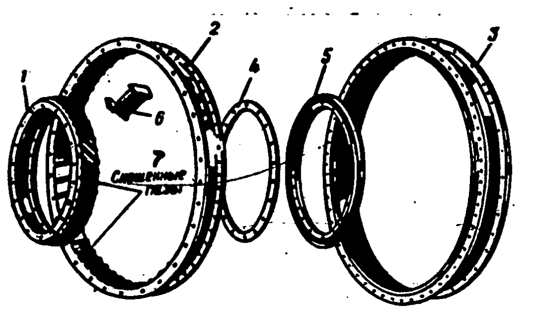

Fig. 131 - Nozzle Parts

1 - Inner ring, 2 - Outer ring, 3 - Turbine casing, 4 - Adjusting ring, 5 - Labyrinth seal, 6 - Vane, 7 - Chamfered slots.

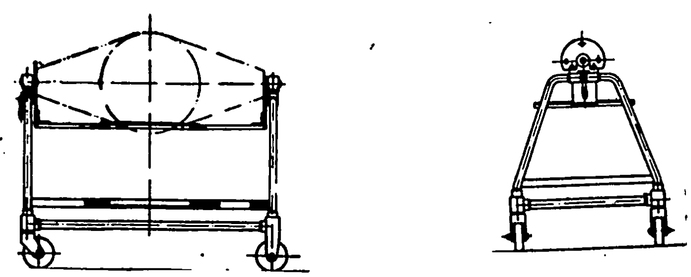

Fig. 132 - Stand for Assembly of Nozzle Intake Ducts and Nozzle.

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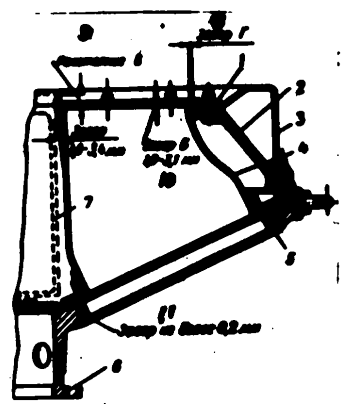
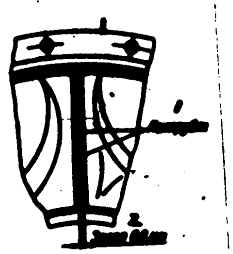


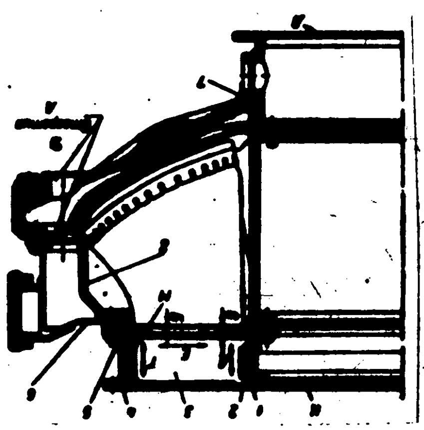
Fig. 133 - Nozzle Inlet Duct Assembly. Seat Checking

1 - Test guide ring, 2 - Casing cover, 3 - De-aerator case, 4 - Air duct, 5 - Adapter flange, 6 - Nozzle air inlet housing, 7 - No legend, 8 - Clearance, 9 - Distance B, 10 - Clearance Б, 11 - Clearance not greater than 0.2 mm.



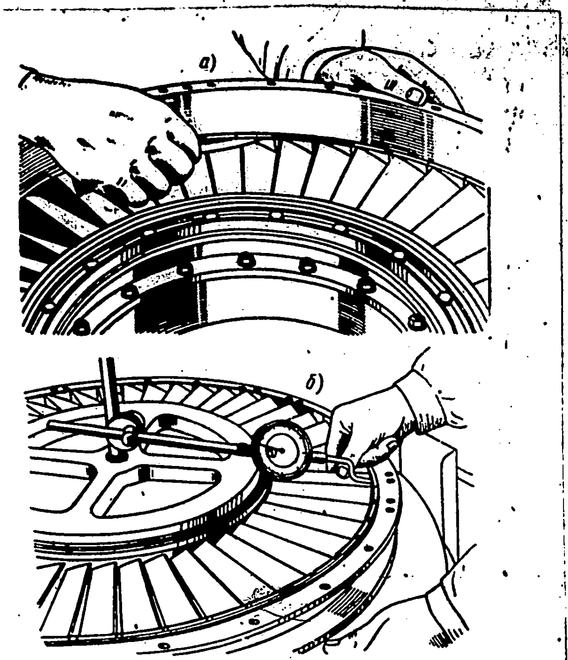
1 - Air ducts,
2 - Clearance.

Fig. 134 - Checking Clearance between Air Ducts



1 - Nozzle inner ring,
2 - Case,
3 - Nozzle vanes,
4 - Nozzle outer ring,
5 - Guide ring,
6 - De-aerator case,
7 - Nozzle inlet duct casing,
8 - Cover,
9 - Holes.

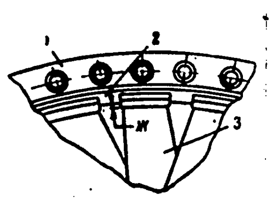
Fig. 135 - Nozzle Air Ducts and [illegible] Assembly



a - Checking radial clearances of nozzle vanes,

b - Checking axial clearances of nozzle vanes.

Fig. 136 - Checking Settings of Nozzle Vanes



1 - Outer ring,
2 - Crosspiece
3 - Vane.

Fig. 137 - Checking Positions of Vanes in Regard to Upper Ring

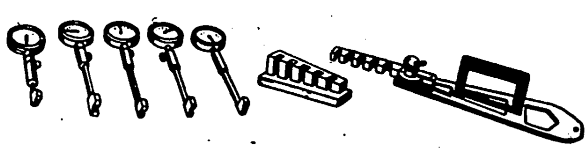


Fig. 138 - Devices for Checking Nozzle Passages.

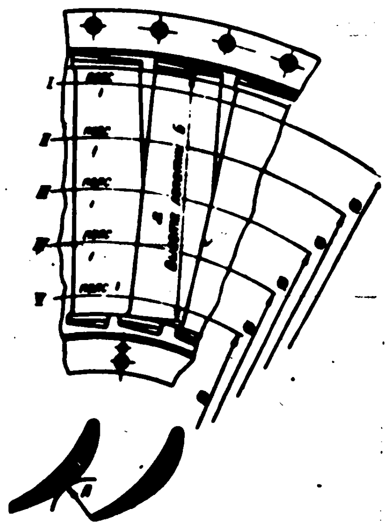


Fig. 139 - Places for Measuring Nozzle Passages and Height of Vanes

1 - Ring, 2 - Vane height.

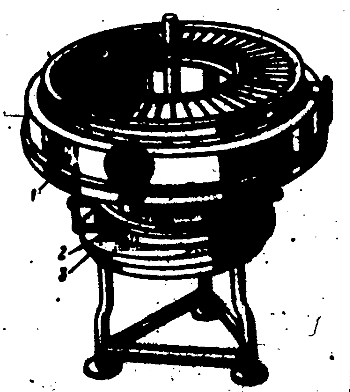


Fig. 140 - Device for Measuring Play of Inner Ring of [illegible]
in Respect to Inlet [illegible]

1 - Nozzle, 2 - Device, 3 - [illegible]

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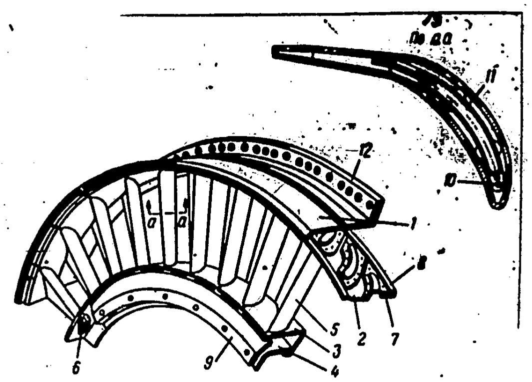
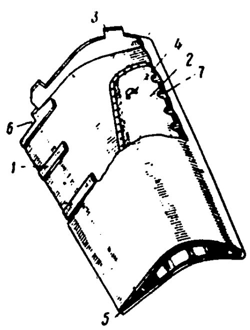


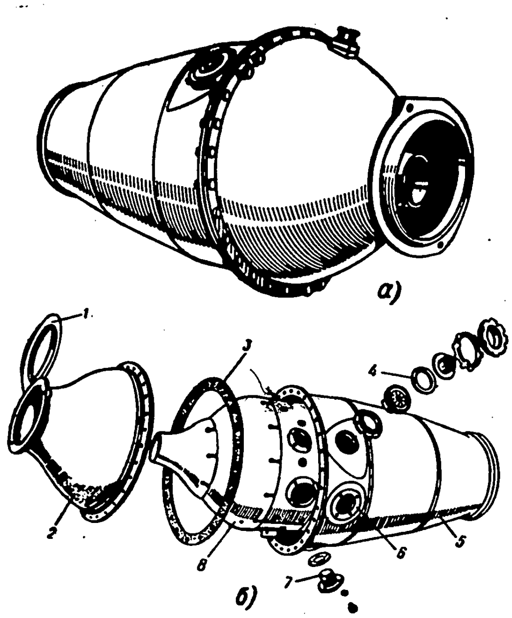
1 - Outer shroud ring,
2 - Vane tip ring,
3 - Vane-support ring,
4 - Inner shroud ring,
5 - Vane,
6 - Vane root on the vane support ring,
7 - Hood,
8 - Rigid ring,
9 - Inner flange,
10 - Hole in deflector for cooling air,
11 - Deflector,
12 - Outer flange.

Fig. 141 - Axial Flow Compressor Engine Nozzle



1 - Plate,
2 - Deflector,
3 - Spacer cover,
4 - Spherical boss,
5 - Slot in the trailing edge of vanes,
6 - Cutout in the trailing edge of vanes,
7 - Holes in deflector.

Fig. 142 - Nozzle Vane



a - Assembled chamber,
b - Chamber parts,
1 - Spherical ring,
2 - Entry section,
3 - Gasket,
4 - Crossover tube parts,
5 - Housing,
6 - Flange for mounting of starting plug,
7 - Suspension cup,
8 - Fire tube.

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Fig. 143 - Combustion Chamber

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Fig. 144 - Combustion Chamber Crossover Tubes

1 - Inner tube, 2 - Outer tube, 3 - Crossover tube housing,
4 - Seal ring, 5 - Copper-asbestos liner, 6 - Nuts,
7 - Combustion chamber casing.

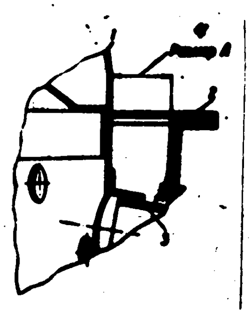

Fig. 145 - Checking Distances between Fire Tube and Combustion Chamber Casing

1 - Fire tube,
2 - Casing,
3 - Crossover tube,
4 - Distance A.

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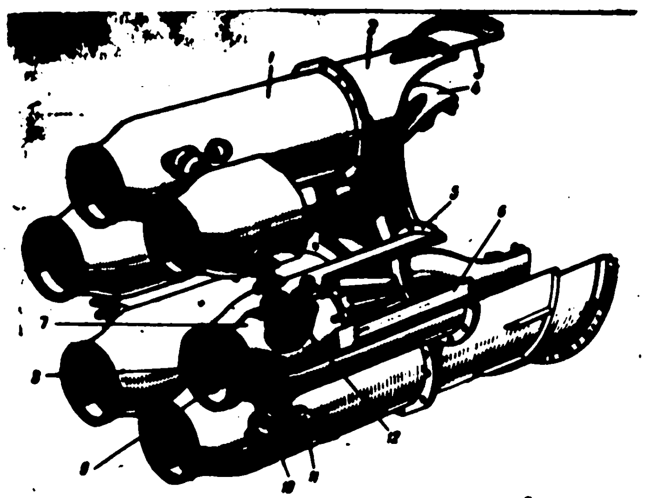


Fig. 146 - Axial Flow Compressor Engine Combustion Chamber and Nozzle Inlet Ducts Assembly

1 - Combustion chamber, 2 - Nozzle inlet ducts, 3 - Place for nozzle assembly mounting, 4 - Inner section of nozzle inlet ducts, 5 - Flange for attaching combustion chamber to nozzle inlet ducts, 6 - Corrugated outer lining, 7 - Entry section, 8 - Scoop, 9 - Swirler, 10 - Corrugated crossover tube, 11 - Plug, 12 - Fuel nozzle.

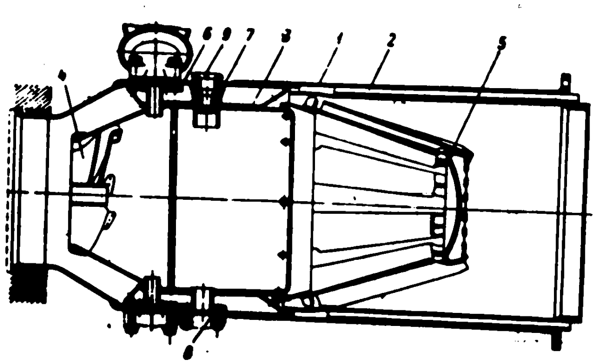


Fig. 147 - Combustion Chamber

1 - Housing, 2 - Outer liner, 3 - Entry section, 4 - Swirler, 5 - Bottom, 6 - Crossover tube mounting flange, 7 - Sleeve, 8 - Flange, 9 - Mounting plugs.

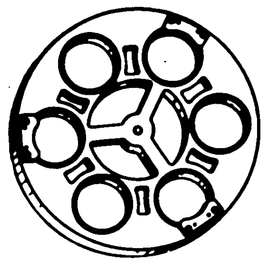


Fig. 148 - Device for Checking Coaxiality of Combustion Chambers

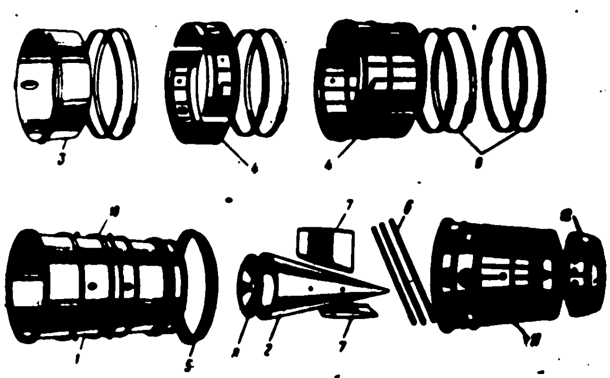


Fig. 149 - Centrifugal Compressor Engine Exhaust Cone

1 - Outer cone, 2 - Inner cone, 3 - Insulation pad, 4 - Outer cone shroud, 5 - Mounting flange, 6 - Tie rods, 7 - Rod braces, 8 - Cone bottom, 9 - Clamp rings, 10.- Reinforcing rings, 11 - General view of exhaust cone, 12 - Exhaust nozzle.

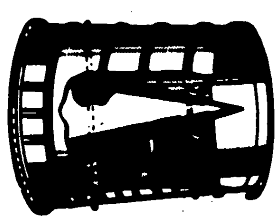


Fig. 150 - Inner Exhaust Cone Mounting

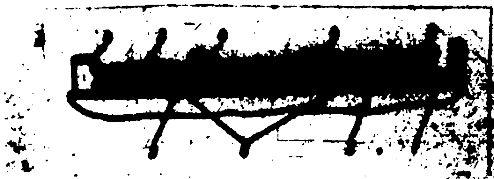


Fig. 151 - Laying Insulation [illegible]

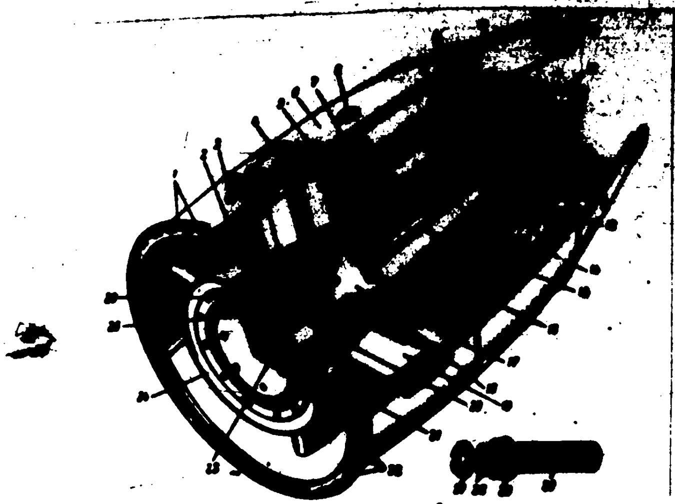
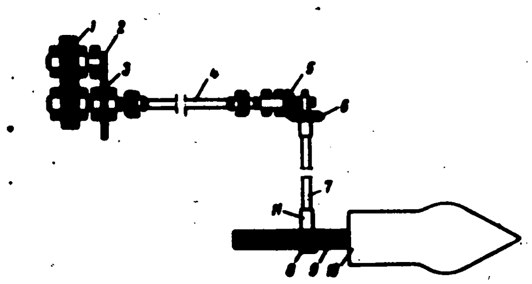


Fig. 152 - Axial Flow Compressor Engine Exhaust Cone

1 - Flange connecting exhaust cone with support housing, 2 - Inner liner, 3 - Control rod splined hub, 4 - Bevel gear, 5 - Deflector rings, 6 - Exhaust pipe housing, 7 and 11 - Ring clamps, 8 - Sight ports, 9 - Rear cone, 10 - Air deflector, 12 - Variable cone, 13 - Bracket, 14 - Stiffener, 15 - Rod, 16 - Outer cone, 17 - Outer strut, 18 - Rod bracket, 19 - Inner strut, 20 - Rack, 21 - Inner cone, 22 - Holes for cooling air, 23 - Stop, 24 - Cover, 25 - Spur gear, 26 - Shaft, 27 - Nut, 28 - Thrust washer, 29 - Cage.



