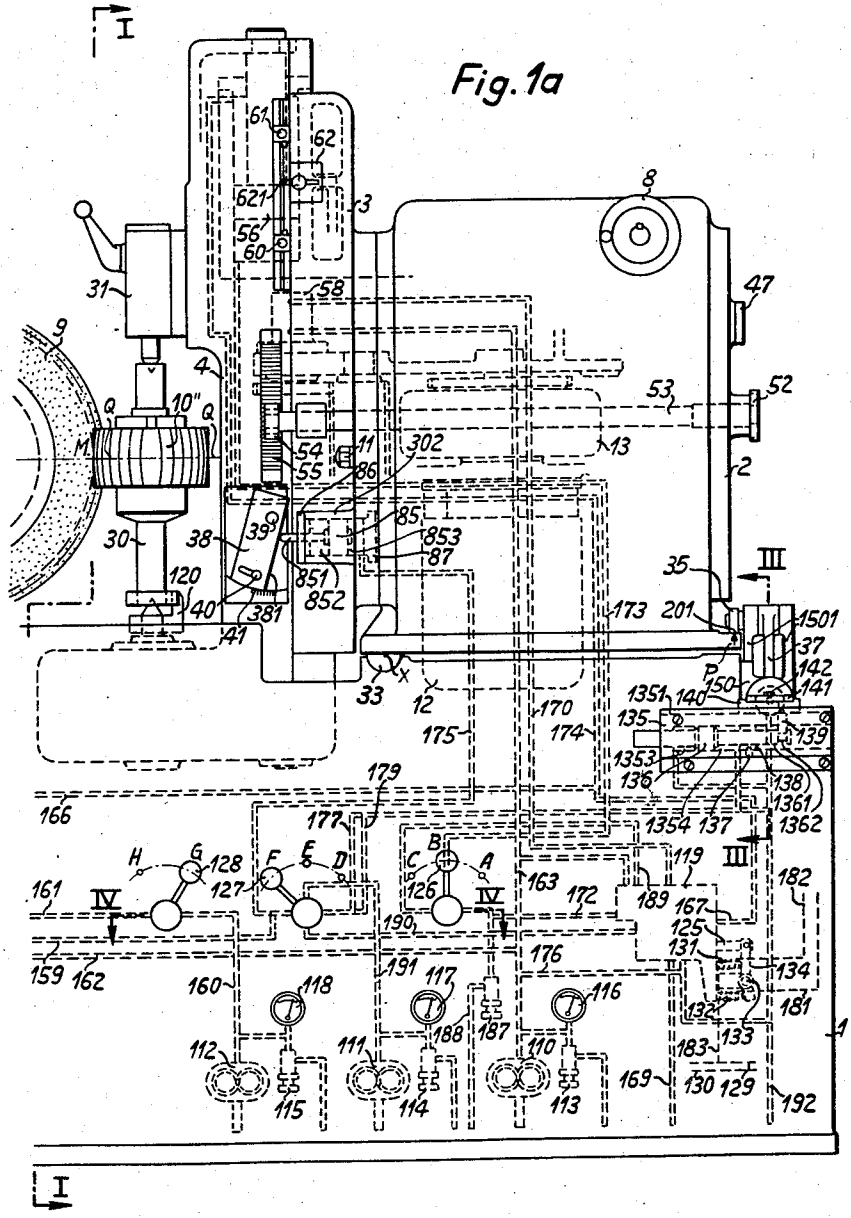
June 24, 1958 A. RICKENMANN 2,839,875

MACHINE FOR THE GRINDING OF CYLINDRICAL, CONICAL AND CROWNED SPUR GEARS AND HELICAL GEARS BY THE GENERATING PRINCIPLE

Filed Sept. 17, 1956 18 Sheets-Sheet 1

Fig. 1a



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MACHINE FOR THE GRINDING OF CYLINDRICAL, CONICAL AND CROWNED SPUR GEARS AND HELICAL GEARS BY THE GENERATING PRINCIPLE

Filed Sept. 17, 1956 18 Sheets-Sheet 2

Fig. 18

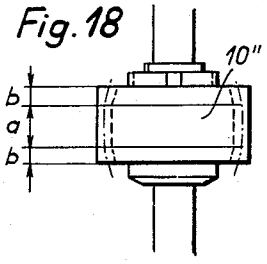


Fig. 17

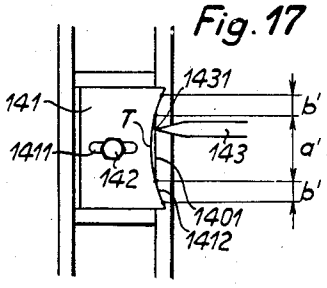
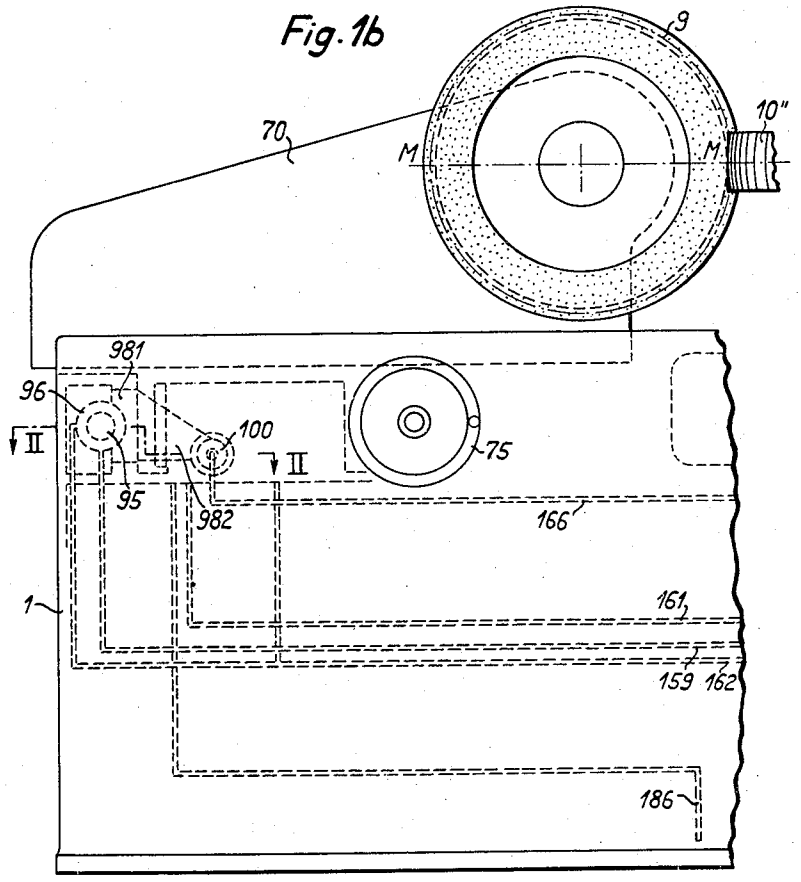


Fig. 1b



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MACHINE FOR THE GRINDING OF CYLINDRICAL, CONICAL AND CROWNED SPUR GEARS AND HELICAL GEARS BY THE GENERATING PRINCIPLE