1 - Servo-motor driven gear,
2 and 3 - Reduction gear,
4 - Rod,
5 and 6 - Bevel gear,
7 - Vertical shaft,
8 - Bracket spur gear,
9 - Rack,
10 - Variable cone,
11 - Splined sleeve.

Fig. 153 - Schematic of Control Mechanism of Variable Cone

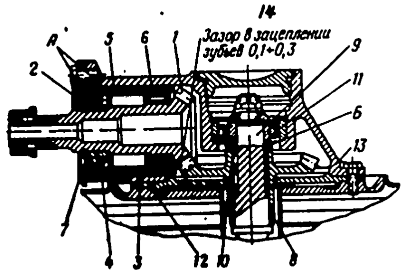


Fig. 154 - Bevel Gear Box

1 - Gear with shaft, 2 - Ball bearing, 3 - Ball and roller bearing support, 4 - Housing, 5 - Spacer hub, 6 - Roller bearing, 7 - Ball bearing support flange, 8 - Gear, 9 - Gear shaft, 10 - Drive shaft coupling, 11 - Ball bearing, 12 - Flange under bevel gear housing, 13 - Bevel gear housing, 14 - Meshing clearance, A and Б - adjusting rings.

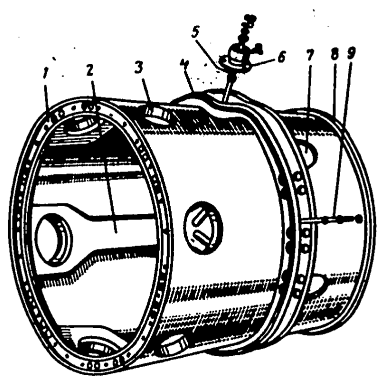


Fig. 155 - Support Casing

1 - Front flange of casing, 2 - Casing pocket, 3 - Front opening in casing, 4 - Stiffener, 5 - Upper vertical bolt, 6 - Engine rear suspension lug, 7 - Rear opening in casing, 8 - Rear casing flange, 9 - Tie rod attaching casing to support.

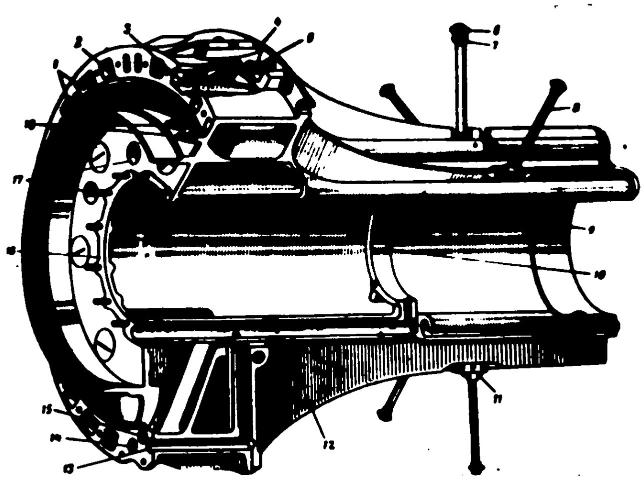


Fig. 156 - Support Assembly

1 - Holes for ignition plugs and ignition system,
2 - Struts,
3 - Exhaust cone air cooling channels,
4 - Front lugs attaching flange,
5 - Air intake installation hole,
6 - Lock washer,
7 - Nut,
8 - Rod,
9 - Turbine rear bearing seat,
10 - Turbine front bearing seat,
11 - Bracket,
12 - Ribs,
13 - Oil draining holes from scavenge main oil line of the support,
14 - Holes for oil feed to bearings,
15 - Oil draining settling tank holes,
16 - Compressor rear bearing cage attaching flange,
17 - Air holes for cooling of turbine disc,
18 - Air holes for cooling nozzle assembly vanes.

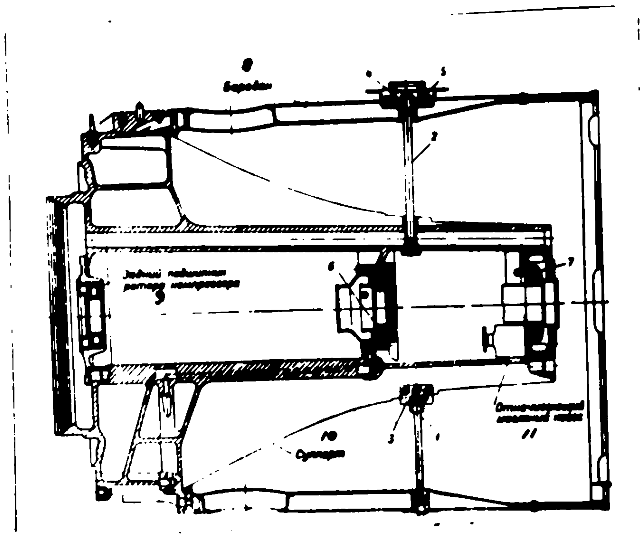


Fig. 157 - Support-Casing Cross Section

1 and 2 - Rods,
3 - Bracket,
4 - Lock,
5 - Adjusting nut,
6 - Turbine rotor front ball bearing,
7 - Turbine rotor rear roller bearing,
8 - Casing,
9 - Compressor rotor rear bearing,
10 - Support,
11 - Scavenge pump.

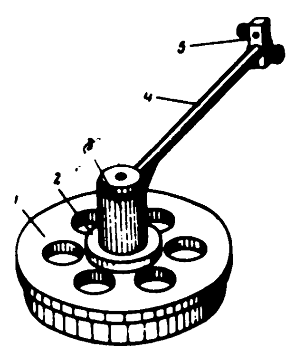


Fig. 158 - Device for Checking Play of Support Casing Shoulder

1 - Body, 2 - Flange, 3 - Hub, 4 - Stem, 5 - Clamp.

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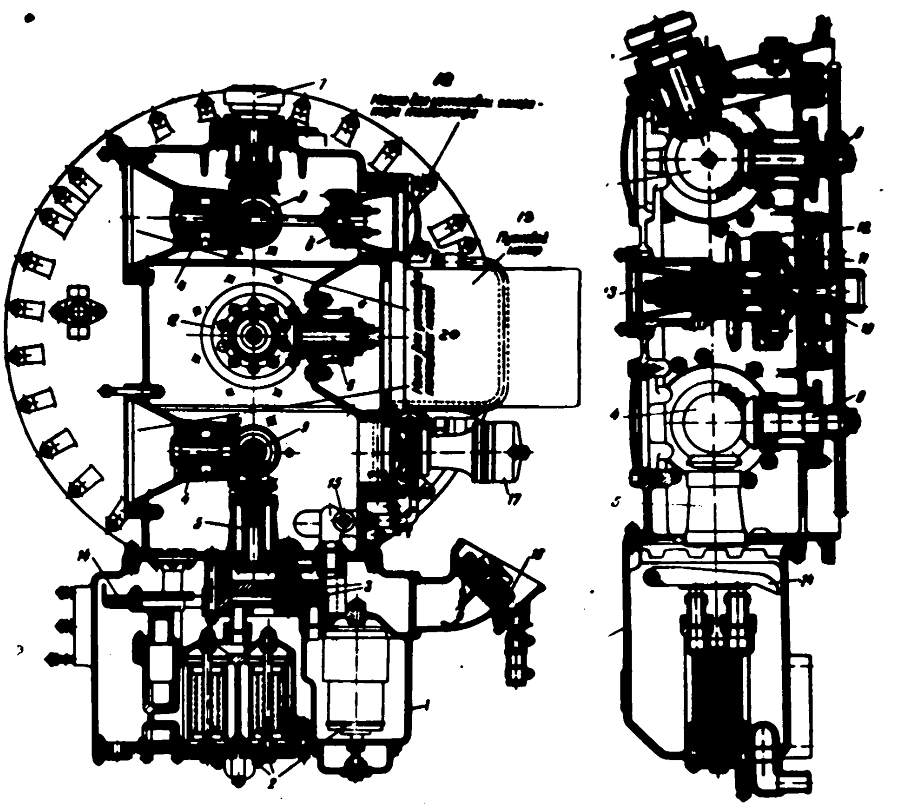

Fig. 159 - Centrifugal Compressor Engine Accessories Drive Gear Case

1 - Sump,
2 - Oil filters,
3 - Oil pump,
4 - Fuel pump drives,
5 - Oil pump drive,
6 - Tachometer generator drive,
7 - Airplane accessory drive power take-off housing,
8 - Starter drive,
9 - Intermediate drive assemblies,
10 - Main drive shaft assembly,
11 - Coupline ratchet,
12 - Starter drive bevel gear,
13 - Breather,
14 - De-aerator tray,
15 - Relief valve,
16 - Oil intake vent,
17 - Oil manometer indicator,
18 - Place for tachometer generator
19 - Starter motor,
20 - Place for fuel pumps.

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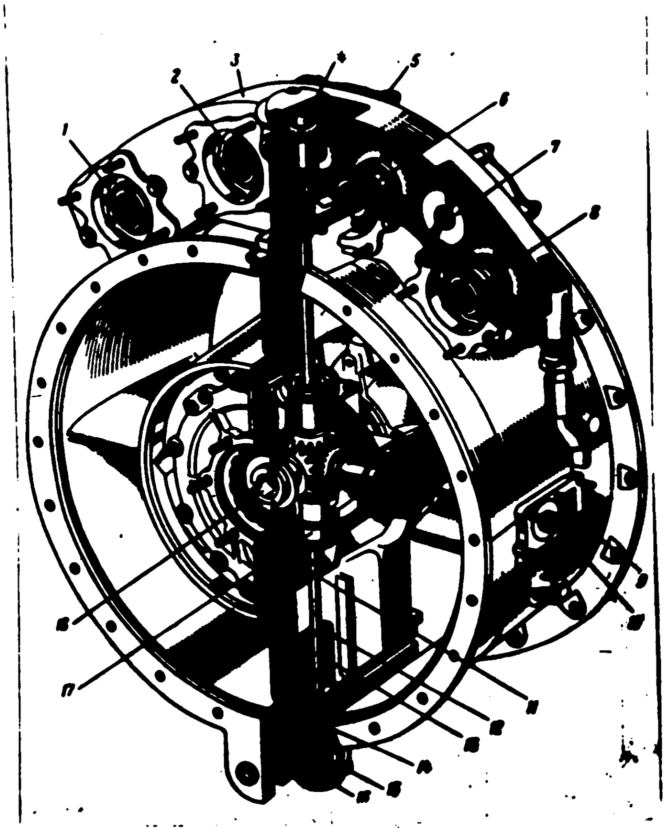

Fig. 160 - Axial Flow Compressor Accessory Drive Power Take-Off Housing

1 - Fuel pump; 2 - Hydraulic pump drive; 3 - Accessory drive gear case;
4 - Drive shaft; 5 - Generator drive; 6 - De-airator drive; 7 - Idle gear;
8 - Tachometer generator drive; 9 - Oil draining casing attaching flange;
10 - Manual turning assembly; 11 - Upper oil filter; 12 - Oil pump filter;
13 - Oil pump drive shaft; 14 - Oil pump; 15 - Oil pump drive gear;
16 - Drive cover; 17 - Oil pump drive bearing; 18 - Ratchet.

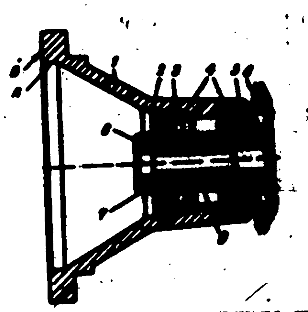

Fig. 161 - Fuel Pump Drive

1 - Fuel pump drive casing
2 - Retaining ring
3 and 5 - Ball bearing cup
4 - Ball bearing
6 - Fuel pump drive gear
7 - Nut
8 - Lock washer
9 - Spacer hub

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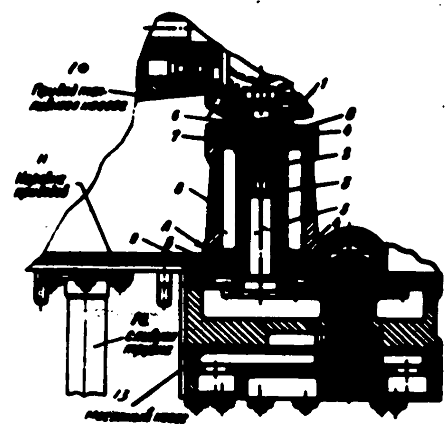

Fig. 162 - Oil Pump Drive Assembly

1 - Bevel gear
2 - Inner splines
3 - Spur gear with shaft
4 - Ball bearing
5 - Spacer
6 - Adjusting ring
7 - Steel cup
8 - Drive housing
9 - Spring ring
10 - Fuel pump drive
11 - Drive gear accessory case
12 - Drain pipe
13 - Oil pump

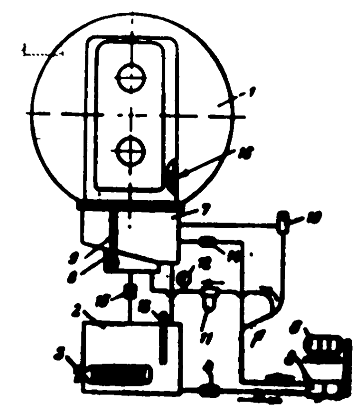

Fig. 163 - Schematic of Drive Gear Accessory Case Testing Fixture

1 - Drive gear accessory case
2 - Oil tank
3 - Electric heater
4 - Pipeline valve
5 - Oil pump
6 - Electric motor
7 - Draining oil tank
8 - Measuring oil tank
9 - Measuring glass
10 - Relief valve
11 - Filter
12 - Manometer
13 - Thermocouple
14 - Control valve
15 - Oil drain valve
16 - Place for jet.

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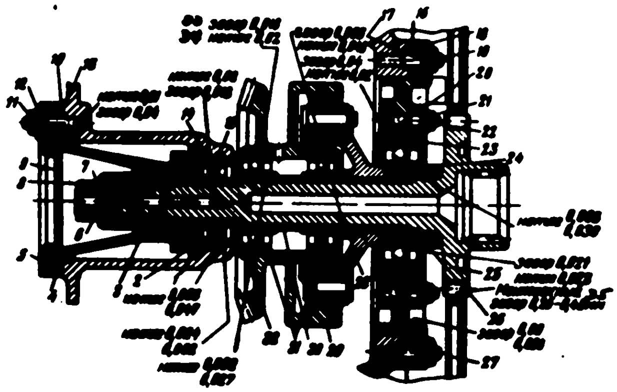

Fig. 164 - Spur Drive Gear Assembly

1 - Thrust ring

2 - Retaining ring

3 - Breather sleeve

4 - Breather casing

5 - Breather cover

6 - Washer

7 - Retaining washer

8 - Nut

9 - Breather screen

10 - Gasket

11 - Nut

12 - Washer

13 - Drive gear accessory case

14 - Roller bearing

15 - Roller bearing cup

16 - Adjusting washer

17 - Retaining washer

18 - Drive spur gear bearing flange

19 - Nut

20 - Ball bearing cup

21 - Retaining washer

22 - Nut

23 - Thrust disc

24 - Ball bearing

25 - Spur drive gear

26 - Space hub

27 - Spur driven gear

28 - Starter clutch

29 - Starter driven bevel gear

30 - Spacer hub

31 - Ball bearing

32 - Spacer hub

33 - Clearance

34 - Torque

35 - Installation clearance.

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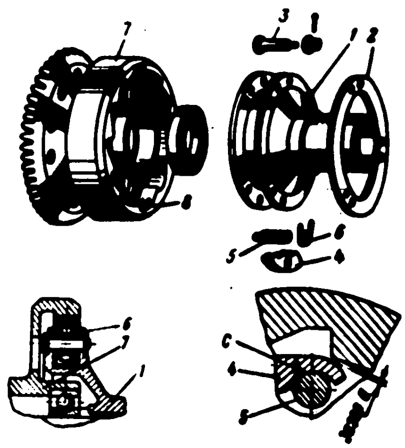

Fig. 165 - Drive Spur Gear Assembly
Ratchet Mechanism Parts

1 - Hub
2 - Thrust ring
3 - Pawl pin
4 - Pawl
5 - Dowel
6 - Spring
7 - Sleeve
8 - Sleeve splines
9 - Clearance.

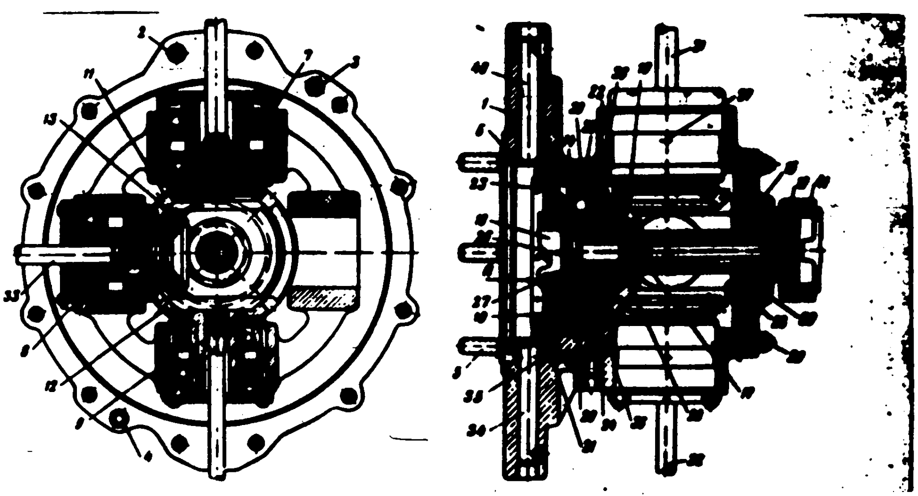

Fig. 166 - Axial Flow Compressor Engine Bevel Gear or Accessory Drive Power Take-Off Assembly

1 - Housing; 2 - Positioning plugs; 3-4 - Mounting screws; 5 - Starter motor attaching stud; 6 - Ring; 7 - Accessory case drive; 8 - Manual turning assembly drive; 9 - Oil pump drive; 10 - Bevel gear or power take-off drive gear; 11 - Accessory drive gear, 12 - Oil pump drive gear; 13 - Manual turning assembly drive gear; 14 - Front ball bearing; 15 - Rear roller bearing; 16 - Drive gear shaft; 17 - Shaft adjusting screw; 18 - Ratchet; 19 - Drive gear ball bearing liner; 20 - Drive gear ball bearing cage; 21 - Ball bearing attaching nut; 22 - Adjusting ring; 23 - Nut; 24 - Splined coupling; 25 - Spring ring; 26 - Plug; 27 - Spring ring; 28 - Cover; 29 - Cover attaching stud; 30 - Spring ring; 31 - Accessory case drive shaft; 32 - Oil pump drive shaft; 33 - Manual turning assembly drive shaft; 34, 35, 36, 40 - Oil channels; 37 - Holes for oiling accessory drive power take-off parts; 38 - Casing holes for oiling of bearing; 39 - Holes in liner for oiling of bearing; 41 - Front compressor shaft.

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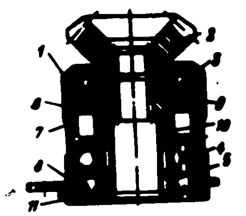

Fig. 167 - Manual Turning Assembly Drive

1 - Casing
2 - Gear
3 - Roller bearing
4 - Ball bearing
5 - Lock washer
6 - Adjusting ring
7 - Spacer
8 - Nut
9 - Roller bearing inner race
10 - Spacer
11 - Nut.

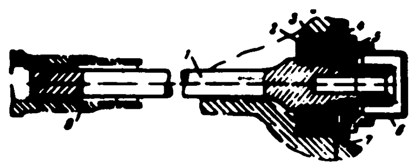

Fig. 168 - Engine Manual Turning Assembly

1 - Drive shaft
2 - Ball bearing
3 - Ball bearing liner
4 - Dowel
5 - Thrust ring
6 - Housing
7 - Accessory drive power take-off oil draining case
8 - Drive gear.

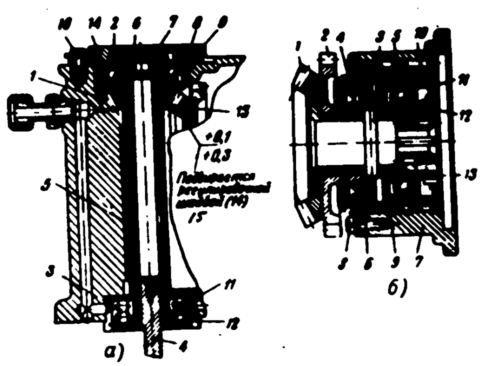

Fig. 169 - Accessory Drive Shaft and Bevel Gear Drive

a - Drive shaft

1 - Accessory drive bevel gear; 2 - Ball bearing; 3 - Roller bearing; 4 - Drive shaft; 5 - Drive shaft positioning tube; 6 - Screw; 7 - Spring ring; 8 - Ball bearing case; 9 - Cover; 10 - Screw; 11 - Roller bearing liner; 12 - Spring ring; 13 - Power take-off bevel gear; 14 - Adjusting ring; 15 - Selected by means of adjusting washer.

b - Accessory Drive Power Take-off

1 - Bevel gear; 2 - Spur gear; 3 - Dowel; 4 - Roller Bearing; 5 - Ball bearing; 6 - Bearing liner; 7 - Drive housing; 8 - Screw; 9 - Adjusting ring; 10 - Nut; 11 - Spring ring; 12 - Nut; 13 - Plate washer.

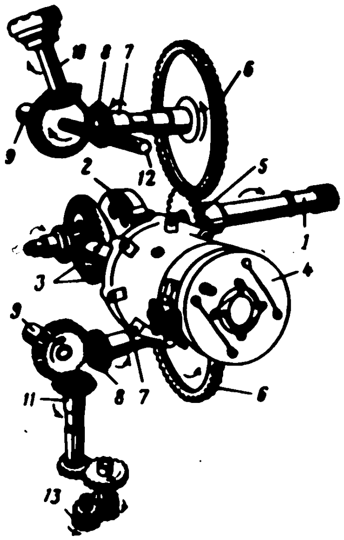

Fig. 170 - Kinematic of Centrifugal Compressor Engine Drive Gear Accessory Case

1 - Main drive shaft
2 - Ratchet clutch
3 - Bevel gear
4 - Starter
5 - Spur gear
6 - Large spur gears
7 - Intermediate shafts
8 - Bevel gears
9 - Gears with fuel pump drive shafts
10 - Auxiliary airplane drive gear shaft
11 - Oil pump gear
12 - Tachometer generator drive shaft
13 - Oil pump gears

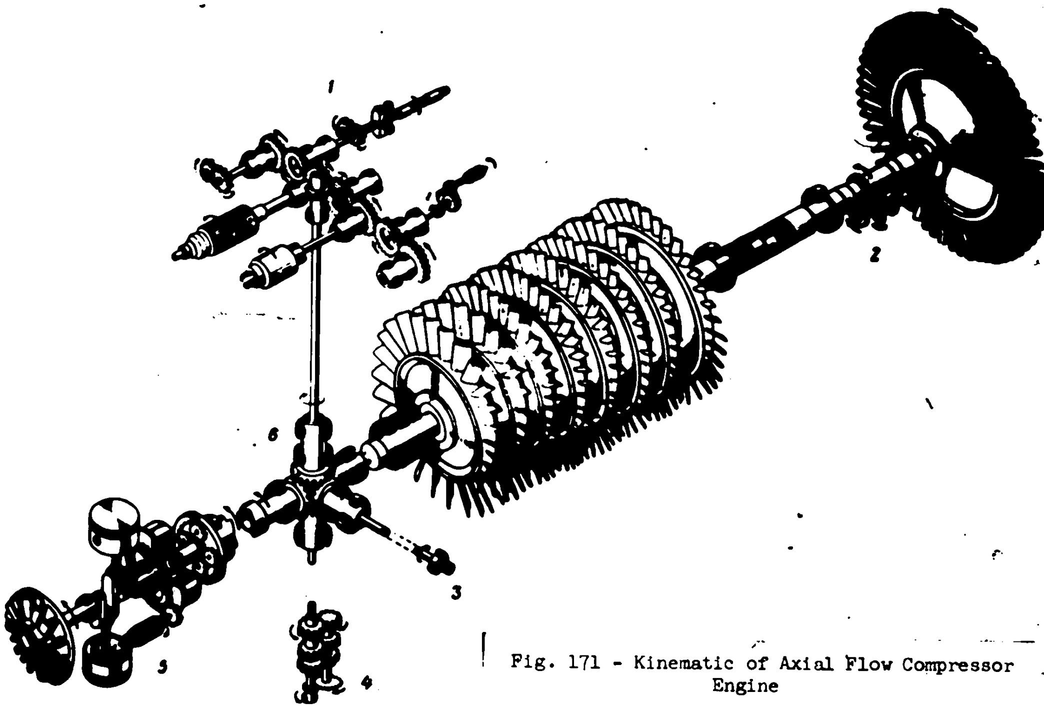

Fig. 171 - Kinematic of Axial Flow Compressor Engine

1 - Accessory case drive gears; 2 - Scavenge oil pump gears; 3 - Engine manual turning assembly; 4 - Oil pump gears; 5 - Starter motor; 6 - Power take-off assembly.

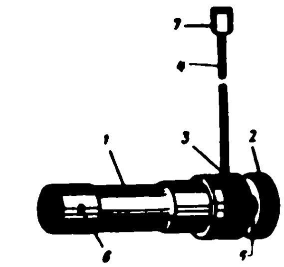

Fig. 172 - Fixture for Checking Backlash of Accessory Drive Bevel Gears

1 - Split cylinder
2 - Nut
3 - Cone
4 - Rod
5 - Dowel pin
6 - Joint pin
7 - Plate for installation of indicator leg.

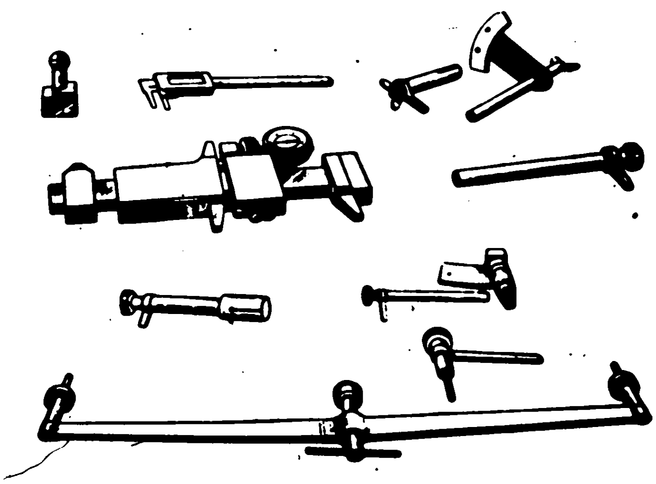

Fig. 173 - Fixtures for Checking Clearances between Gear Teeth of Centifugal Compressor Engine Drive Gear Accessory Case.

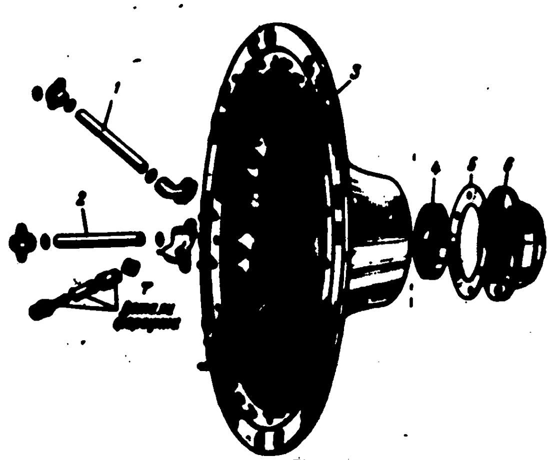

Fig. 174 - Front Roller Bearing Assembly

1 - Oil inlet tube
2 - Air inlet tube
3 - Housing
4 - Roller bearing
5 - Gasket
6 - Labyrinth seal
7 - Jet parts.

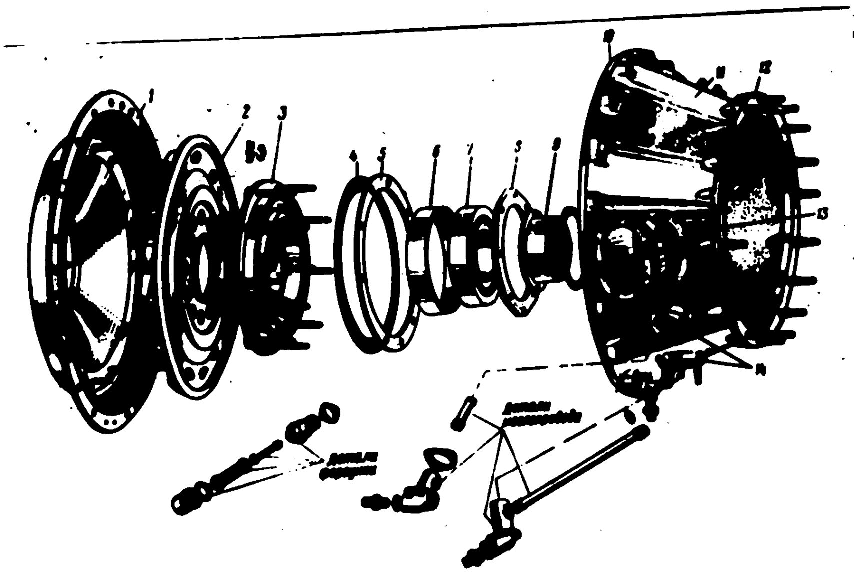

Fig. 175 - Center Radial Thrust Ball Bearing Assembly Details

1 - Cooling impeller front cover; 2 - Rear wall of cooling impeller; 3 - Middle bearing cover; 4 - Gasket; 5 - Adjusting ring; 6 - Steel ring; 7 - Ball bearing; 8 - Tightening washer; 9 - Labyrinth seal; 10 - Front flange; 11 - Housing; 12 - Rear flange; 13 - Inspection port; 14 - Openings for oil tubes.

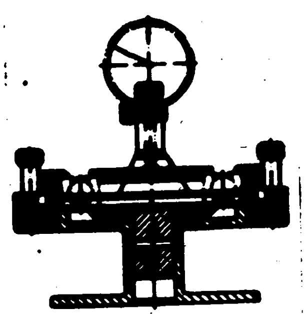

Fig. 176 - Device for Checking Axial Play in Ball Bearing

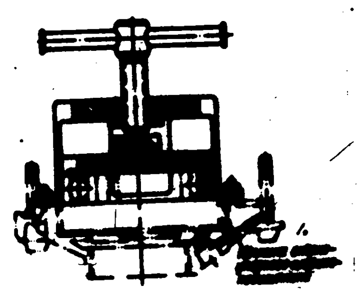

Fig. 177 - Device For Pressing In Of Ball Bearing

1 - Radial thrust ball bearing cover.

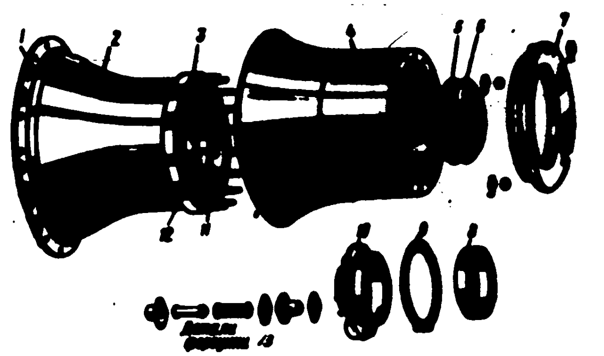

Fig. 178 - Rear Bearing Support Assembly Parts

1 - Front flange
2 - Bearing support
3 - Rear flange
4 - Shroud
5 - Gasket
6 - Rear labyrinth seal
7 - Deflecting ring
8 - Roller bearing
9 - Gasket
10 - Front labyrinth seal
11 - Bearing seat support
12 - Bearing seat
13 - Nozzle parts

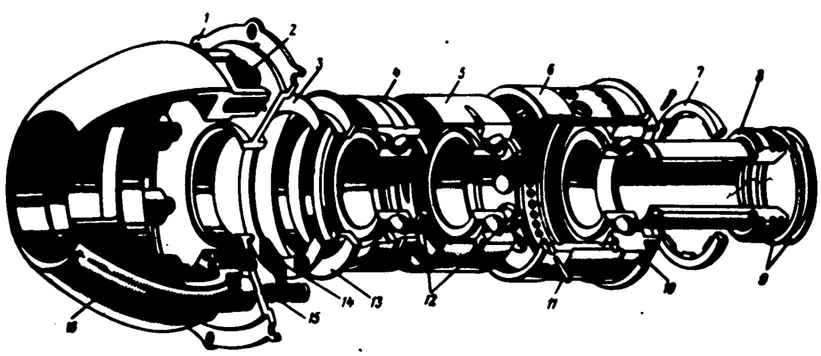

Fig. 179 - Compressor Rotor Front Three-Row Ball Bearing Assembly

1 - Cover attaching bearing to accessory drive power take-off housing; 2 - Plug; 3 - Adjusting ring; 4 - Inner bearing support; 5 - Middle bearing support; 6 - Outer bearing support; 7 - Nut; 8 - Bearing liner; 9 - Oil seal rings; 10 - Retaining strip hole; 11 - Dowel; 12 - Spacer rings; 13 - Thrust ring; 14 - Retaining strip; 15 - Spring; 16 - Spherical bearing support casing.

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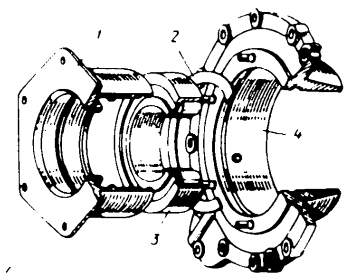

Fig. 15[illegible] - Compressor Rotor Rear Roller Bearing Parts

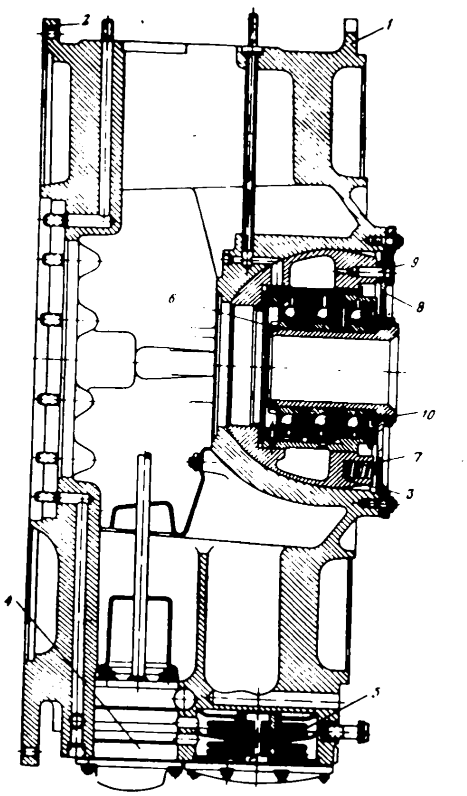

Fig. 151 - Front Three-Row Ball Bearing In Accessory Drive Power Take-off Housing

1 - Housing rear flange
2 - Housing front flange
3 - Compressor rotor shaft ball bearing spherical housing
4 - Oil pump housing
5 - Oil filter
6 - Bearing nut
7 - Springs pressing bearing to accessory drive power take-off bearing
8 - Cover attaching bearing to accessory drive power take-off housing
9 - Positioning dowel
10 - Sealing rings

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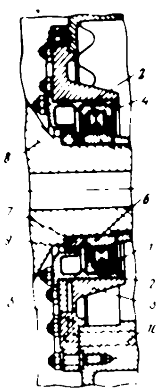
1.