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Fig. 2

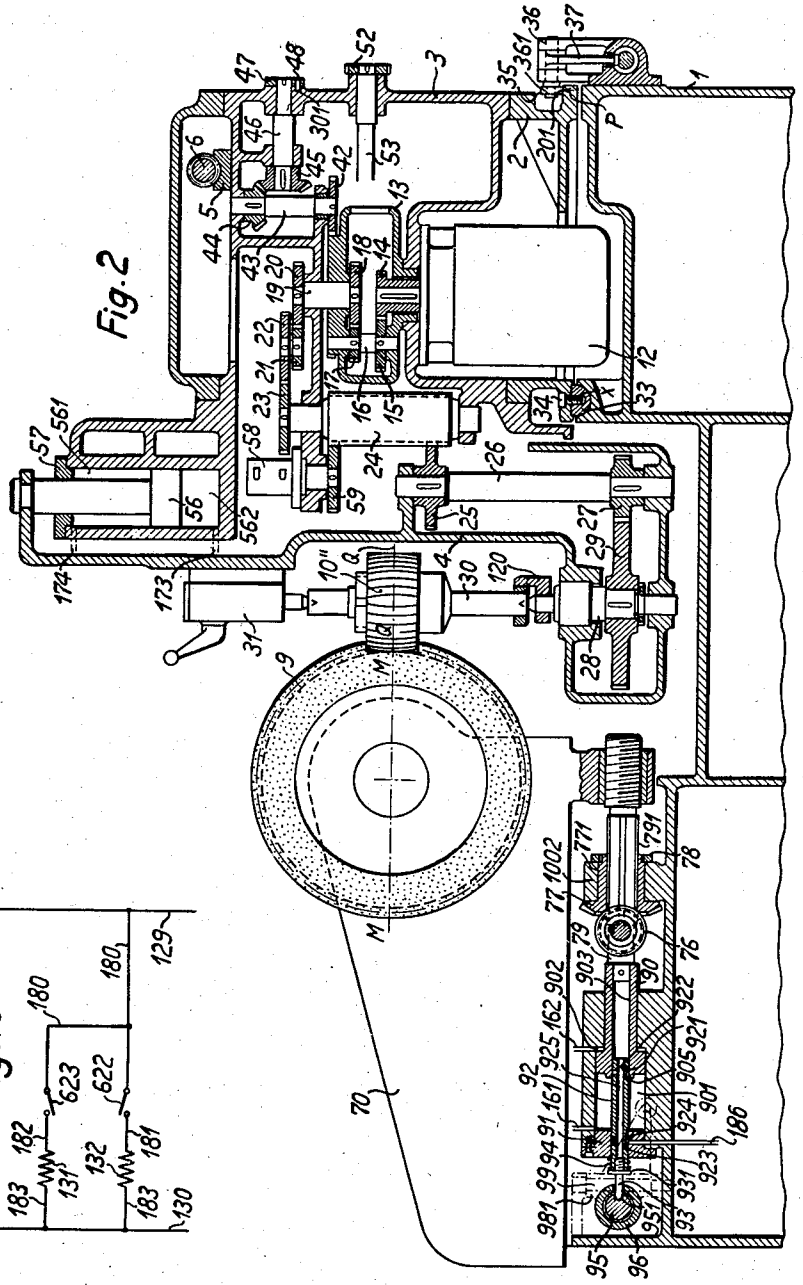


Fig. 16

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Fig. 7

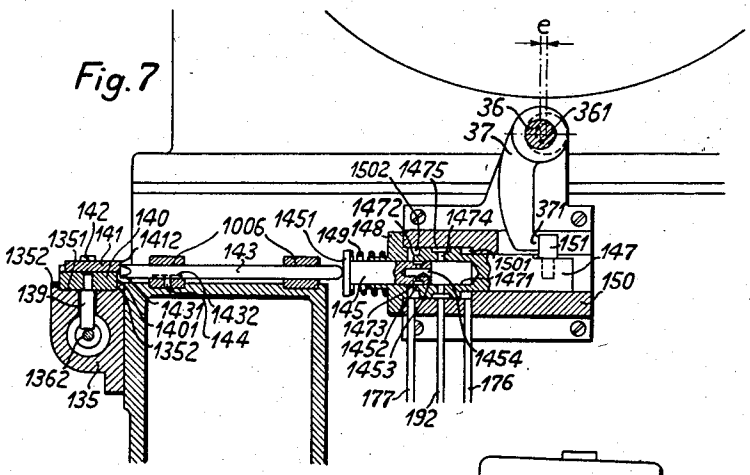
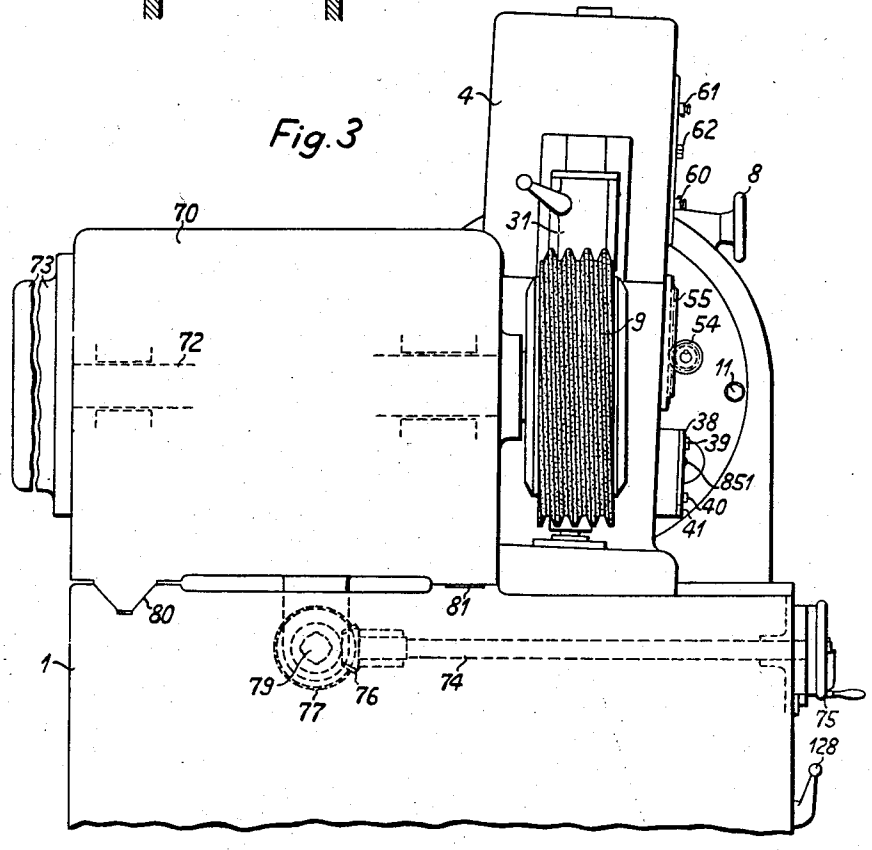


Fig. 3



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June 24, 1958 A. RICKENMANN 2,839,875

MACHINE FOR THE GRINDING OF CYLINDRICAL, CONICAL AND CROWNED SPUR GEARS AND HELICAL GEARS BY THE GENERATING PRINCIPLE

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Fig. 6

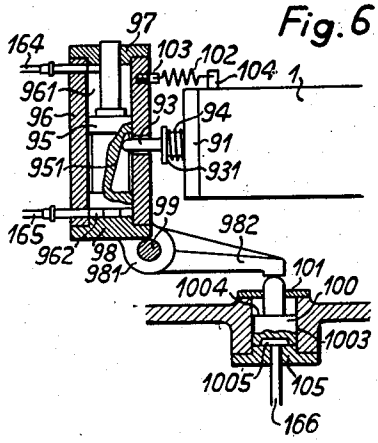
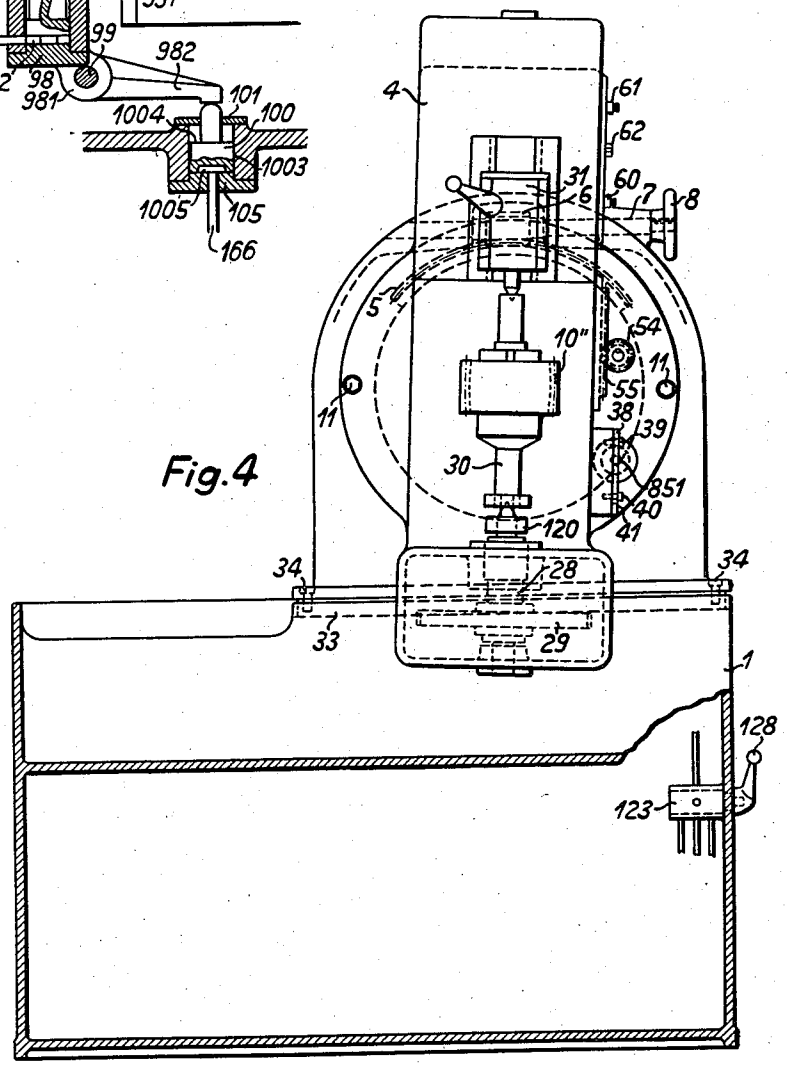