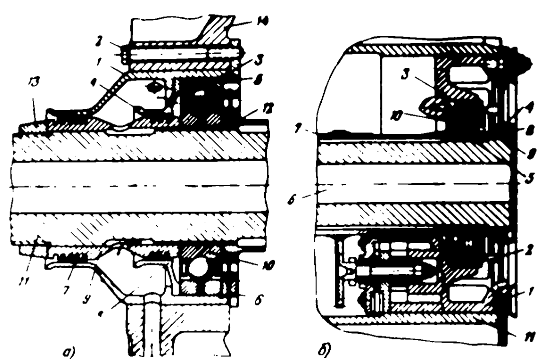


Fig. 1[illegible] - Axial Flow Compressor Engine Turbine Front and Rear Bearings

a - Turbine rotor front bearing assembly

1 - Bearing housing
2 - Bearing attaching bolt
3 - Ball bearing outer ring
4 - Housing cover
5 - Nut
6 - Retaining ring
7 and 8 - Sealing rings
9 - Seals
10 - Ball bearing inner race
11 - Rotor shaft
12 - Spacer
13 - Turbine shaft nut
14 - Support.

b - Turbine rotor rear bearing assembly

(1) Bearing housing
(2) Liner
(3) Roller bearing outer race
(4) Bearing cover
(5) Roller bearing inner race
(6) Turbine rotor shaft
(7) Shaft spacer
(8) Rear seal
(9) Sealing rings
(10) Roller bearing
(11) Support rear flange

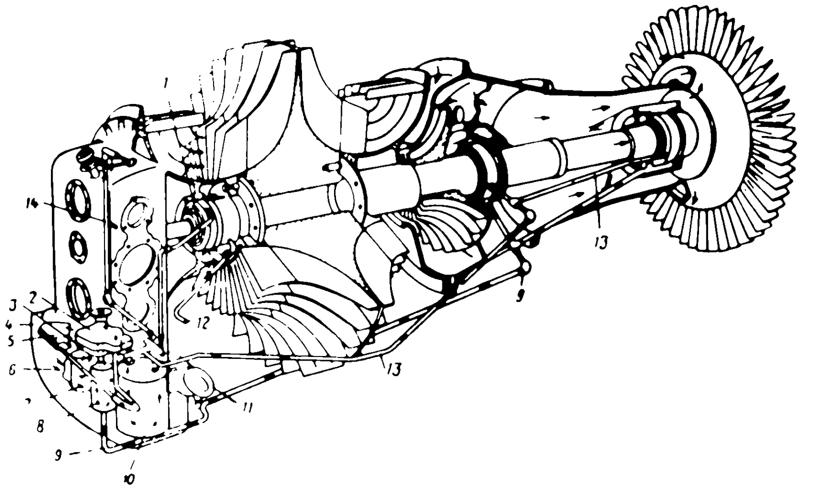


Fig. 1[illegible] - Centrifugal Compressor Engine Oil System

1 - Front bearing pressure oil line

2 - Scavenge oil stage

3 - Pressure oil stage

4 - Oil pump casing

5 - De-aerator tray

6 - Oil intake

7 - Pressure stage oil filter screen

8 - Scavenge stage oil filter screen

9 - Center and rear bearings scavenge oil lines

10 - Slotted high-pressure oil filter

11 - Opening for oil in casing

12 - Air intake pipe to labyrinth seal

13 - Center and rear bearings pressure oil lines

14 - Pressure oil lines to airplane accessory gears and to gear lubricating pipes.

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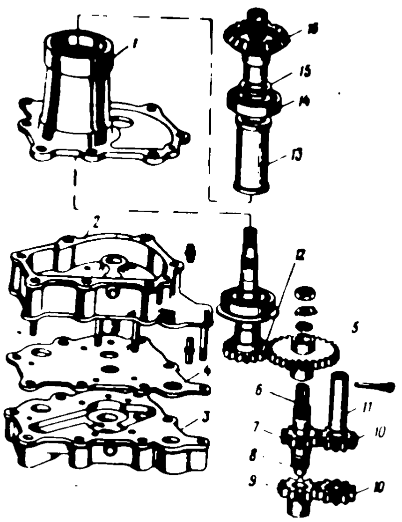

Fig. 155 - Oil Pump With Drive

1 - Oil pump drive housing
2 - Scavenge stage
3 - Pressure stage
4 - Center plate
5 - 7 - 9 - Drive gears
6 and 8 - Splines
10 - Driven gears
11 - Oil pump shaft
12 - Drive spur gear
13 - Spacer
14 - Ball bearing
15 - Adjusting washer
16 - Bevel gear.

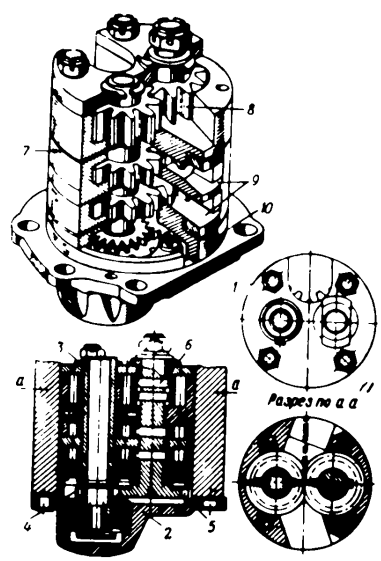

Fig. 15[illegible] - Oil Pump

1 - Bolts
2 - Pump cover
3 - Oil pump shaft
4 and 5 - Gears
6 - P[illegible]
7 - Groove
8 - [illegible] stage
9 - Pressure stage
10 - Body
11 - Cross section [illegible]

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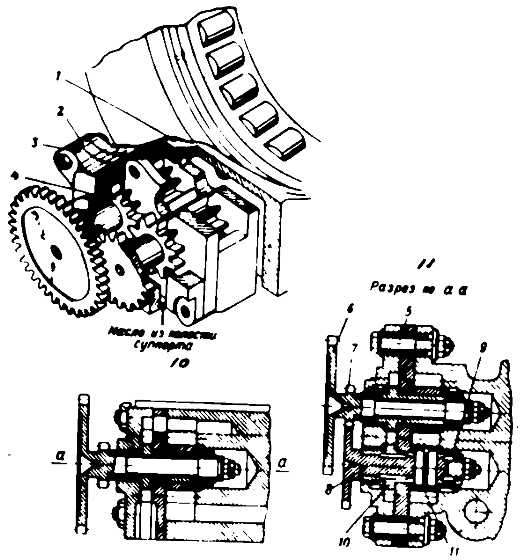

Fig. 187 - Oil Scavenge Pump

1 - Oil pump body

2 - Center plate

3 - Oil pump cover

4 - 10 and 11 - Oil pump gears

5 - Bolts

6, 7 and 8 - Gears

9 - Bushing

10 - Oil from support

11 - Cross-section at a a.

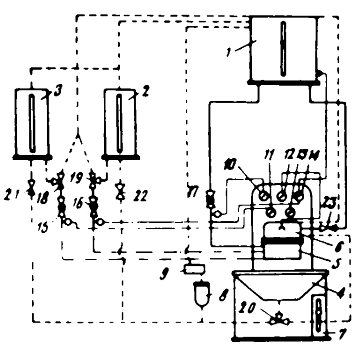

Fig. 188 - Schematic of Oil Pump Testing Installation.

1 - Service tank
2 - Metering tank of scavenge stage of pump
3 - Metering tank of pressure stage of pump
4 - Installation stand
5 - Lower casing
6 - Upper casing
7 - Rheostat
8 - Oil filter
9 - Auxiliary oil pump
10 - Vacuum meter
11 - Manometer
12 - RPM indicator
13 - Manometer
14 - Air thermometer
15, 16 and 17 - Valves
18, 19 and 20 - Three-way valves
21, 22 and 23 - Valves.

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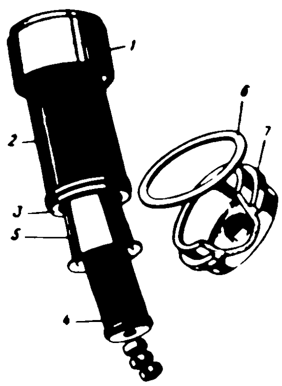

Fig. 189 - High-Pressure Oil Filter

1 - Outer liner

2 - Outer filter

3 - Inner liner

4 - Inner filter

5 - Spacer

6 - Rubber ring

7 - Filter cap.

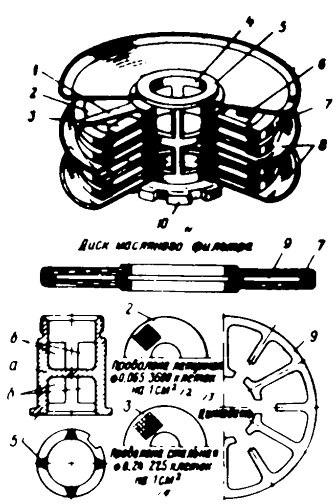

Fig. 190 - Oil Filter

a - partition   b - openings

1 - Spacer
2 - Fine mesh screen
3 - Coarse mesh screen
4 - Opening
5 - Body
6 - Inner washer
7 - Rim
8 - Partition
9 - Shaped washer
10 - Nut
11 - Oil filter disc
12 - Brass wire ∅0.065 3600 mesh per 1 cm^2
13 - To be galvanized
14 - Steel wire ∅0.24 225 mesh per 1 cm^2.

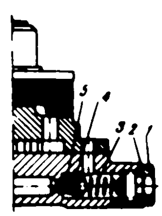

Fig. 191 - Relief Valve

1 - Adjusting screw   3 - Spring
2 - Gasket   4 - Ball seat
5 - Ball

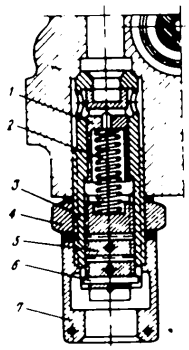

Fig. 192 - Relief Valve

1 - Relief valve cup

2 - Spring

3 - Relief valve housing

4 - Nut

5 - Relief valve screw

6 - Dowel

7 - Cap

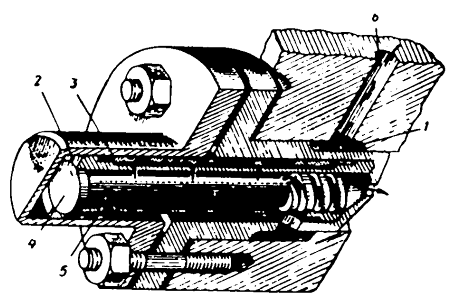

Fig. 193 - Oil Jet

1 - Oil annulus

2 - Brass bushing

3 - Screen

4 - Rod with spiral

5 - Hole connecting cavity between bushing and jet housing

6 - Oil intake channel.

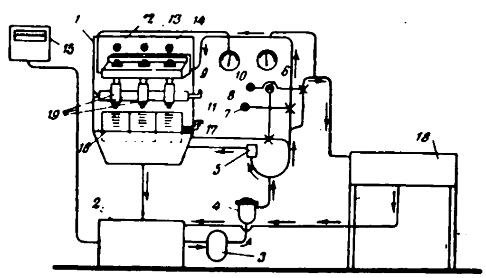

Fig. 194 - Schematic of Installation for Calibration Tests of Oil Jets

1 - Installation stand; 2 - Service tank; 3 - Pump with drive; 4 - Filter; 5 - Relief valve; 6, 7, and 8 - Control valves; 9, 10 - Manometers; 11 - Oil cutoff lever; 12, 13 and 14 - Valves; 15 - Contact galvanometer; 16 - Metering retorts; 17 - Metering retort oil draining lever; 18 - Stand for hydraulic testing of other parts; 19 - Jets being tested.

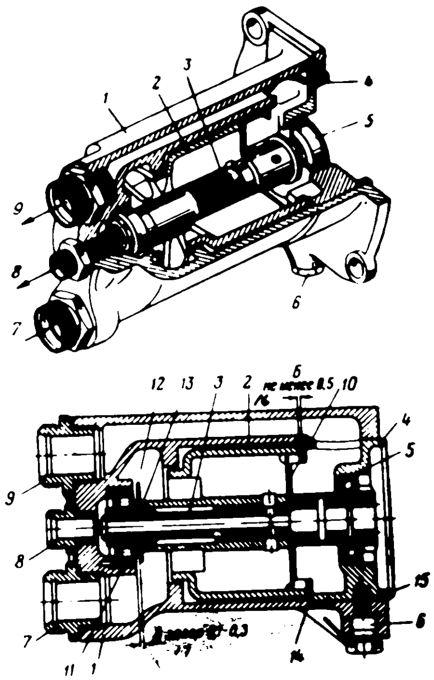

Fig. 195 - De-Aerator

1 - Casing
2 - Centrifuge
3 - Drive shaft
4 - Cover
5 - Ball bearing
6 - Screw
7 - Oil inlet tube
8 - Air outlet tube
9 - Oil outlet tube
10 - Rotating washer
11 - Roller bearing
12 - Deflecting washer
13 - Centrifuge sleeve
14 - Washer
15 - Dowel
16 - Not less than 0.5
17 - Clearance 0.1 - 0.3.

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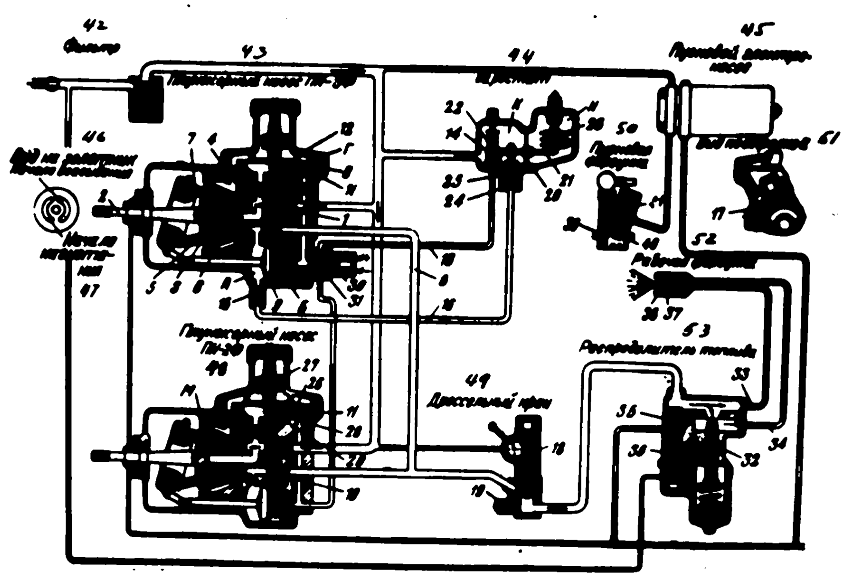

Fig. 196 - Centrifugal Compressor Engine Fuel System

1 - Filter
2 - Coupling shaft
3 - Rotor
4 - Gate valve
5 - Plunger
6 - Plunger
7 - Rocker arm
8 - High-pressure channel
9 - Servo-piston
10 - Jet
11 - Pump valve
12 - RPM governor
13 - Channel connecting pump with barostat
14 - Barostat valve
15 - Damper
16 - Channel connecting damper with barostat
17 - Discharge valve
18 - Throttle valve metering needle
19 - Idling valve
20 - Flexible partition of barostat
21 - Lever
22 - Barostat valve spring
23 - Aneroid
24 - Diaphragm
25 - Piston
26 - RPM governor membrane
27 - Governor spring
28 - Pump valve lever
29 - Valve spring
30 - Solenoid
31 - Solenoid valve
32 - Distributor fuel valve
33 - Auxiliary line to fuel nozzles
34 - Main line to fuel nozzles
35 - Cut-off valve
36 - Distributor casing
37 - Atomizer
38 - Jet nozzle
39 - Plug
40 - Igniter plug atomizer
41 - Igniter plug needle

A and Б - Servo-piston cavities
B and Г - RPM governor chambers
K - Barostat valve chamber
H - Barostat aneroid chamber
M - Openings connecting central rotor valve with rotor

42 - Filter
43 - Plunger pump
44 - Barostat
45 - Starting electric pump
46 - Gate valve view - suction start
47 - Pressure start
48 - Plunger pump
49 - Throttle valve
50 - Ignitor plug
51 - View along arrow a
52 - Fuel plug
53 - Fuel distributor.

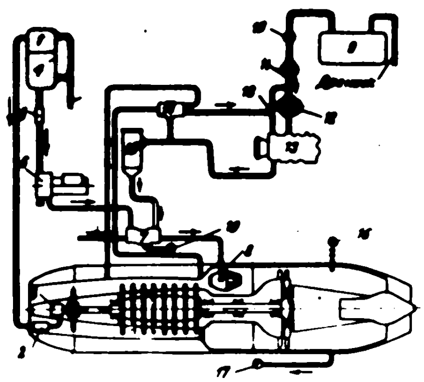

Fig. 197 - Axial Flow Compressor Engine Fuel System

1 - Upper section of fuel tank
2 - Starter motor fuel filter
3 - Starter motor
4 - Lower section of fuel tank
5 - Fuel filter of starter fuel
6 - Starter fuel pump
7 - Distributing box
8 - Fuel plug
9 - Airplane fuel tank
10 - Fire valve
11 - Main low-pressure fuel filter
12 - Main fuel pump
13 - RPM governor
14 - Compressor pressure limiter
15 - High-pressure fuel filter
16 - Thermoelectric thermometer in exhaust cone
17 - Gas pressure manometer in exhaust cone
18 - By-pass pipe from RPM governor
19 - Manometer
20 - Drain.