Fig. 4



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MACHINE FOR THE GRINDING OF CYLINDRICAL, CONICAL AND CROWNED SPUR GEARS AND HELICAL GEARS BY THE GENERATING PRINCIPLE

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Fig. 5

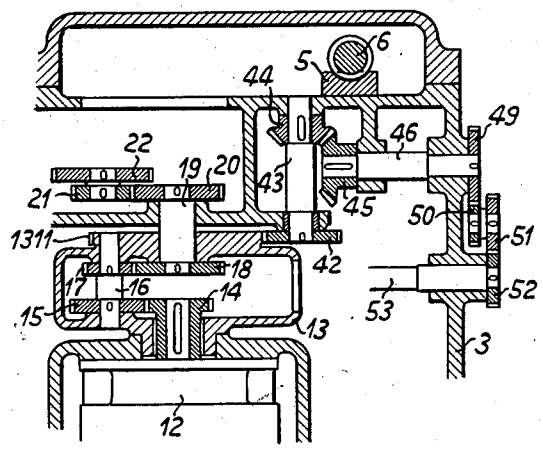


Fig. 12

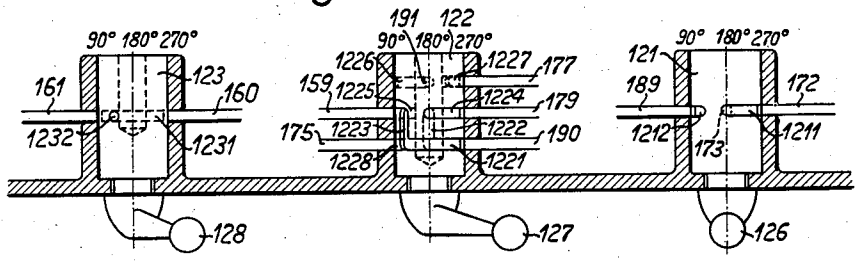


Fig. 13

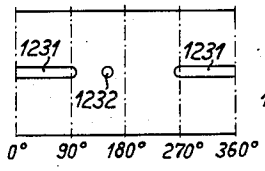


Fig. 14

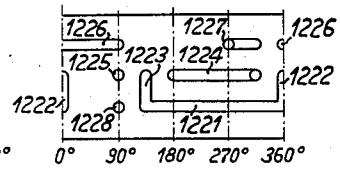
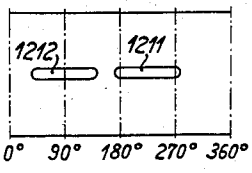


Fig. 15



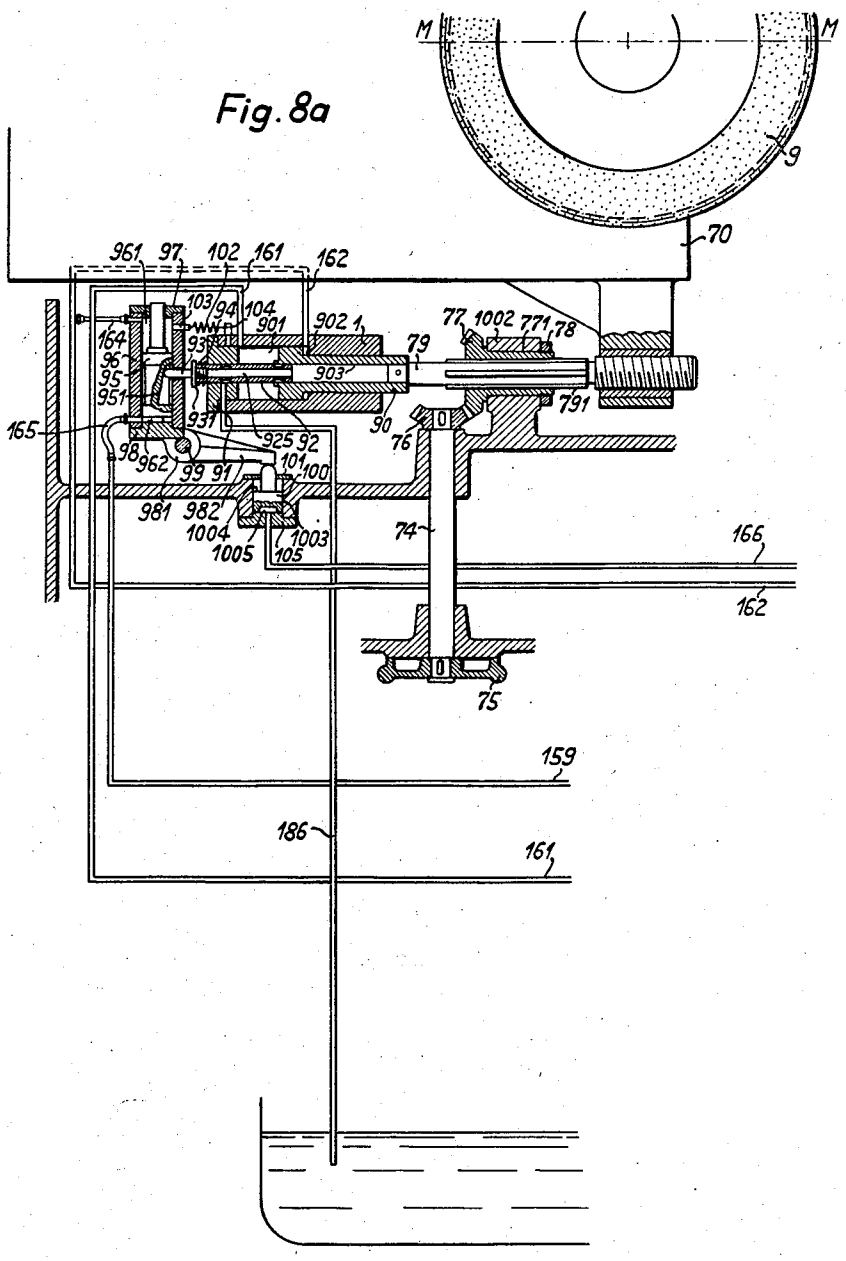
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MACHINE FOR THE GRINDING OF CYLINDRICAL, CONICAL AND CROWNED SPUR GEARS AND HELICAL GEARS BY THE GENERATING PRINCIPLE

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Fig. 8a



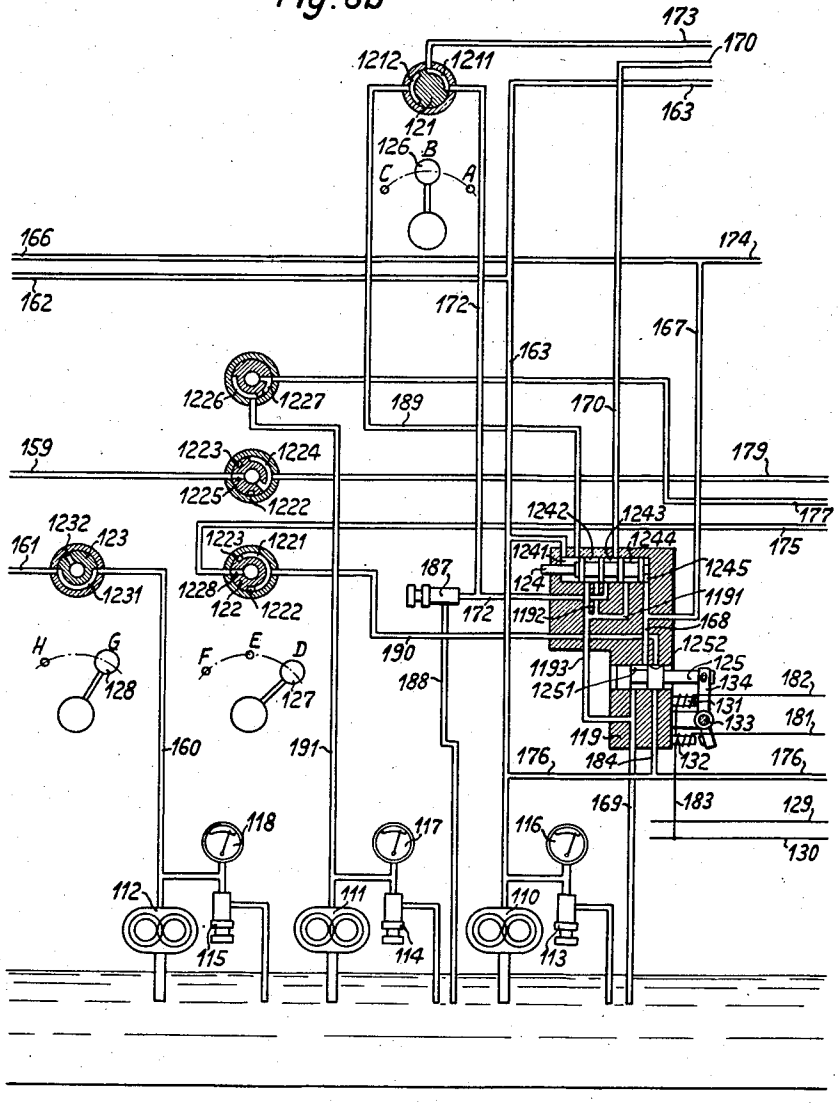
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Fig. 8b

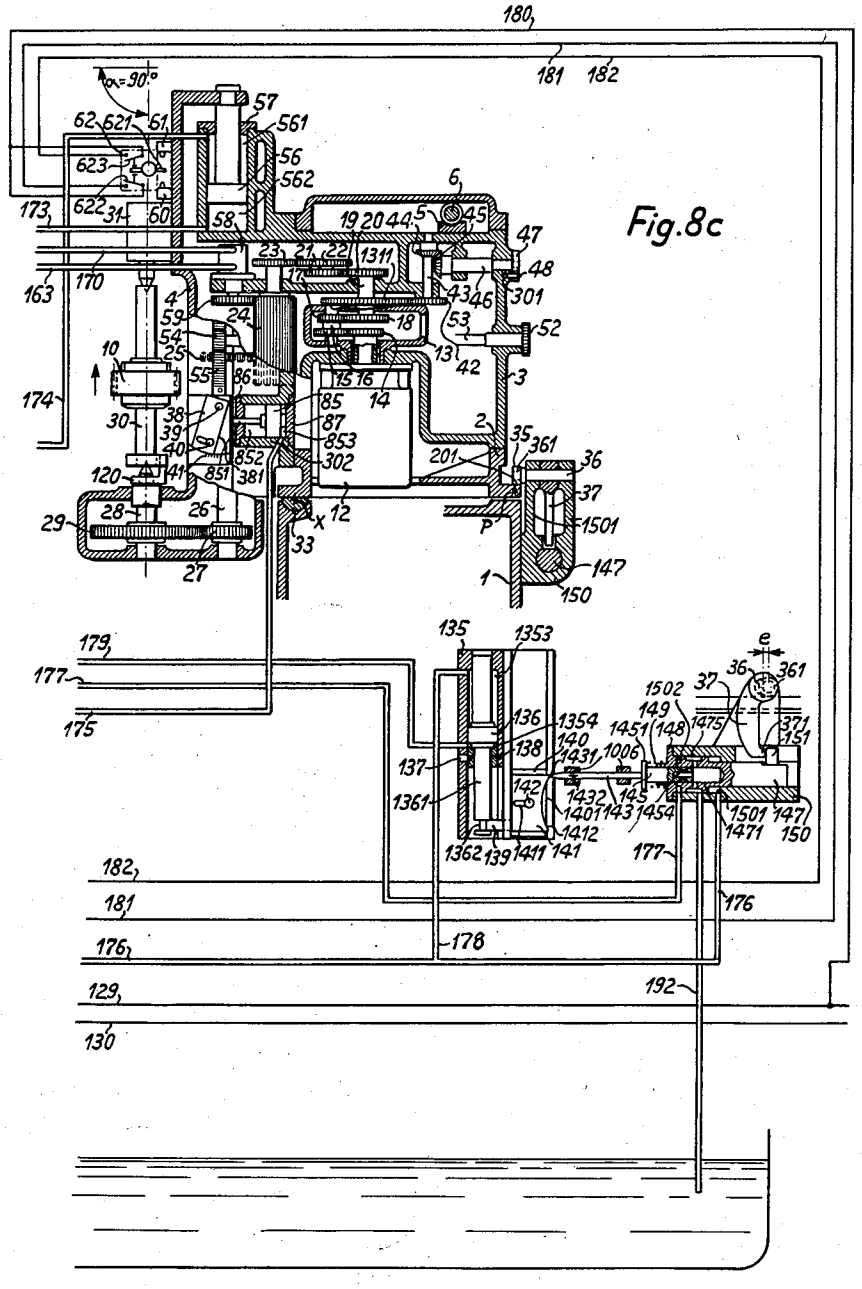


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MACHINE FOR THE GRINDING OF CYLINDRICAL, CONICAL AND CROWNED SPUR GEARS AND HELICAL GEARS BY THE GENERATING PRINCIPLE

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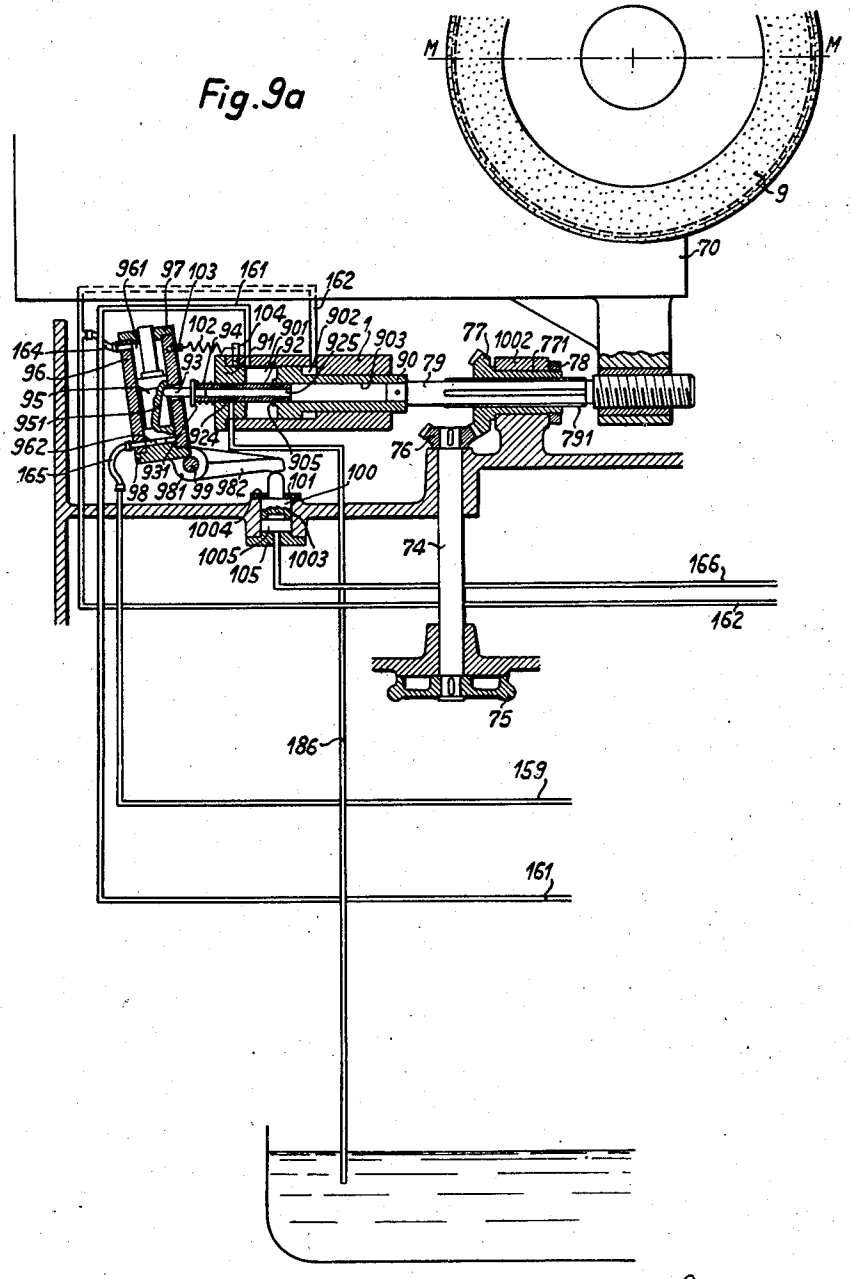
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MACHINE FOR THE GRINDING OF CYLINDRICAL, CONICAL AND CROWNED SPUR GEARS AND HELICAL GEARS BY THE GENERATING PRINCIPLE