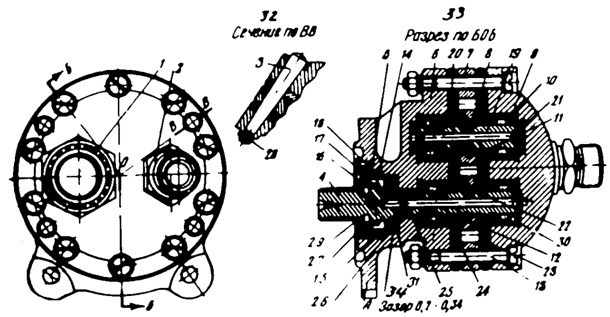

Fig. 198 - Fuel Pump of Gear Driven Type

1 - Intake suction pipe sleeve; 2 - Pressure pipe; 3 - Tapered dowel; 4 - Drive gear shaft; 5 - Rubber cup; 6 - Pump front cover; 7 - Pump body; 8 and 20 - Intermediate walls; 9 - Pump rear cover; 10 - Needle bearing; 11 - Driven gear; 12 - Drive gear; 13 - Bolt; 14 - Spring ring; 15 - Retainer cup; 16 - Nut; 17 - Plate lock; 18 - Screw; 19 - Driven gear shaft; 21 - Thrust bearing; 22 - Ball; 23 - Gasket; 24 - Bearing ring; 25 - Labyrinth seal; 26 - Seal ring; 27 - Cup housing; 28 - Lockpin; 29 - Lock ring; 30 - Needle bearing ring; 31 - Lock washer; 32 - Cross section at ВВ; 33 - Cross section at БОБ; 34 - Clearance 0.2 - 0.34.

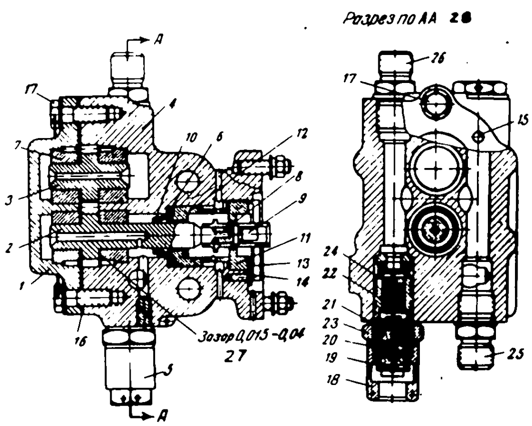

Fig. 199 - Starting Fuel Pump

1 - Cover; 2 - Drive gear; 3 - Driven gear; 4 - Body; 5 - Relief valve; 6 - Rubber cup; 7 - Bronze bushing (thrust bearing); 8 - Butt; 9 - Coupling; 10 - Cup spring; 11 - Oilseal nut; 12 - Oilseal bushing; 13 - Oilseal nut lock; 14 - Lock screw; 15 - Lock pin; 16 - Gasket; 17 - Cover attaching screw; 18 - Relief valve cap; 19 - Dowel; 20 - Relief valve screw; 21 - Relief valve body; 22 - Spring; 23 - Nut; 24 - Relief valve cup; 25 - Suction inlet; 26 - Pressure pipe inlet; 27 - Clearance 0.015 - 0.04; 28 - Cross section at AA.

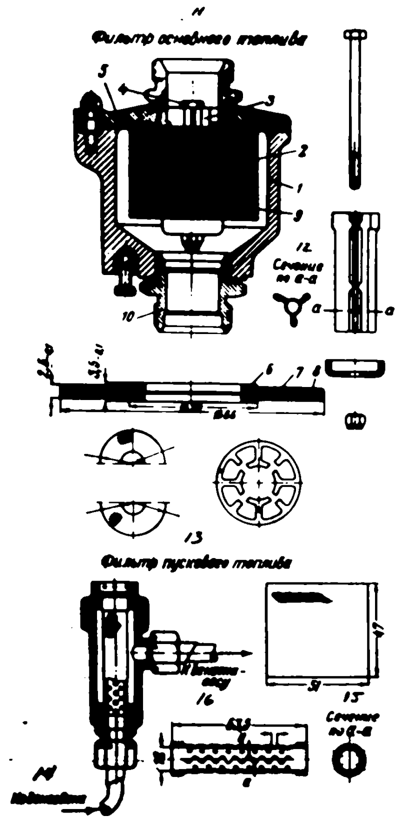

Fig. 200 - Fuel Filters of Main and Starter Fuels

1 - Filter body
2 - Disc set
3 - Hollow body
4 - Disc tightening bolt
5 - Cover with pipe connection
6 - Screen rim for inner tightening
7 - Shaped washer on which discs are placed
8 - Outer rim
9 - Sprocket washers for adjusting clearances between the discs
10 - Pipe connection
11 - Main fuel filter
12 - Cross section at a-a
13 - Starter fuel filter
14 - From gasoline tank
15 - Cross section at a-a
16 - To gasoline pump.

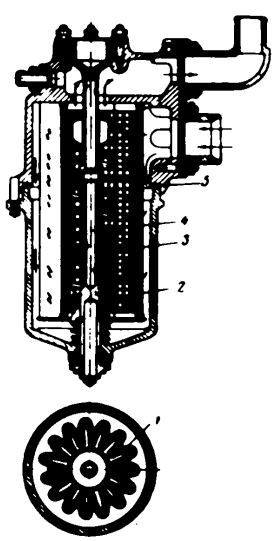

Fig. 201 - Low-Pressure Fuel Filter

1 - Filter

2 - Screen

3 - Spiral spring

4 - Bolt

5 - Rubber ring

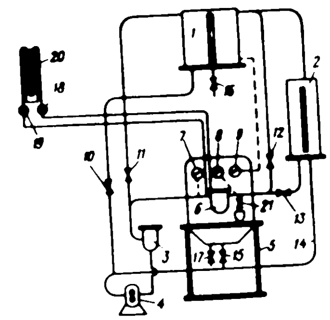

Fig. 202 - Schematic of Fuel Filter Testing Installation

1 - Service tank; 2 - **Metering** tank; 3 - Fuel filter; 4 - Pump with drive; 5 - Installation stand; 6 - Fuel filter being tested; 7 - Manometer for measuring pressure with kerosene before filter; 8 - Manometer for measuring **pressure** with kerosene beyond filter; 9 - Thermometer for measuring kerosene temperature in service tank; 10, 11, 12, 13, 15 and 21 - Adjusting valves; 14 - Manifold; 16, 17 - Kerosene draining valves; 18, 19 - Valves; 20 - Piezometer.

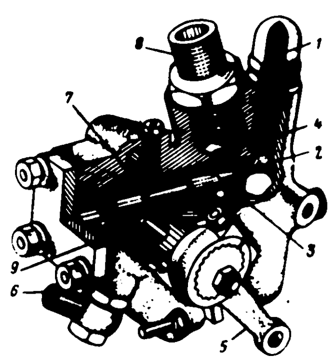

Fig. 203 - Throttle Valve

1 - Idling adjusting screw

2 - Pressure equalizing channel

3 - Plunger

4 - Idling jet

5 - Control lever

6 - Drain connection

7 - Rack and pinion gear

8 - Fuel intake connection

9 - Control lever gears

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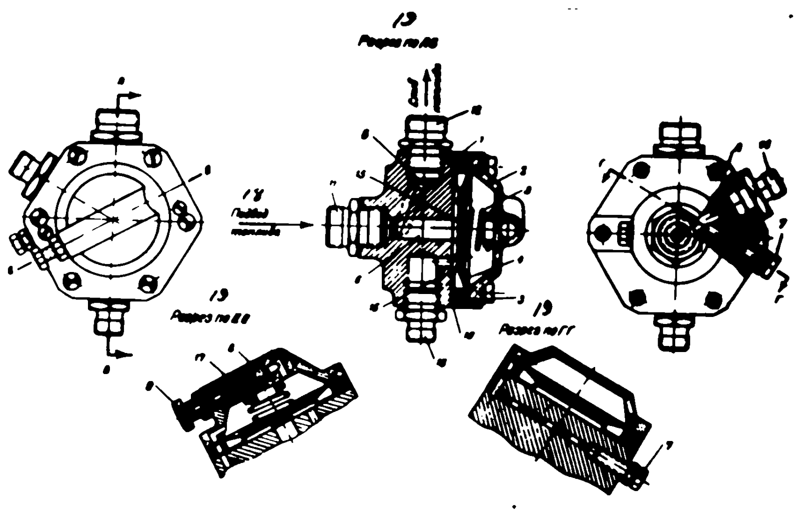

Fig. 204 - Compressor Pressure Limiter

1 - Valve body; 2 - Membrane cover; 3 - Intermediate plate; 4 - Membrane; 5 - Spring; 6 - Slide valve; 7 - Adjusting screw; 8 - Ball; 9 - Ball valve adjusting screw; 10 - Gasket; 11, 12 - Fuel pipe connections; 13, 14 - Air inlet connections; 15 - Spring ring; 16 - Membrane plate; 17 - Ball valve spring 18 - Fuel intake; 19 - Cross section ...; 20 - Fuel drain.

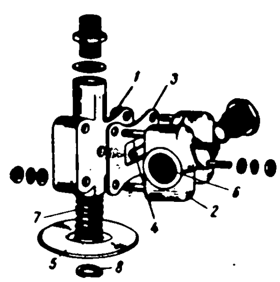

Fig. 205 - Drain Valve

1 - Body	5 - Plate
2 - Cover	6 - Cavity
3 - Plate	7 - Spring
4 - Tongue with valve	8 - Retaining ring

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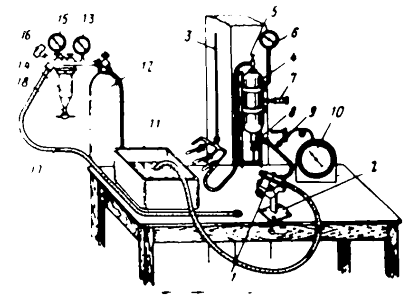

Fig. 206 - Schematic of Drain Valve Test Stand

1 - Drain valve; 2 - Drain valve attaching base; 3 - Compressed air manifold; 4 - Low-pressure receiver; 5 - Receiver air inlet valve; 6 - Receiver manometer; 7 - Air outlet valve; 8 - Drain valve air inlet valve; 9 - Manometer air inlet valve; 10 - Manometer; 11 - Clean gasoline tank; 12 - Compressed air cylinder; 13 - Cylinder manometer; 14 - High-pressure receiver; 15 - Receiver manometer; 16 - Valve air inlet valve; 17 - Hose; 18 - Receiver air

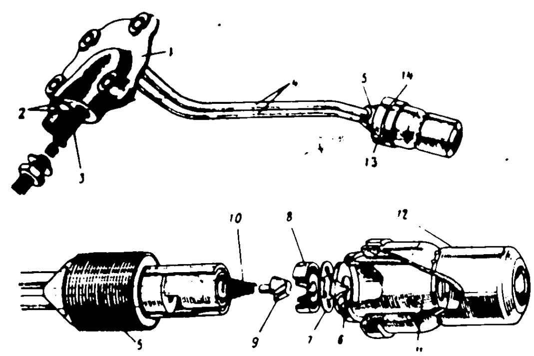

Fig. 207 - Disassembled Duplex Nozzle

1 - Flange; 2 - Fuel intake; 3 - Filter; 4 - Manifold; 5 - Nozzle body; 6 - Nozzle jet; 7 - Atomizer washer; 8 - Atomizer chamber; 9 - Atomizer; 10 - Spring; 11 - Cup; 12 - Nozzle casing; 13 - Lock nut; 14 - Retaining washer.

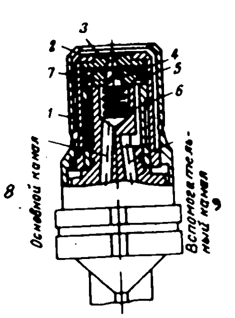

Fig. 208 - Fuel Nozzle Cross Section

1 - Nozzle casing
2 - Cup
3 - Nozzle jet
4 - Atomizer
5 - Atomizer washer
6 - Conic spring
7 - Atomizer chamber
8 - Primary line
9 - Secondary line.

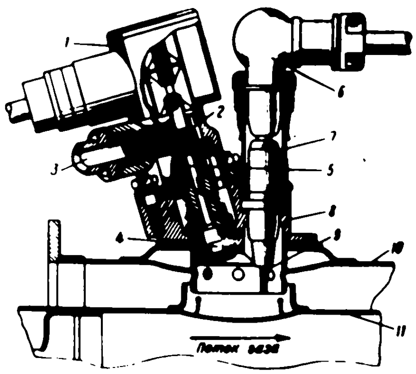

Fig. 209 - Starter Nozzle

1 - Starter nozzle fuel feed control solenoid; 2 - Solenoid needle valve; 3 - Starter fuel feed connection; 4 - Atomizer; 5 - Filter; 6 - Starter nozzle; 7 - Starter nozzle housing; 8 - Igniter housing; 9 - Main electrode of starter nozzle; 10 - Combustion chamber housing; 11 - Fire tube; 12 - Gas Flow.

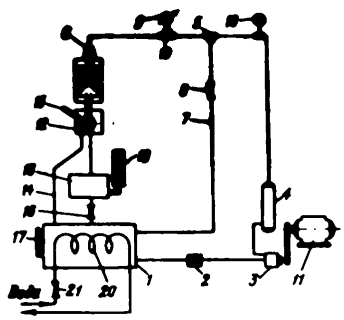

Fig. 210 - Schematic of Fuel Nozzle Discharge Testing Installation

1 - Fuel tank; 2 - Filter; 3 - Pump; 4 - Surge tank; 5 - Throttle valve; 6 - Fuel nozzle; 7 - Drain pipe; 8 - Drain valve; 9 - Manometer; 10 - Relief valve; 11 - Electric motor; 12 - Discharge valve housing; 13 - Metering tank; 14 - Drain pipe; 15 - Discharge valve handle; 16 - Outlet valve; 17 and 19 - Glass gauges; 18 - Manometer; 20 - Coil; 21 - Water main tap; 22 - Water.

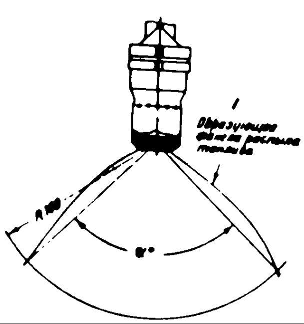

Fig. 211 - Fuel Nozzle -- Fuel Atomization Angle Testing Diagram

a - Atomization angle

1 - Generatrix of flame of fuel atomization.

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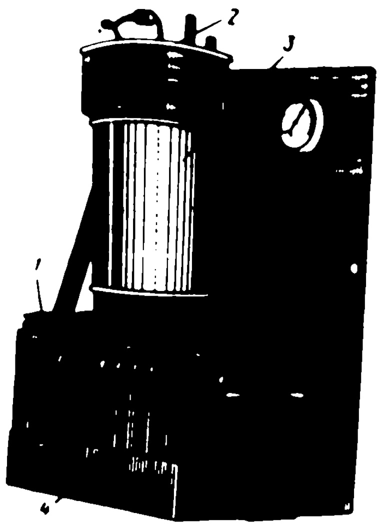

Fig. 212 - Installation for Determining Uniformity of Atomization of Fuel Nozzles

1 - Metering retorts

2 - Upper chambers

3 - Lower chamber

4 - Fuel tank.

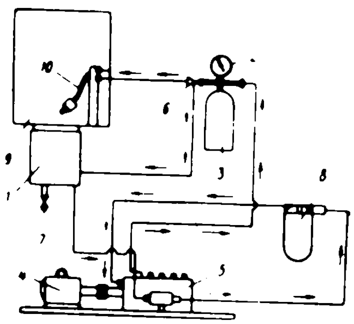

Fig. 213 - Schematic of Installation for Hydraulic Testing of Fuel Plugs

1 - Service tank
2 - Manometer
3 - Receiver
4 - Electric motor
5 - Pump
6 - Fuel Drain valve
7 - Tank drain valve
8 - Filter
9 - Cabinet
10 - Fuel plug.

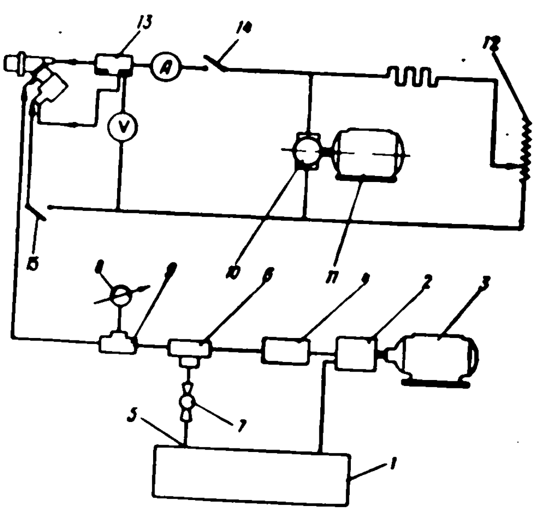

Fig. 214 - Schematic of Installation for Testing Discharge, Atomization Angle, Igniting Quality and Spark Formation of Starter Nozzle

1 - Fuel tank; 2 - Pump; 3 - Electric motor; 4 - Filter; 5 - Drain pipe; 6 - Drain valve; 7 - Discharge valve; 8 - Manometer; 9 - Relief valve; 10 - Generator; 11 - Electric motor; 12 - Rheostat; 13 - Coil; 14 and 15 - Switches.