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Fig. 9a



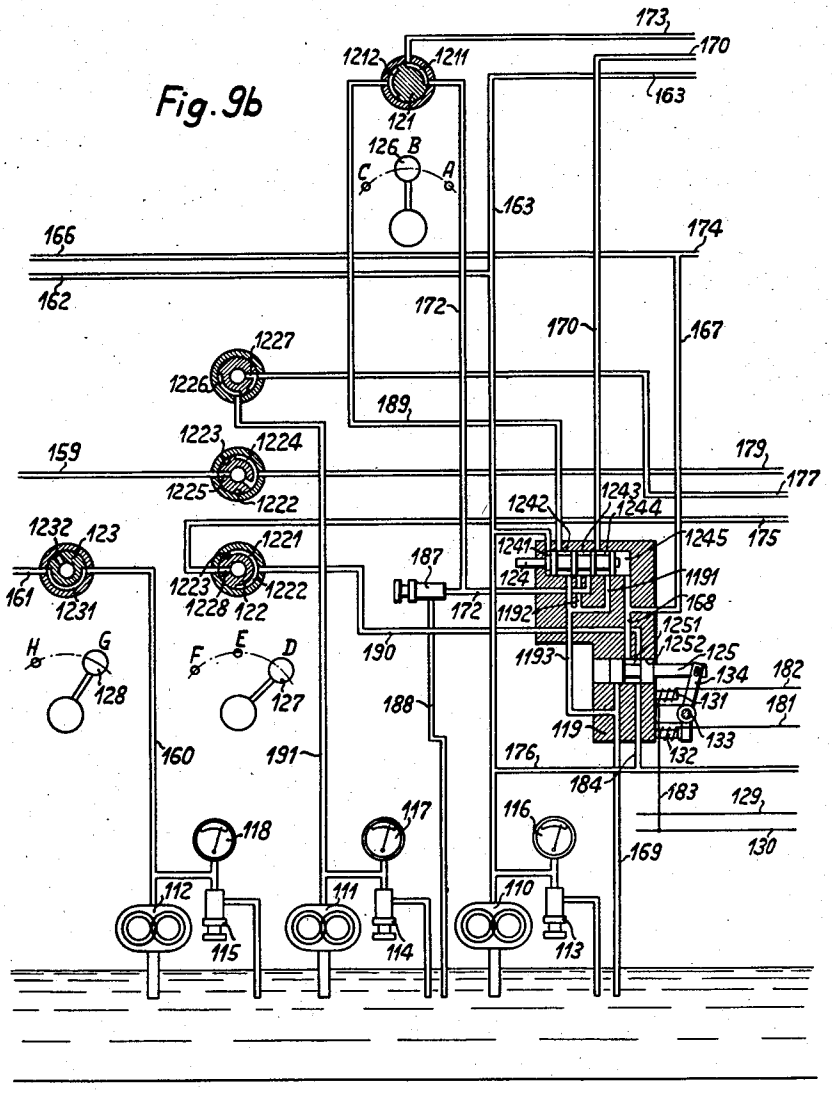
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MACHINE FOR THE GRINDING OF CYLINDRICAL, CONICAL AND CROWNED SPUR GEARS AND HELICAL GEARS BY THE GENERATING PRINCIPLE

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Fig. 9b

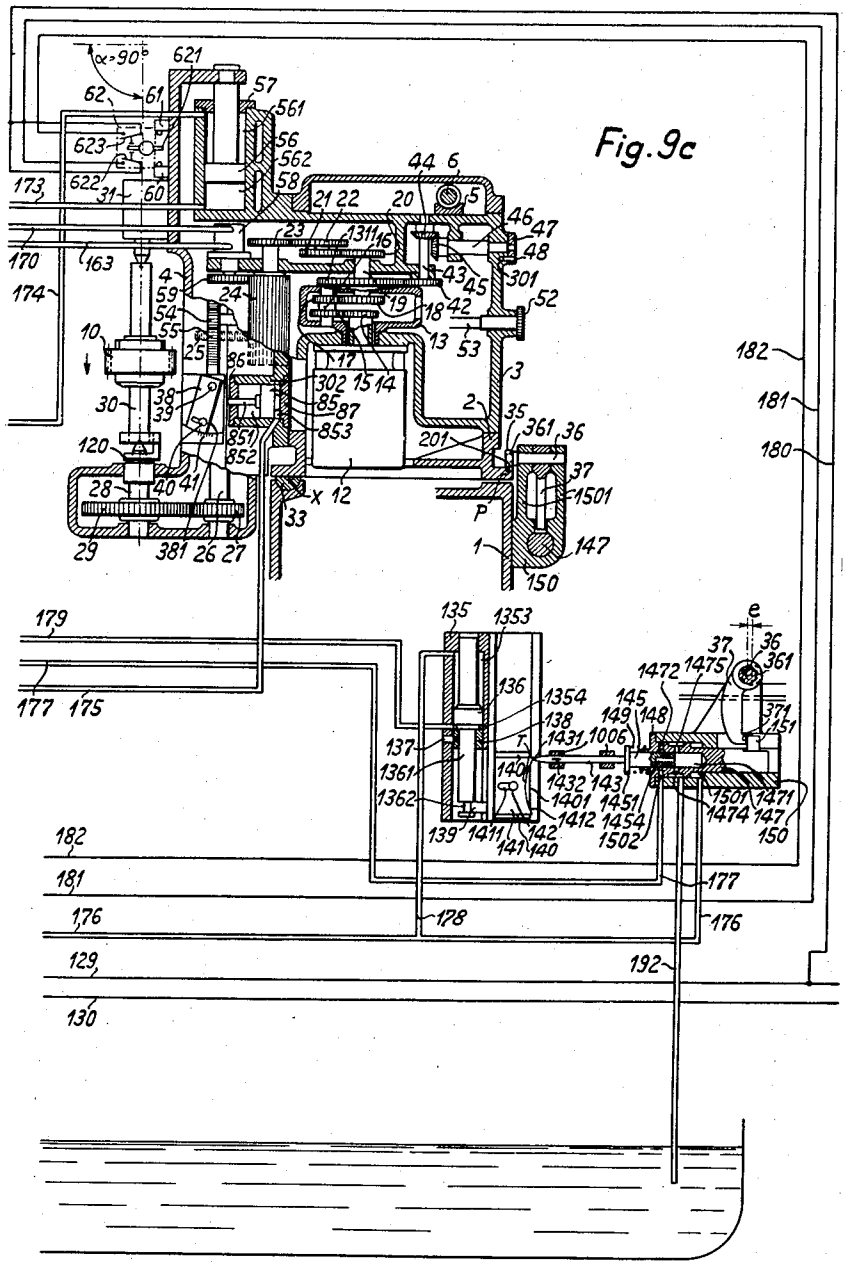


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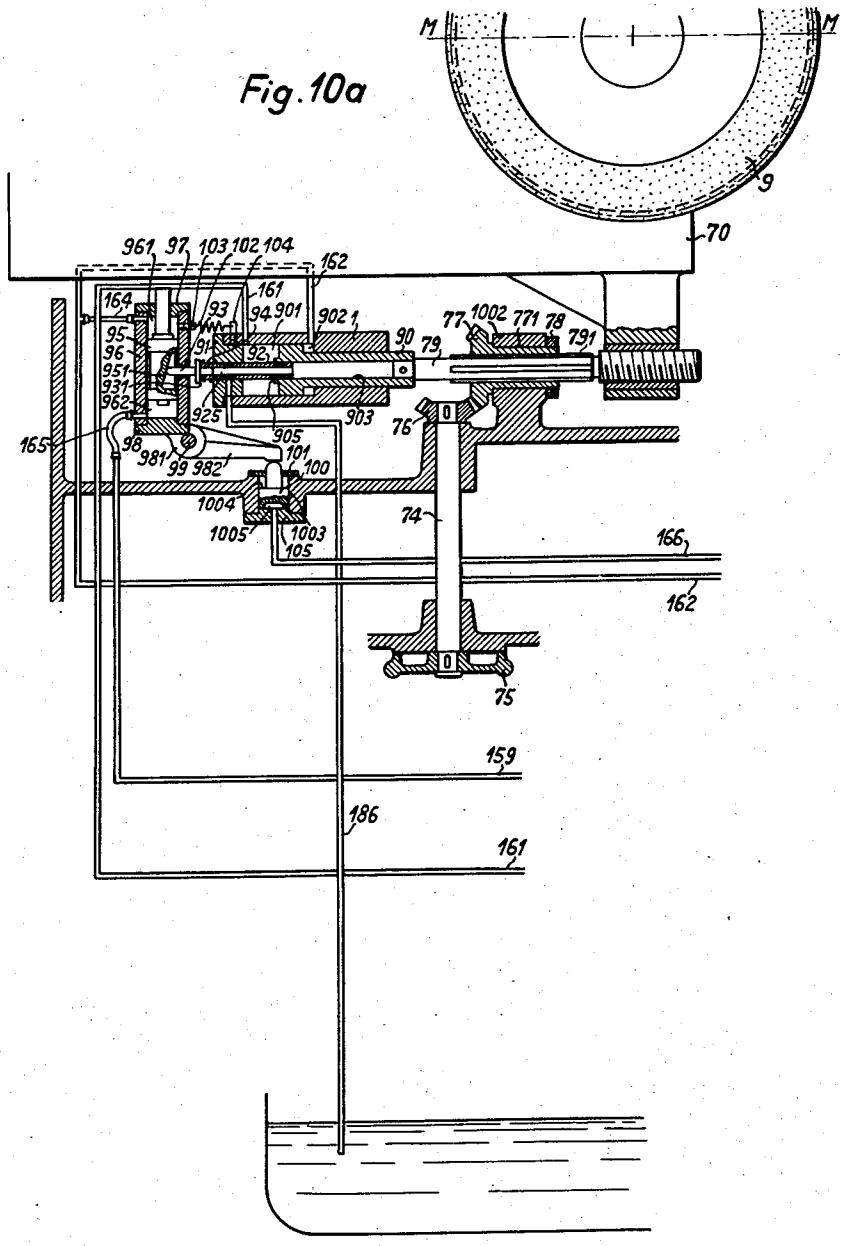
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MACHINE FOR THE GRINDING OF CYLINDRICAL, CONICAL AND CROWNED SPUR GEARS AND HELICAL GEARS BY THE GENERATING PRINCIPLE

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Fig. 10a



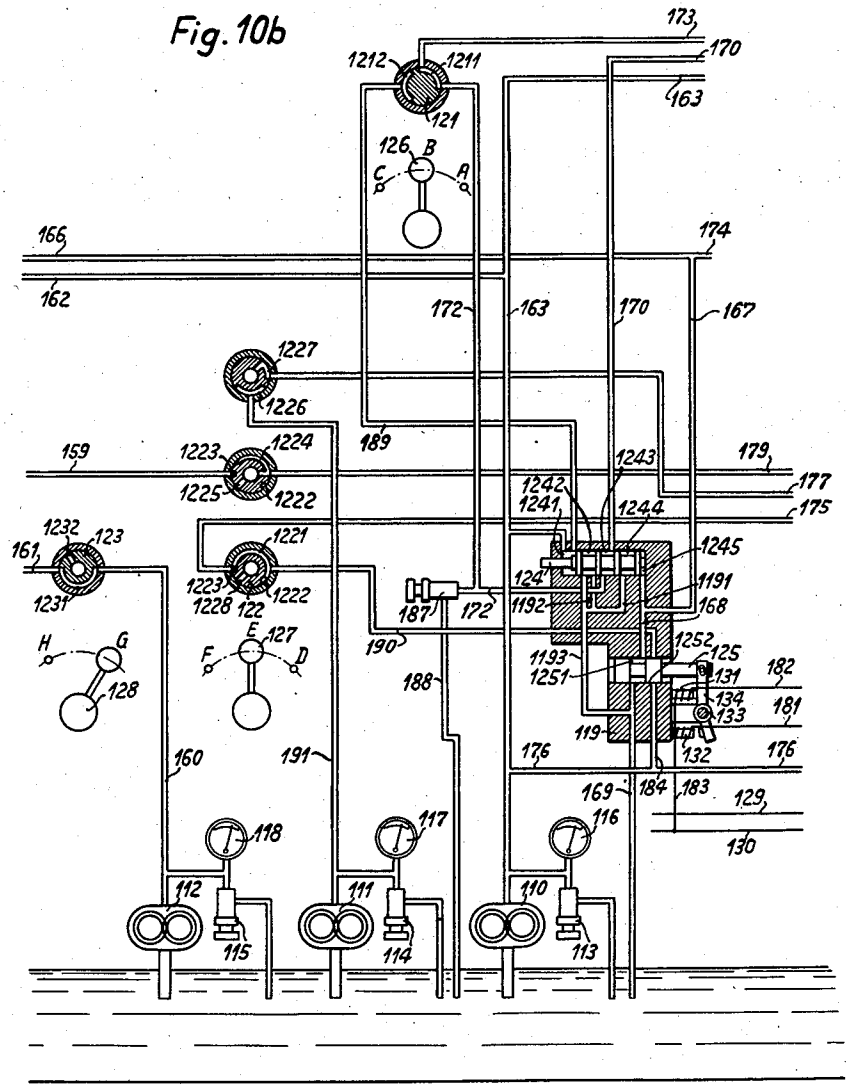
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Fig. 10b



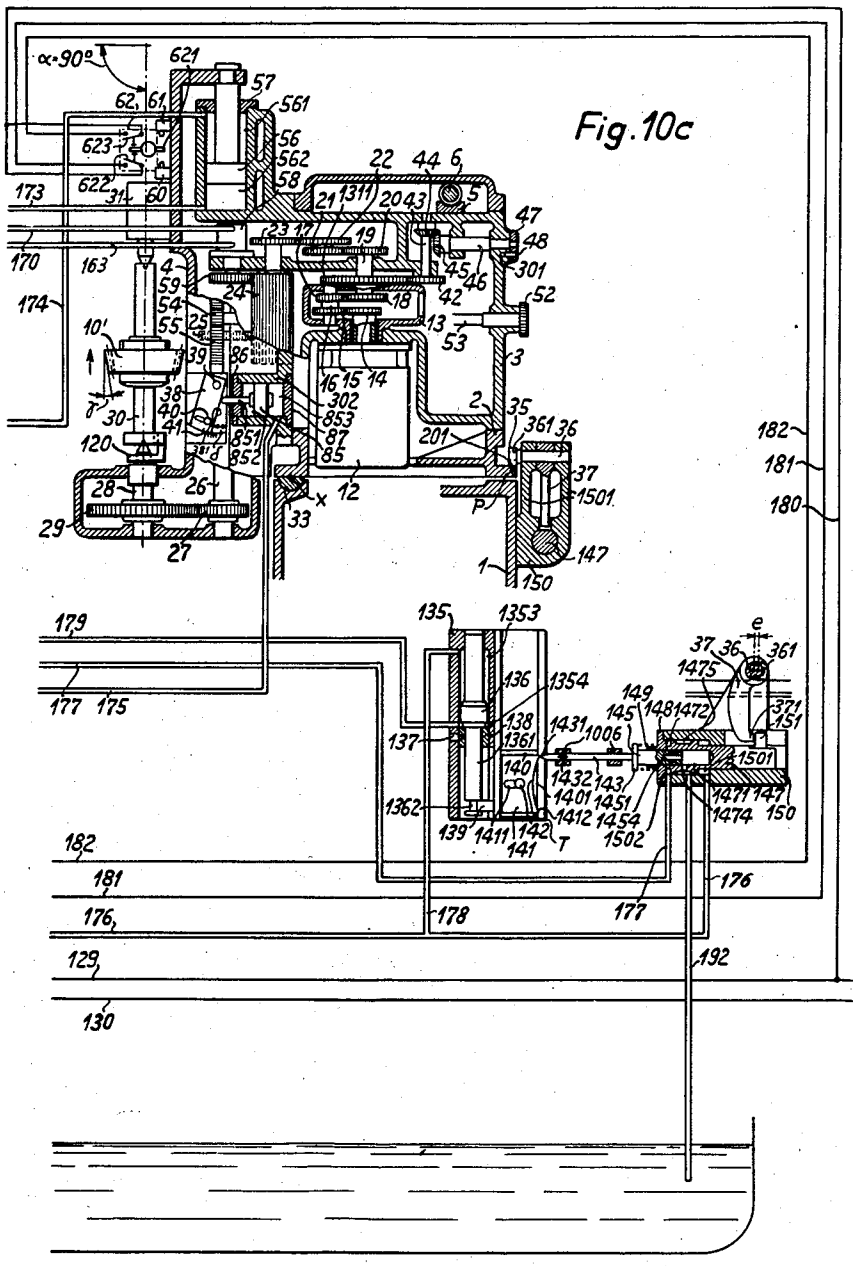
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MACHINE FOR THE GRINDING OF CYLINDRICAL, CONICAL AND CROWNED SPUR GEARS AND HELICAL GEARS BY THE GENERATING PRINCIPLE