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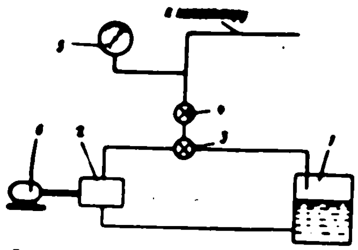

Fig. 215 - Schematic of Installation for Testing of Fuel Manifold

1 - Service tank
2 - Pump
3 - Pressure control valve
4 - By-pass valve
5 - Manometer
6 - Electric motor.

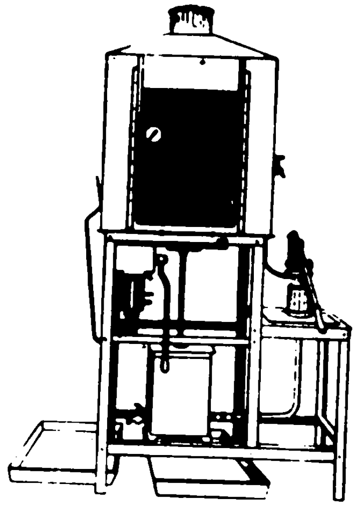

Fig. 216 - General View of Installation for Hydraulic Testing of Fuel Nozzles

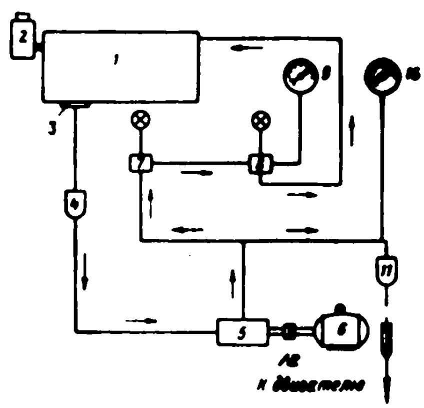

Fig. 217 - Schematic of Installation for Testing Fuel System of Assembled Engines

1 - Kerosene tank; 2 - Filter with fuel intake; 3 - Screen filter in tank; 4 - Low-pressure filter; 5 - Pump; 6 - Electric motor; 7 - High-pressure valve; 8 - Low-pressure valve; 9 - Low-pressure manometer; 10 - High-pressure manometer; 11 - High-pressure filter; 12 - To motor.

90

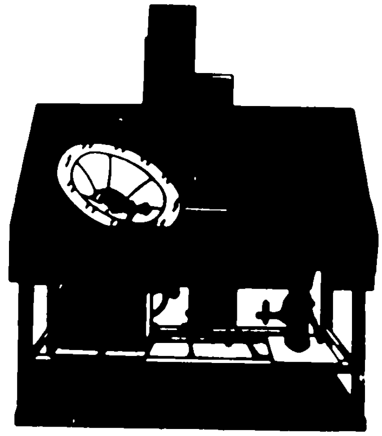

Fig. 218 - General View of Installation for Hydraulic Testing of Bearing Housings

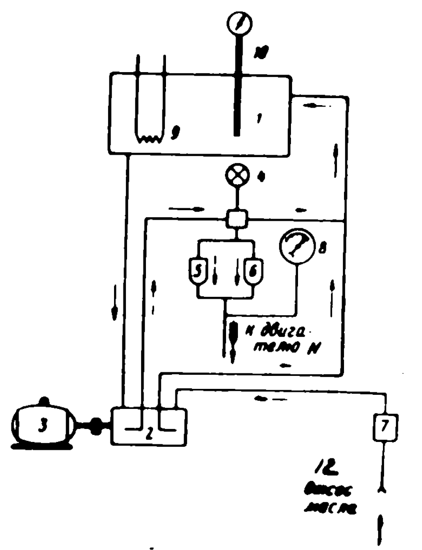

Fig. 219 - Schematic of Installation for Flushing Oil System of Assembled Engine

1 - Filling tank; 2 - Pump; 3 - Electric motor; 4 - Adjusting valve; 5 - 6 - Filters; Oil scavenge filter; 8 - Manometer; 9 - Spiral of electric heater of oil; 10 - Thermometer; 11 - To engine; 12 - Oil drawn off.

91

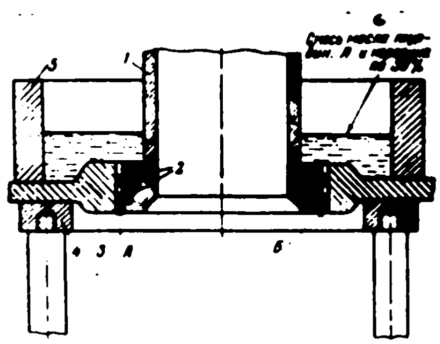

Fig. 220 - Testing of Seal Rings for Air Tightness

1 - Shaft
2 - Seal rings
3 - Cover
4 - Stand
5 - Ring
6 - Blend of turbine oil Л and kerosene, 50% each

92

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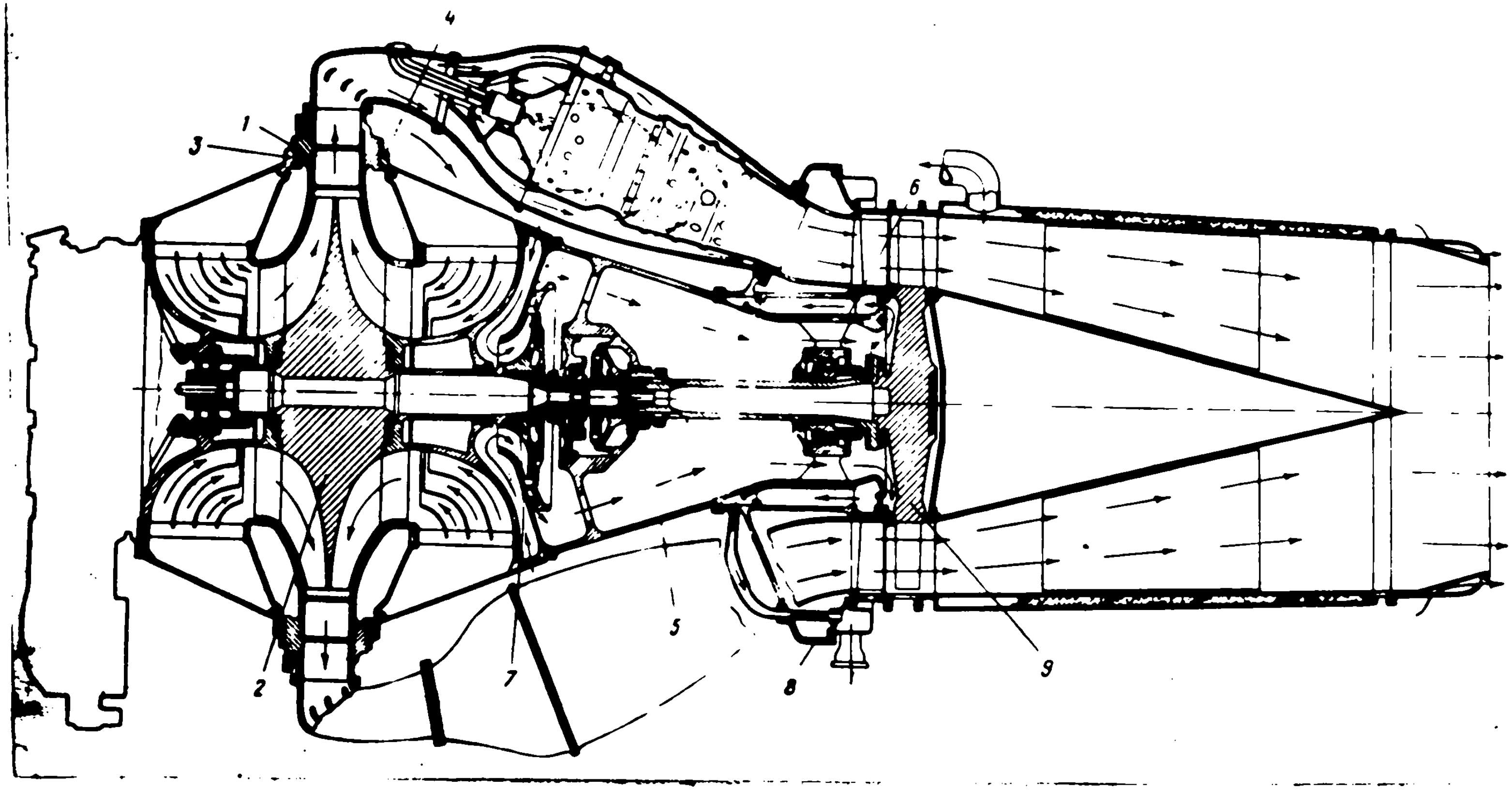

Fig. 250 - Section Through An Engine With Centrifugal Compressor

1 - Compressor casing; 2 - Compressor rotor; 3 - Front truss ring; 4 - Rear truss ring; 5 - Center bearing housing; 6 - Rear bearing housing; 7 - Fan impeller; 8 - Nozzle inlet ducts with nozzle; 9 - Turbine rotor.

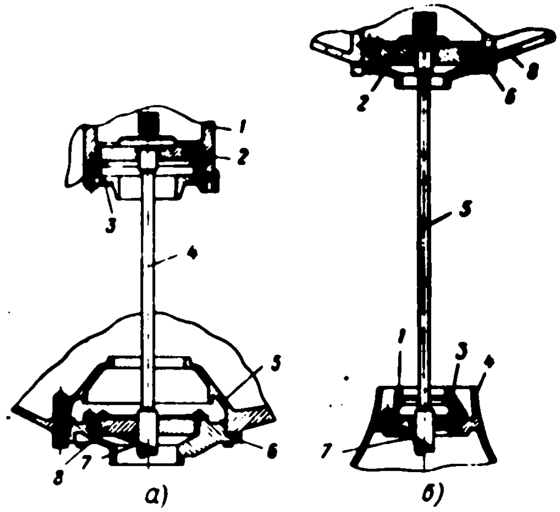

Fig. 251 - A Device for Checking Coaxiality of Engine Bearing Supports

a - Checking Coaxiality of the Rear and Center Bearing Supports

1 - rear bearing housing; 2 and 8 - ring gages; 3 - seal housing; 4 - arbor; 5 - center bearing housing; 6 - center bearing cover; 7 - gage.

b - Checking Coaxiality of Center and Prong Bearing Supports

1 - seal housing; 2 and 3 - ring gage; 4 - front bearing housing; 5 - arbor mounting; 6 - center bearing cover; 7 - gage; 8 - center bearing housing

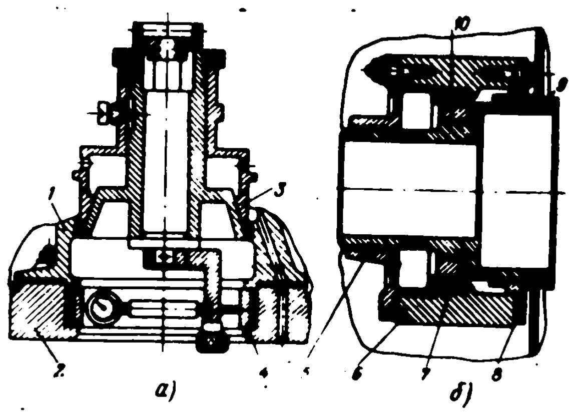

Fig. 252 - Devices (a and b) for Checking Coaxiality of Labyrinth Seals

1 - labyrinth seal; 2 - front roller bearing housing; 3 - the device; 4 - front roller bearing outer race; 5 - front labyrinth seal; 6 - rear bearing housing; 7 - rear roller bearing outer race; 8 - rear labyrinth seal; 9 - mounting; 10 - ring

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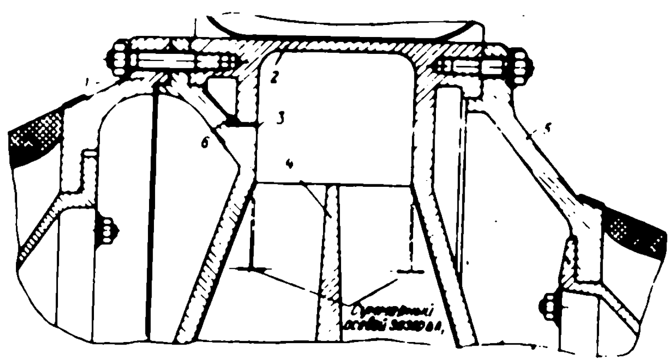

Fig. 253 - Compressor Rotor Impeller Installed in the Casing for Measurement of Total Clearance

1 - front trussing; 2 - compressor casing; 3 - casing cover; 4 -compressor rotor; 5 - rear trussing; 6 - seal gasket.
Inscription: Total and play A_1

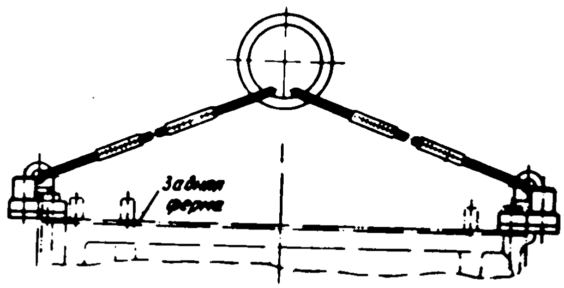

Fig. 254 - A Lifting Sling for the Rear Truss Ring

Inscription: Rear Truss Ring

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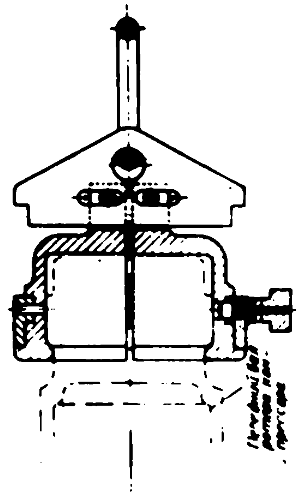

Fig. 255 - Compressor Rotor Puller

Inscription: Front Rotor Compressor Shaft

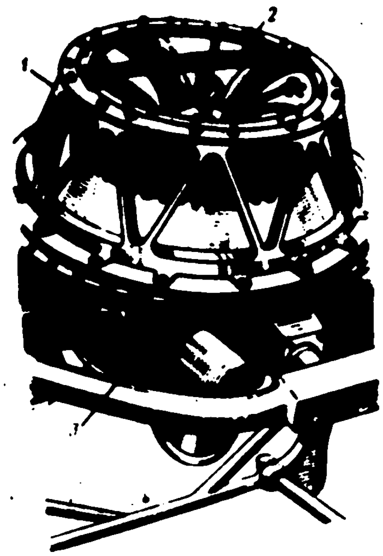

Fig. 256 - Assembly Compressor Housing With a Gage for Checking the Total Clearance

1 - front trussing; 2 - the gage; 3 - compressor casing

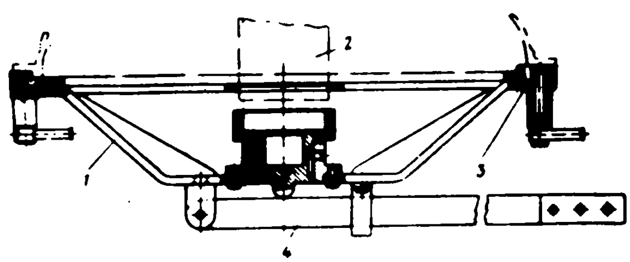

Fig. 257 - A Jack for Axial Shifting of the Compressor Rotor

1 - jack; 2 - rotor rear shaft; 3 - rear trussing; 4 - rotor shifting handle

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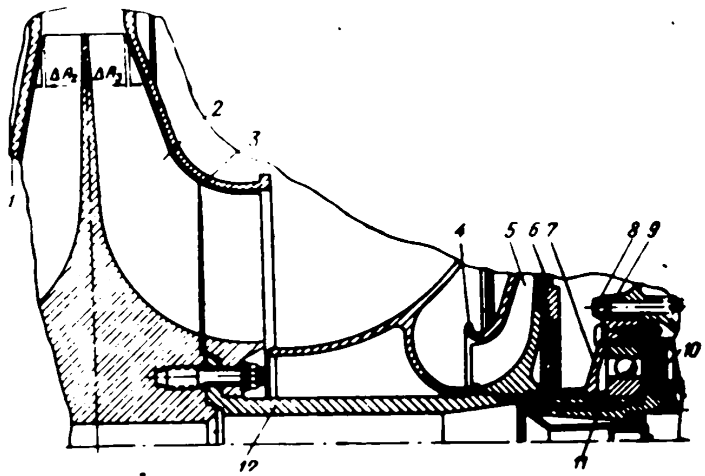

Fig. 258 - An Assembled Compressor Rotor With the Center Ball Bearing for Checking and Adjustment of Clearances

1 - casing cover; 2 - impeller; 3 - casing; 4 - fan impeller front cover; 5 - fan impeller; 6 - impeller rear wall; 7 - center radial thrust ball bearing housing; 8 - center bearing housing cover; 9 - adjusting ring and paronite gaskets; 10 - driven splined coupling; 11 - bearing adjusting ring; 12 - compressor rotor rear shaft

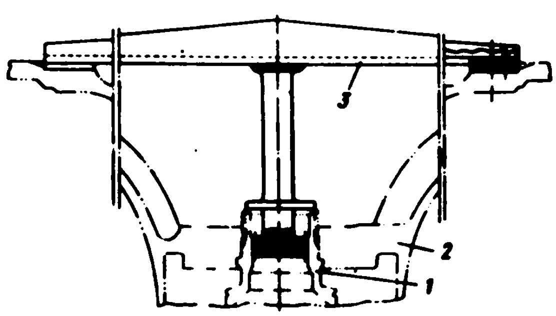

Fig. 259 - A Device for Preventing the Compressor Rotor From Turning

1 - compressor rotor front shaft;
2 - front bruss ring;
3 - the device

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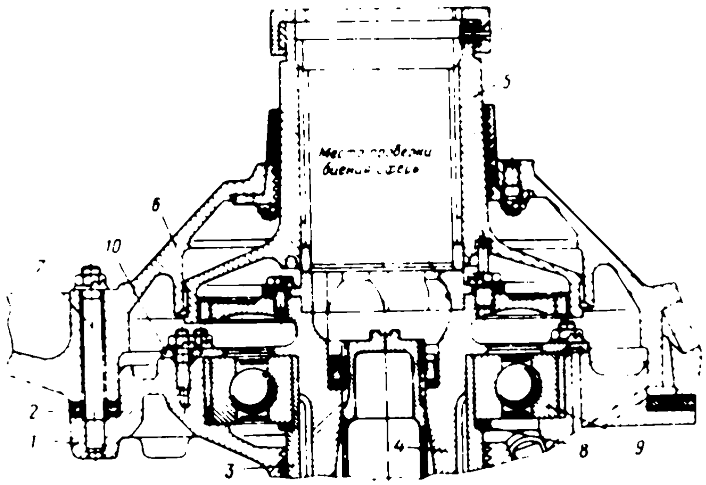

Fig. 260 - Center Ball Bearing Assembly

1 - bearing cover; 2 - adjusting ring and seal gaskets; 3 - compressor rotor rear shaft; 4 - driven splined coupling; 5 - drive splined coupling; 6 - center bearing housing; 7 - studs joining the cover with the center bearing housing; 8 - adjusting ring; 9 - ball bearing; 10 - clamp ring.

Inscription: a spot for checking the play of the sphere

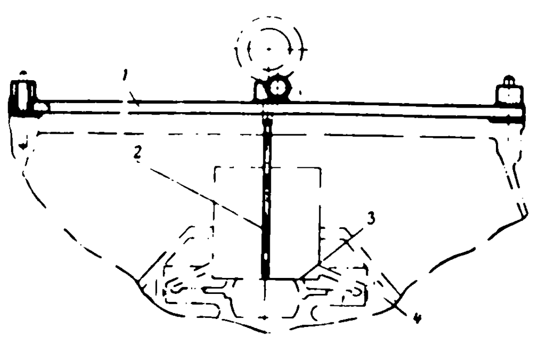

Fig. 261 - A Jack for Measuring Compressor Rotor Axial Clearances in the Casing

1 - jack; 2 - indicator leg; 3 - driven coupling cover face; 4 - center bearing housing

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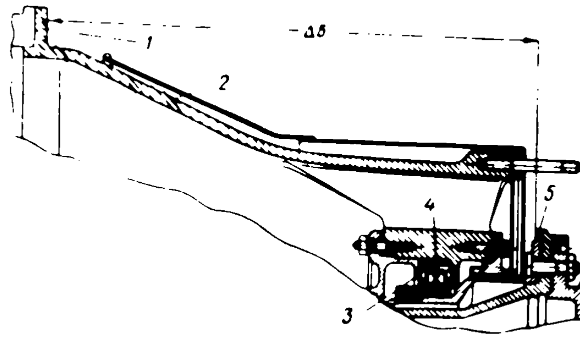

Fig. 262 - Measuring B_1 Dimension

1 - housing flange; 2 - rear bearing housing; 3 - outer roller bearing race; 4 - roller bearing; 5 - rotor hub; 6 - turbine rotor

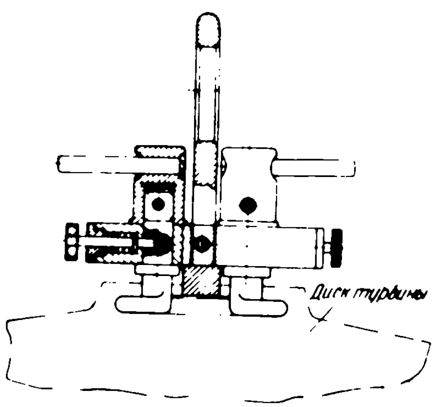

Fig. 263 - Turbine Rotor Lifting Fixture

Inscription: Turbine Disc

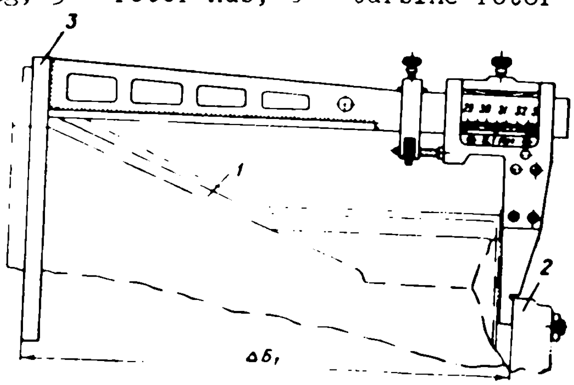

Fig. 264 - A Device for Checking B_1 Dimension

1 - rear bearing housing;
2 - turbine rotor;
3 - the device

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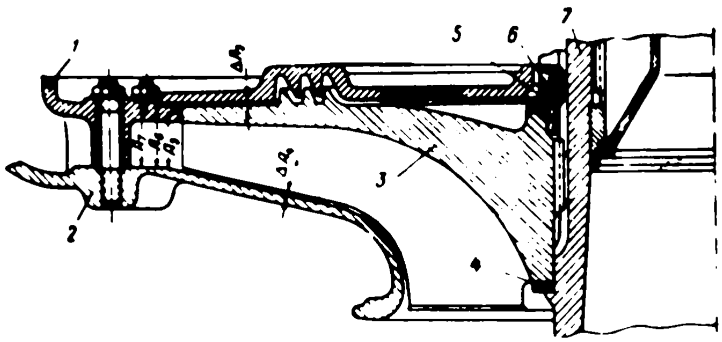

Fig. 265 - Fan Impeller Assembly

1 - fan rear wall; 2 - front cover; 3 - fan impeller; 4 - adjusting ring; 5 - thrust ring; 6 - nut; 7 - compressor rotor rear wall

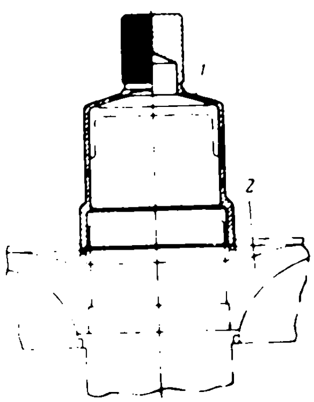

Fig. 266 - A Chuck for Forcing the Fan Impeller Onto the Shaft

1 - chuck;
2 - fan impeller

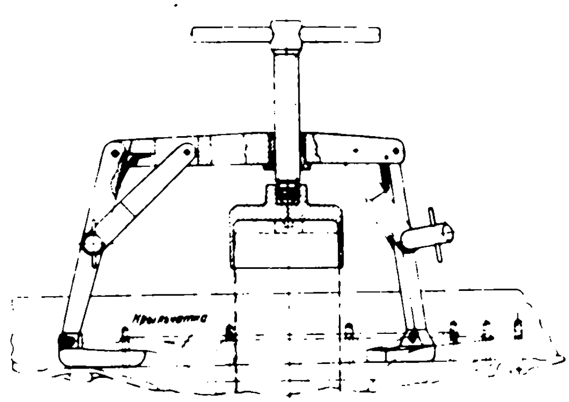

Fig. 267 - Fan Impeller Puller

Inscription: Impeller

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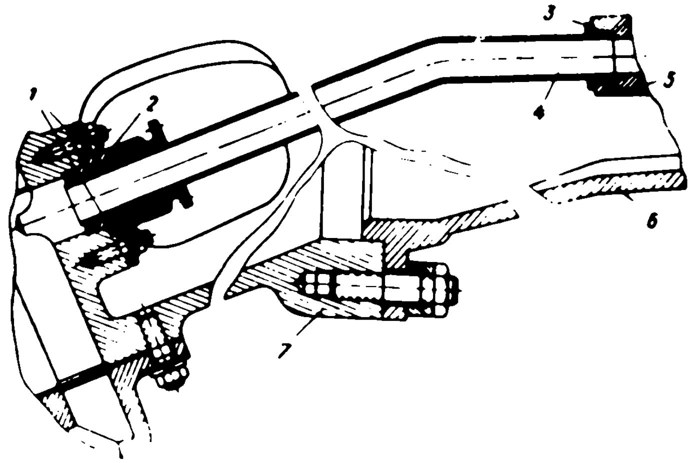

Fig. 268 - A Portion of Oil Lines for Center and Rear Bearing Housings

1 and 3 - sealing rings; 2 - sealing cup; 4 - pressure line pipe; 5 - housing lug; 6 - rear bearing housing; 7 - center bearing housing.

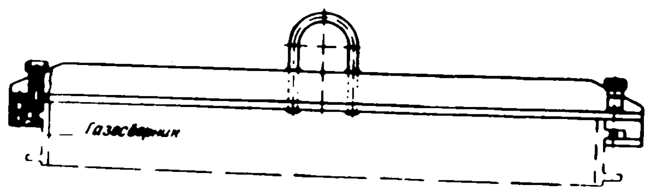

Fig. 270 - Fixture for Lifting Nozzle Inlet Ducting

Inscription: Nozzle Inlet Ducting

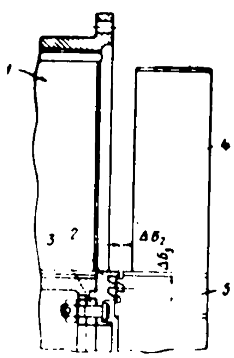

Fig. 269 - Places for Measuring Axial and Radial Clearances Between the Labyrinth Seal and Turbine Rotor Disc Faces

1 - nozzle diaphragm;
2 - labyrinth seal;
3 - adjusting ring;
4 - rotor blade;
5 - turbine rotor disc.

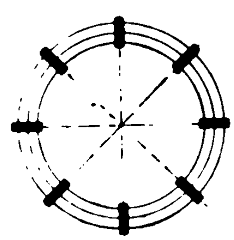

Fig. 271 - A System for Placing Lead Check Plates on the Labyrinth Seal

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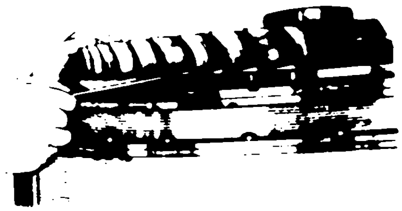

Fig. 272 - Checking B_2 Clearance

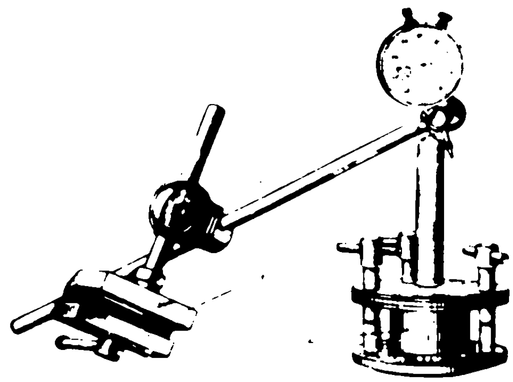

Fig. 273 - A Device for Measuring Radial Turbine Rotor Clearance in the Roller Bearing

1 - clamp with indicators; 2 - flange sleeve with a pivot bolt

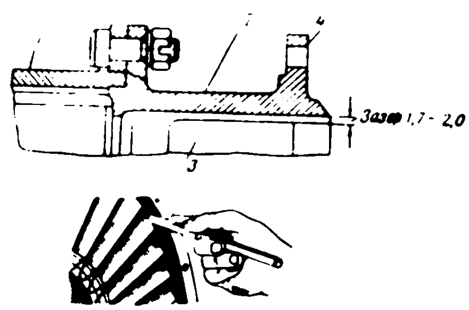

Fig. 274 - Checking Clearance Between the Turbine Rotor Casing and Blade Tips

1 - nozzle; 2 - turbine rotor casing; 3 - turbine rotor blade; 4 - flange for establishing connection with exhaust cone.

Inscription: Clearance 1.7-2.0

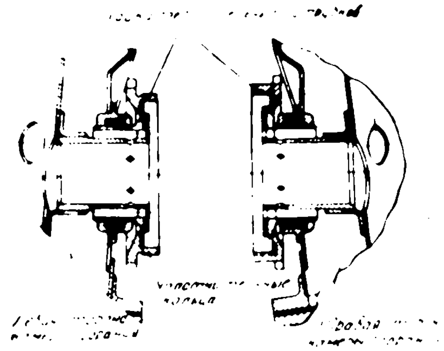

Fig. 275 - Combustion Chamber Crossover Tubes

Inscriptions: top - crossover tube nuts; bottom left - left side of the combustion chamber; bottom center - sealing rings; bottom right - right side of the combustion chamber

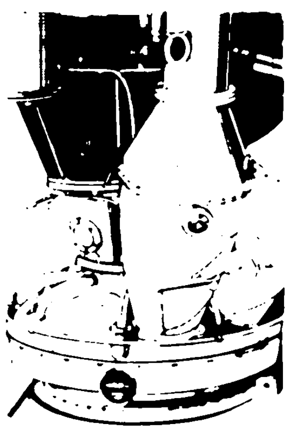

Fig. 276 - Checking the Fit of Combustion Chamber Nozzle Inlet Ducting Adapter Flanges

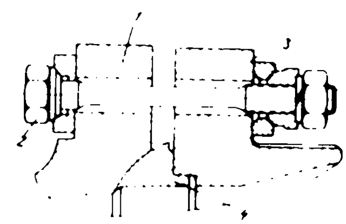

Fig. 277 - Connection of the Combustion Chamber Orifice With the Air Adapter

1 - air adapter; 2 - bolt;
3 - combustion chamber orifice;
4 - spherical ring

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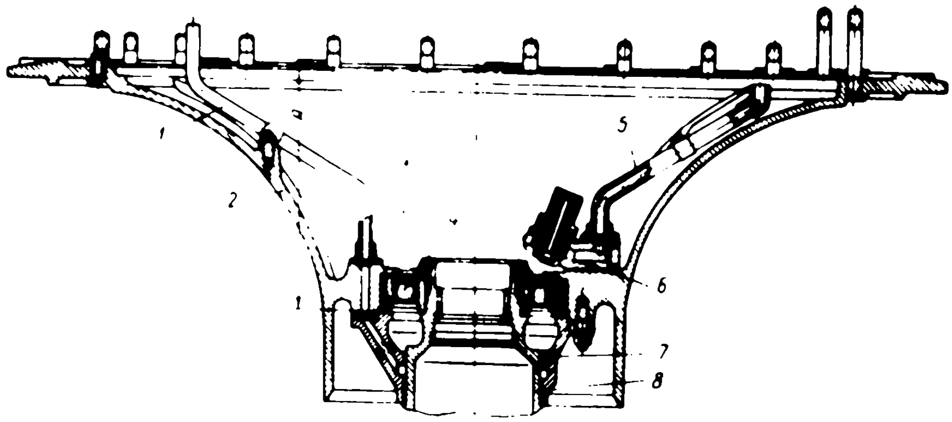

Fig. 278 - Measuring Distance A for Calculation of Side Shifting of the Spring

1 - air line; 2 - front bearing housing; 3 - bearing race; 4 - roller bearing; 5 - oil line; 6 - oil spray nozzle and housing; 7 - labyrinth seal; 8 - rotor front shaft

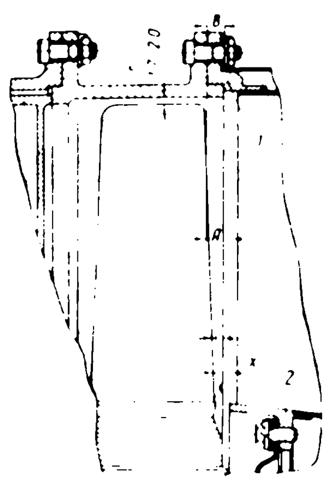

Fig. 279 - Checking the Clearance Between the Turbine Disc and the Inner Cone of the Exhaust Duct

1 - exhaust duct;
2 - inner cone of the exhaust duct

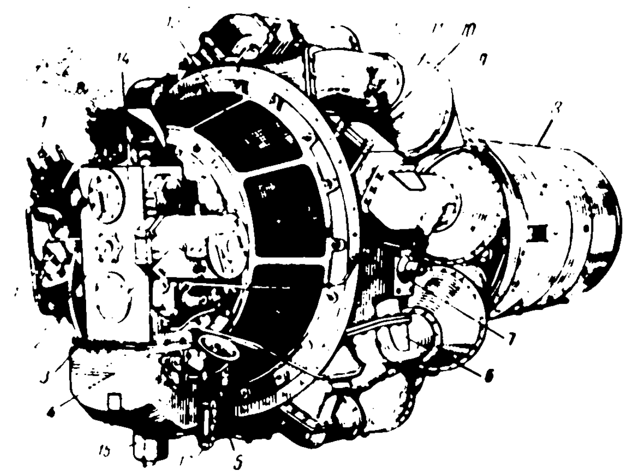

Fig. 280 - Overall View of a Jet Engine [illegible] Centrifugal Compressor

1 - fuel pumps; 2 - air vent; 3 - starter motor; 4 - oil pump box; 5 - oil filler neck; 6 - air adapter; 7 - bracket for attaching the engine to the airframe; 8 - exhaust cone; 9-10 - fuel manifold for fuel and starting plugs; 11 - combustion chamber; 12 - fuel plug flange; 13 - protective screen at the air intake to compressor; 14 - gear box; 15 - barometric regulator; 16 - fuel filter; 17 - stop valve.