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Fig. 10c



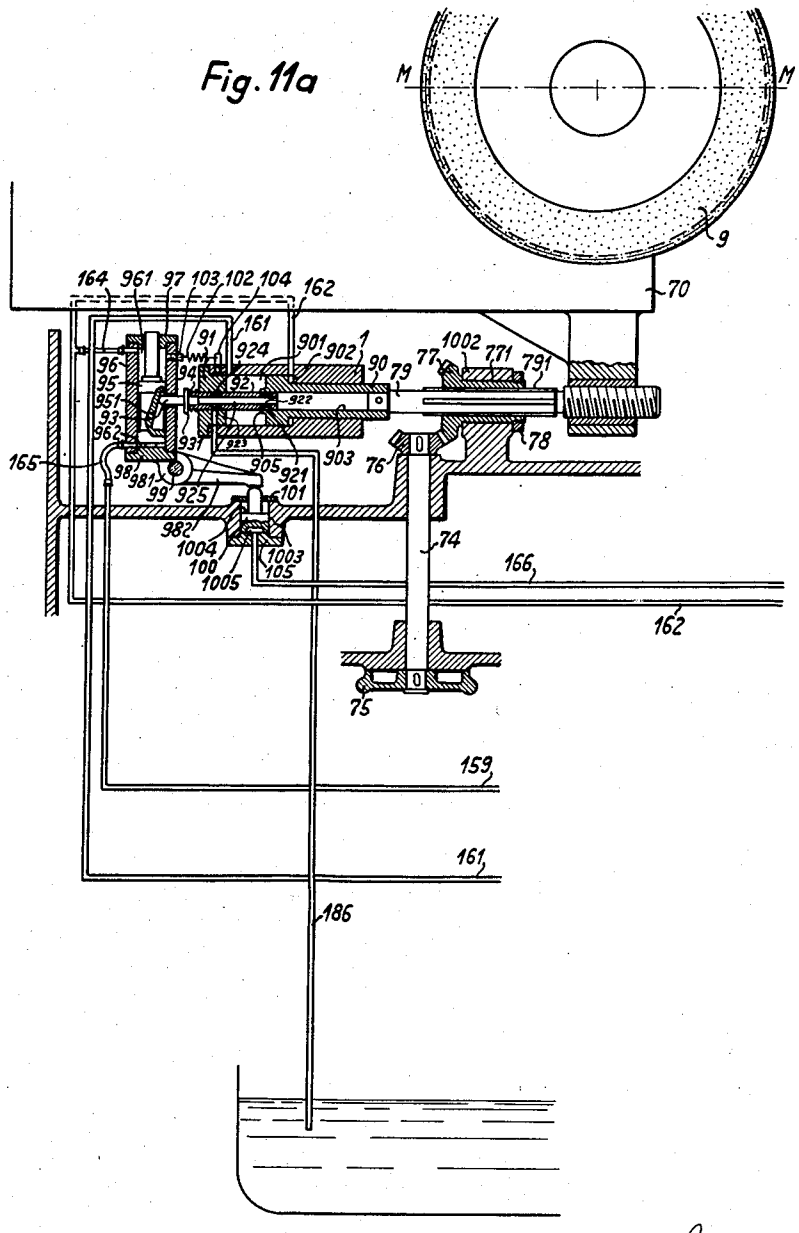
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MACHINE FOR THE GRINDING OF CYLINDRICAL, CONICAL AND CROWNED SPUR GEARS AND HELICAL GEARS BY THE GENERATING PRINCIPLE

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Fig. 11a



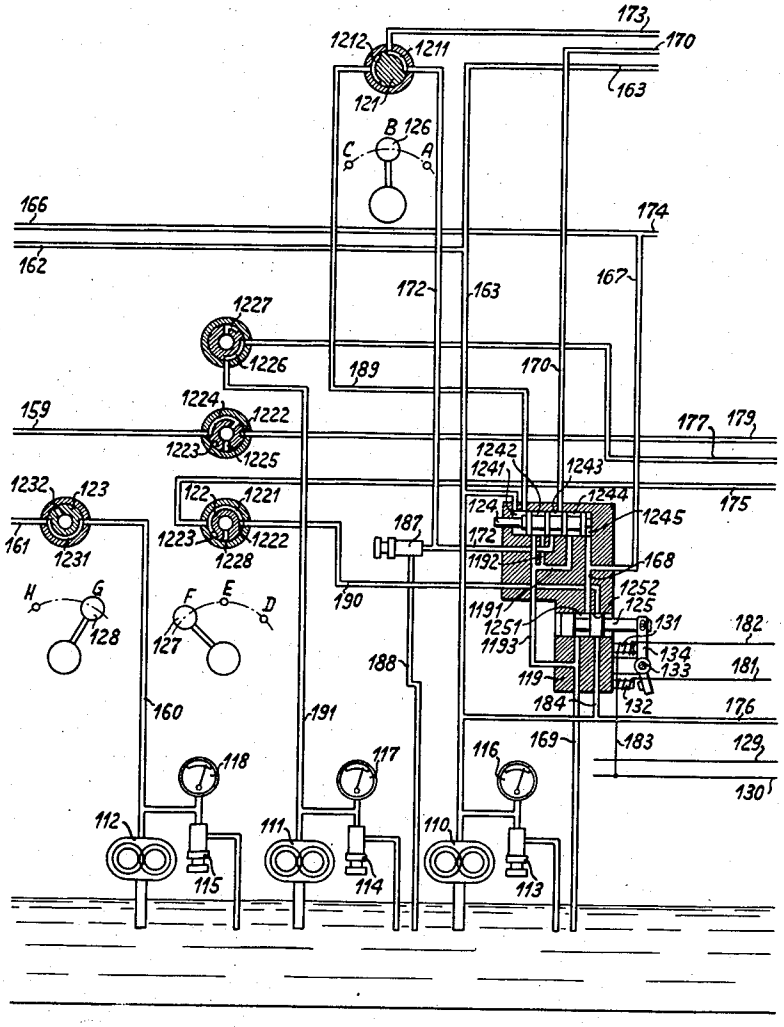
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Fig. 11b



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MACHINE FOR THE GRINDING OF CYLINDRICAL, CONICAL AND CROWNED SPUR GEARS AND HELICAL GEARS BY THE GENERATING PRINCIPLE

Filed Sept. 17, 1956 18 Sheets-Sheet 18

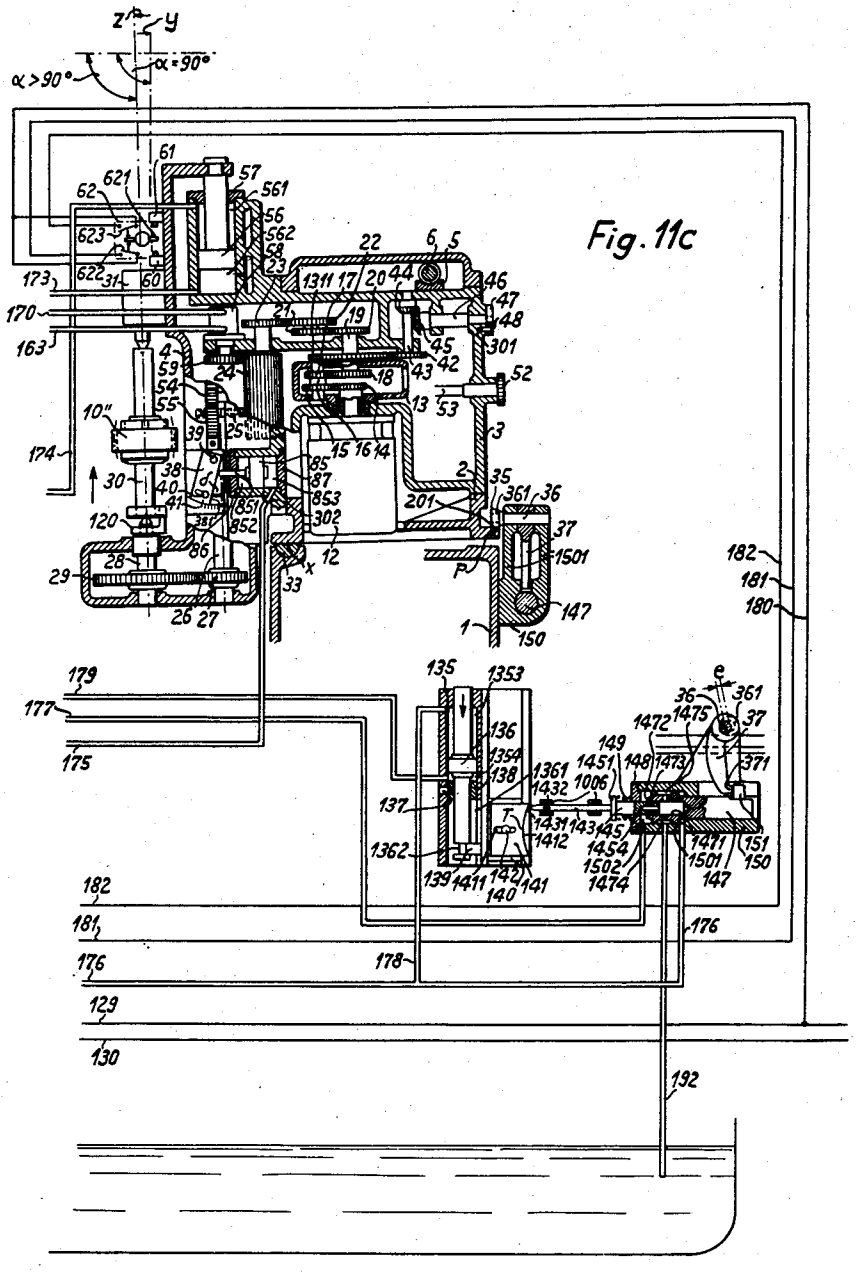


Fig. 11c

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United States Patent Office 2,839,875 Patented June 24, 1958

2,839,875

MACHINE FOR THE GRINDING OF CYLINDRICAL, CONICAL AND CROWNED SPUR GEARS AND HELICAL GEARS BY THE GENERATING PRINCIPLE

Alfred Rickenmann, Kusnacht, near Zurich, Switzerland, assignor to Reishauer-Werkzeuge A. G., Zurich, Switzerland

Application September 17, 1956, Serial No. 610,262

Claims priority, application Switzerland November 18, 1955

3 Claims. (Cl. 51—95)

The present invention relates to devices in gear grinding machines operating on the generating principle which permits the grinding of gears having a non-cylindrical circumferential surface. Two different groups of work pieces fall under the term of gears having a non-cylindrical circumferential surface: the first group includes gears in which the toothing is arranged on the circumferential surface of a cone. To this group belong for example pinion type gear cutters which find use as cutting tools in gear shaping machines. Moreover in textile and book printing machines conical gears are fitted in order to compensate for differences in axial spacing. To the second group belong all those gears which have to be produced barrel-shaped or crowned as regards the direction of their teeth. For the following considerations it is absolutely immaterial whether the crowning extends over the full width or over some sections only of the teeth to be ground.