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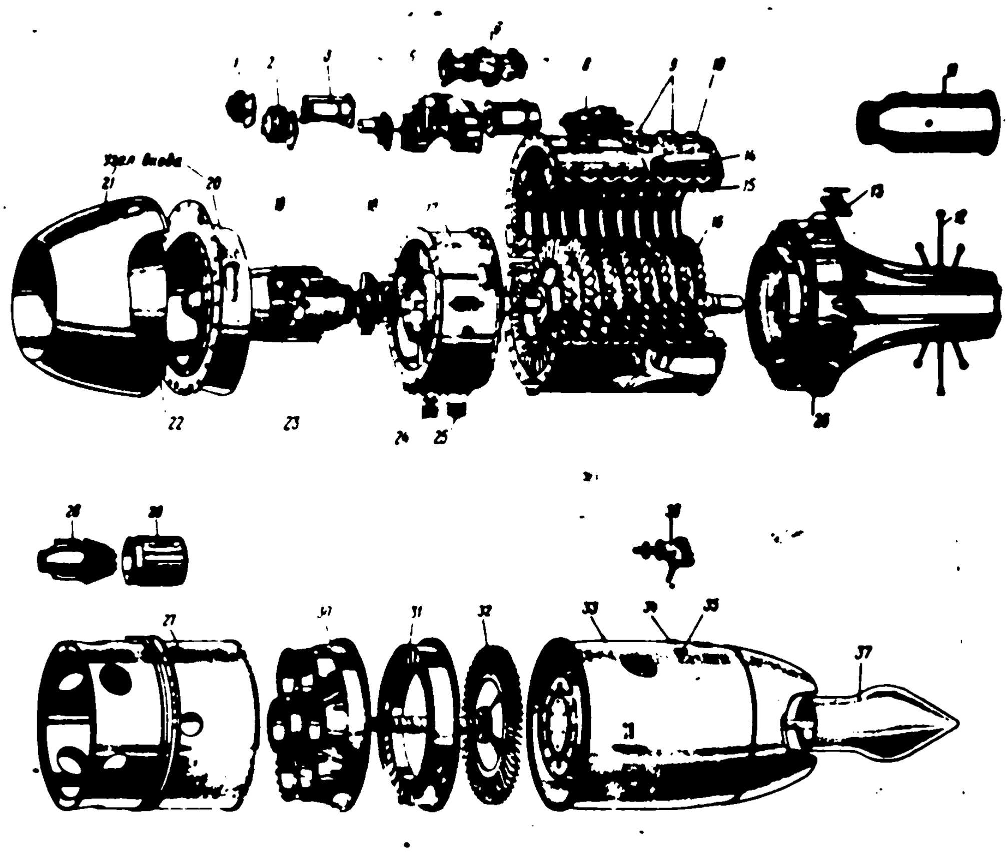

Fig. 281 - Parts and Assemblies of an Engine With Axial-Flow Compressor

1 - landing gear operation pump; 2 - basic fuel pump; 3 - de-aerator; 4 - tachometer generator transmitter; 5 - accessory drive case; 6 - RPM governor; 7 - generator; 8 - speed regulator; 9 - igniters; 10 - compressor stator; 11 - combustion chamber outer casing; 12 - pull rods; 13 - engine lug; 14 - annular fuel supply lines; 15 - guide vane assembly; 16 - compressor rotor; 17 - accessory drive power take-off housing; 18 - main drive assembly; 19 - starter motor fairing; 20 - oil tank; 21 - intake duct; 22 - gasoline tank; 23 - starter motor; 24 - oil pump; 25 - oil filter; 26 - support; 27 - support casing; 28 - entry section; 29 - corrugated muffle; 30 - nozzle intake ducts; 31 - nozzle ring; 32 - turbine rotor; 33 - exhaust cone; 34 - air pressure gage pipe; 35 - thermocouple; 36 - variable cone drive; 37 - variable cone

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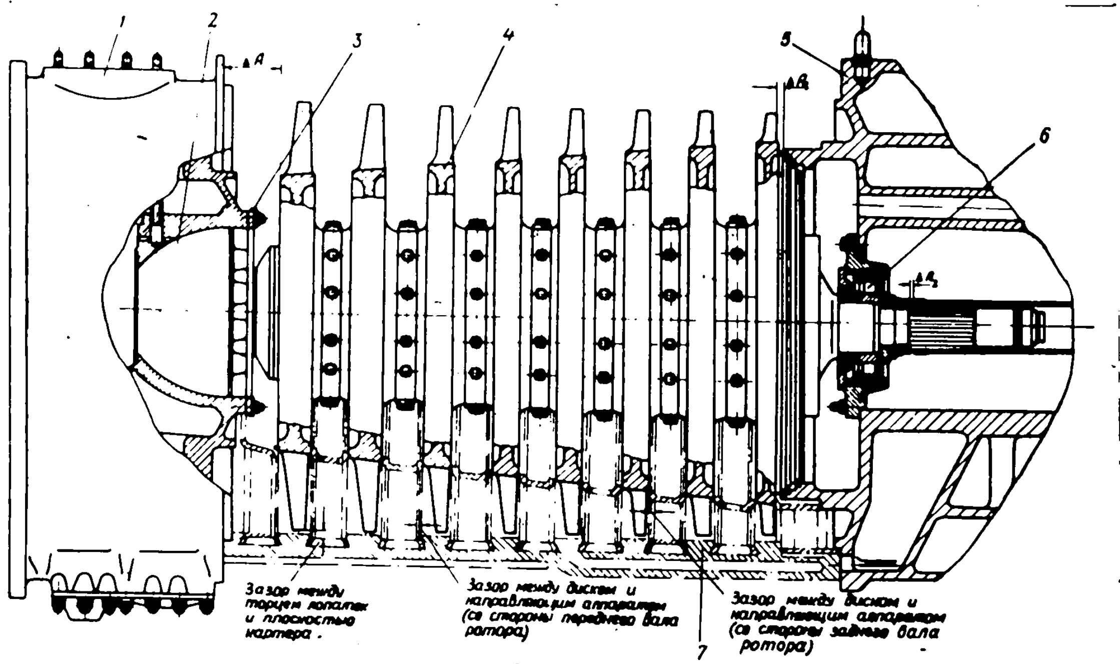

Fig. 282 - Compressor Rotor and Stator Clearances

1 - gearbox; 2 - rotor front bearing spherical housing; 3 - adjusting ring; 4 - rotor; 5 - support; 6 - rear rotor bearing; 7 - bottom half of the stator with guide vanes

Inscriptions: left - clearance between the blade tip and the stator plane; center - clearance between the disc and the guide vane (on the rotor front shaft); right - clearance between the disc and the guide vane (on the rotor rear shaft)

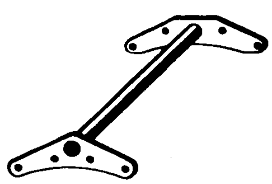

Fig. 283 - Spreader

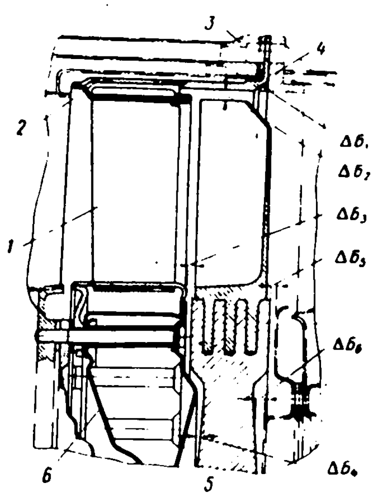

Fig. 285 - Gas Turbine Assembly

1 - nozzle blade; 2 - nozzle ring; 3 - rear casing flange; 4 - exhause cone flange; 5 - turbine shroud; 6 - nozzle ring plate

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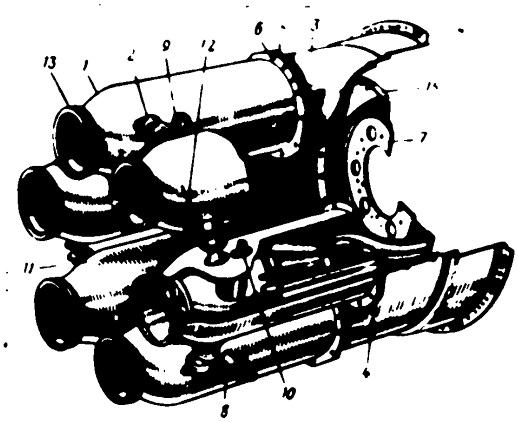

Fig. 284 - Combustion Chamber and Diaphragm Assembly

1 - combustion chamber; 2 - crossover tube; 3 - turbine inlet ducts; 4 - positioning pin; 5 - ferronite gasket; 6 - combustion chamber bolt; 7 - nozzle diaphragm; 8 - torch igniter; 9 - igniter plug fairing; 10 - spray nozzle; 11 - positioning bolt of the forechamber in the casing; 12 - threaded pin retaining the liner in the casing; 13 - combustion chamber orifiee; 14 - outer flange of inlet ducts; 15 - inner flange of inlet ducts

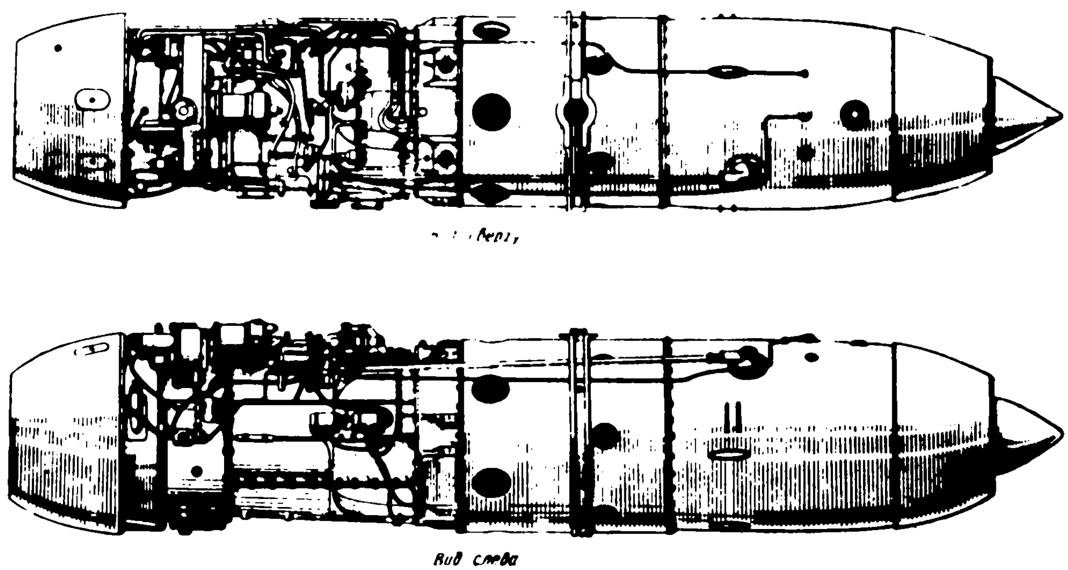

Fig. 286 - Overall View of an Engine With Axial-Flow Compressor

Inscriptions: left - view from top;
right - view from the left side

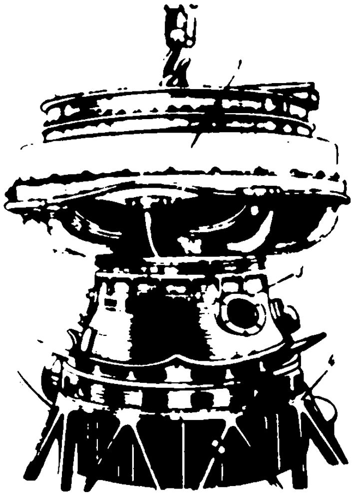

Fig. 287 - Removing the Nozzle Inlet Ducts From the Rear Bearing Housing

1 - nozzle inlet ducts;
2 - rear bearing housing attachment flange;
3 - center bearing housing;
4 - rear truss ring

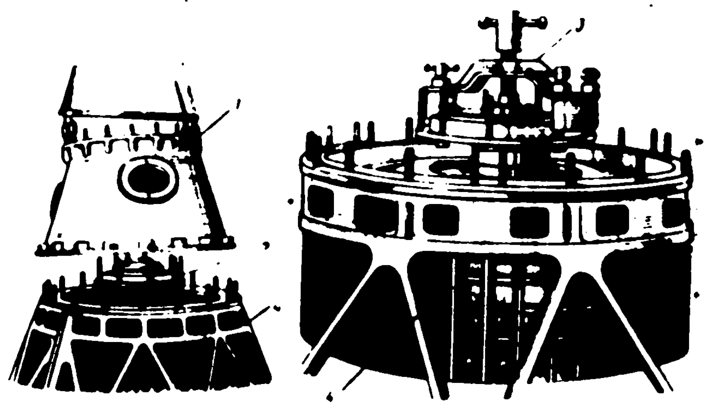

Fig. 288 - Removing the Center Bearing Housing and Bearing Cover

1 - center bearing housing;
2 - center radial thrust bearing;
3 - plug;
4 - rear truss ring

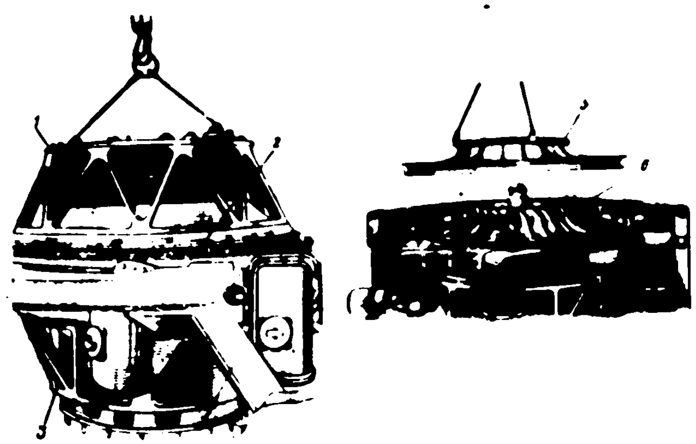

Fig. 289 - Removing the Front Truss Ring Together With Front Bearing Housing and Compressor Casing

1 - front truss ring; 2 - compressor; 3 - rear truss ring;
4 - stand; 5 - compressor casing; 6 - compressor rotor

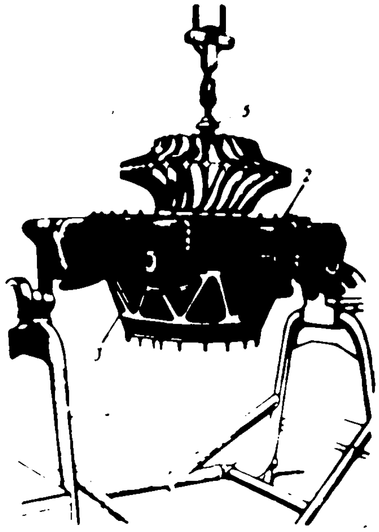

Fig. 290 - Removing Compressor Rotor From Housing

1 - compressor rotor;
2 - air adapter;
3 - rear truss ring;
4 - stand;
5 - eye nut

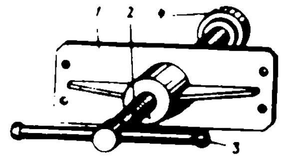

Fig. 291 - Puller for Removing Gearbox from Compressor Rotor Front Shaft

1 - flange; 2 - screw; 3 - handle;
4 - rest

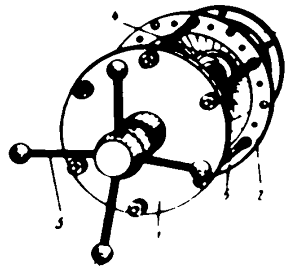

Fig. 292 - Plug for Pressing the Turbine Rotor Rear Bearing Housing Out of Support Seat

1 - flange; 2 - disc; 3 - screw; 4 - handle

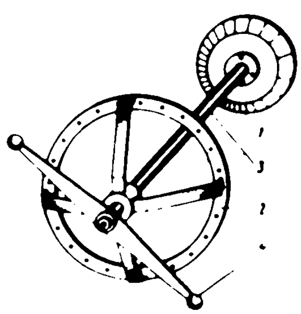

Fig. 293 - Plug for Pressing the Fuel Manifold and Combustion Chamber Assembly out of Support Casing

1 - flange; 2 - disc;
3 - screw; 4 - handle

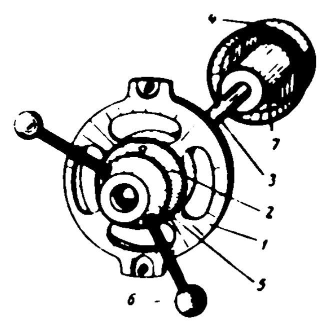

Fig. 294 - Plug for Pressing the Rotor Front Bearing out of Support

1 - flange; 2,4 - sleeves; 3 - shaft;
5 - nut; 6 - handle; 7 - drum

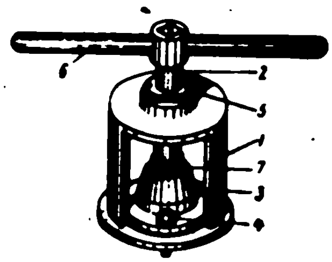

Fig. 295 - Plug for Pressing the Ball Bearing Housing With the Shaft and Centrifuge out of De-aerator

1 - casing; 2,4 - screws;
3 - sleeve; 5 - threaded sleeve;
6 - handle; 7 - split ring

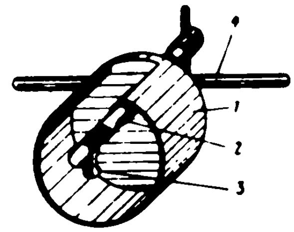

Fig. 296 - Puller for Removing the Oil Pump from Gearbox

1 - cup; 2 - threaded rod;
3 - hook; 4 - handle

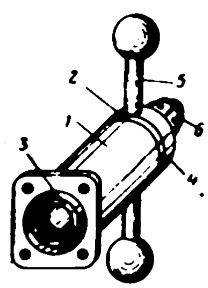

Fig. 297 - Puller for Removing Engine Manual Cranking Drive Spring and Bearing

1 - housing; 2 - round nut; 3 - puller;
4 - screw and nut; 5 - handle; 6 - nut

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