The field of application of the invention extends to spur gears and helical gears. It moreover extends to work pieces the toothing of which is either already pre-machined and has merely to be finished by grinding on the gear grinding machine, or which may be produced directly from the solid.

On gear grinding machines operating on the generating principle hitherto only gears having a cylindrical circumferential surface could be ground. With the known embodiments of such devices the forcibly driven work piece is rotatably guided on a slide between two centre points. The said slide is arranged for translational movement in the direction of the axis of rotation of the work piece. When grinding the work piece the same is shifted past the grinding worm in order that each point of the width of the teeth comes into contact therewith and is ground thereby. When grinding gears having a cylindrical circumferential surface the axial distance between the work piece and the grinding worm remains the same over the whole width of the work piece to be machined. A feature in the production of non-cylindrical gears—which hitherto could not be ground on gear grinding machines operating on the generating principle—consists however in that during the working process the distance between the axes of the tool and of the work piece is varied in accordance with the particular geometrical shape of the latter.

These variations in the distance between the axes may amount in conical gears—depending on their width—to several millimetres. In contrast thereto in crowned gears deviations from the theoretical direction of the teeth are required which are of the order of magnitude of a few microns only.

Devices are known on several other types of gear machining machine tools which permit the production of conical gears or of crowned tooth shapes. These devices have the object to effect the variations in the distance between the axes of the work piece and the tool.

The means coming into action for this purpose have hitherto been entirely different from one another depending on whether they were used for the production of conical gears or of crowned teeth. The choice of the means and/or the structural arrangement of the devices where determined exclusively by the magnitude of the variations of the distance between the axes. Accordingly different types of machine tools had to be brought into action for performing one or the other machining operation.

In one known embodiment of a machine for the grinding of conical gears the work piece to be ground is rotatably mounted about a horizontal axis. A single rib grinding wheel is mounted on a slide, the guide ways of which are disposed at a slope. Their gradient corresponds to the cone of the toothing to be ground. During the grinding process the work piece is restrained in its axial position while the slide carrying the grinding wheel is moved to-and-fro. The disadvantage of this construction consists in that adjustable guide ways are required in order that the same may be adjusted to the varying requirements as regards conicity. This arrangement may be convenient for single-purpose machines i. e. where continually work pieces with the same conicity are to be ground. In another known type of machines for the grinding of conical gears a feeder movement is imparted to the work piece during the grinding process in the direction of its axis of rotation. For this purpose a threaded spindle is provided which is driven through change gears. From this infeed mechanism a second threaded spindle is driven—likewise through change gears. This second spindle is in engagement with a nut which is fixed on the slidably mounted grinding slide, and has the object of effecting the variation of the distance between the axis of the workpiece and the grinding wheel associated with the feeder movement of the workpiece, by altering the position of the grinding slide.

The devices described are unsuitable for the production of crowned gears, since with the means referred to it is not possible to attain the infinitesimal variations in the distance of the axes required. For example the lost motion in those components of the transmission which produce the variations in the axial distances required when grinding conical work pieces, are substantially larger than the variations in axial distance required when grinding crowned toothings. Crowned teeth could be produced hitherto on gear shaving machines. During the shaving process the work piece is not driven by a gear train at a quite definite speed but is set in rotation by the shaving tool. Owing to these driving conditions it is possible to impart to the work piece carrier an effective rocking movement with respect to the longitudinal axis during the shaving process. This movement is controlled by the aid of cam discs and linkages. These means are out of question for the production of conical gears.

When grinding a gear by the generating principle the grinding worm and the work piece are driven separately. In these circumstances the means suitable for shaving are not applicable for the production of crowned gears, since a rocking movement of the work piece carrier is unthinkable owing to the presence and necessity of driving members.

Accordingly other new means and ways had to be searched for, in order to grind on a gear grinding machine operating on the generating principle the two aforesaid groups of gears having non-cylindrical circumferential surfaces.

The following description with accompanying drawings discloses a novel inventive solution for carrying out the program desired.

The idea of the invention consists in that it is made

possible to carry out the grinding process on conical gears as well as of crowned gears on a gear grinding machine operating on the generating principle, by the aid of a single control element, although the variations in axial distances required therefor during the grinding process differ extremely from one another in their order of magnitude. On the machine under consideration, constructed according to the invention the work piece is likewise carried by a slide, which is arranged slidably in the direction of the axis of rotation of the work piece. The main feature of the invention is formed by a template adjustably mounted on the aforesaid slide and acting on a hydraulic control system which controls and influences the device serving for the variation of the distance between the axes of the work piece and of the grinding worm.

The control system governed by the said template of the machine constructed according to the invention comprises two hydraulic copying systems. One of them is in operation when grinding conical gears in order to carry out the necessary variations in the distance of the axes by altering the position of the grinder slide. The other one serves for generating the infinitesimal differences in the axial distance when grinding crowned gears, by means of rocking movements, under the assumption that the work piece is continuously forcibly driven.

The applicability of the invention is not limited to machines in which the work piece is fed along its axis of rotation during the grinding process. It is quite possible to construct the machine in such a manner that the work piece maintains its axial position during the grinding while on the other hand the grinding worm is moved along the axis of the work piece. In this case the aforesaid control template would have to be mounted on the movable grinding slide. The functions and effects of the control system governed by it remain, however, exactly the same. In connection with these considerations it has to be mentioned moreover, that the devices serving for the variation of the distance between the axes can for example be applied in such a manner that the grinding slide keeps stationary when grinding conical gears while the adjustment movement is performed from the opposite side. It is likewise possible when grinding crowned gears to carry out the rocking movements on the side of the grinding worm instead of on the side of the work piece.

An embodiment of the subject of the invention will be described hereinafter with reference to the drawings, in which:

Fig. 1 is a frontal view of the machine (composed of two parts **1***a* and **1***b*),

Fig. 2 is a longitudinal section of the drive of the work piece and the infeed mechanism for the grinding slide,

Fig. 3 is a side elevation of the machine as seen from the left hand side,

Fig. 4 is a cross section of the machine on the line I—I of Fig. 1,

Fig. 5 shows part of the drive of the work piece in section, as a modification of Fig. 2,

Fig. 6 shows a detail of the infeed mechanism of the grinding slide, partly in section on the line II—II of Fig. 1,

Fig. 7 is a detail of the control partly in section on the line III—III of Fig. 1,

Figs. 8 to 11 (each divided into three parts *a, b, c,* respectively) diagrammatically show the hydraulic and electrical control means in various phases of operation,

Fig. 12 shows details of the hydraulic control devices, partly in section on the line IV—IV of Fig. 1,

Figs. 13 to 15 show developments of the rotary slide valves shown in Fig. 12,

Fig. 16 is a diagrammatic illustration of the electric control means,

Fig. 17 shows a detail of the control mechanism, and Fig. 18 shows a work piece.

STRUCTURAL ARRANGEMENT OF THE MACHINE

On the base **1** a support **2** is mounted pivotally. On the latter a guide rail **33** of semi-circular profile is attached by means of screws **34**. It forms at the same time a fulcrum axis X and runs parallel to the axis of the grinding spindle. The accurate position of the support **2** is determined by a disc **35**, which is fixed eccentrically on a shaft **36** at the right hand side of the machine (see Fig. 2), and which bears on the foot portion **201**. This eccentrically mounted disc **35**, its shaft **36** and a lever **37** fixed thereon form part of a control aggregate which will be described later in detail. In the support **2** a drum **3** is journalled which carries the work piece carrier slide **4** which is slidably arranged thereon. On the drum **3** a worm wheel segment **5** is fixed. The associated worm **6** is mounted on a shaft **7** (Fig. 4) journalled in the support **2**, which can be turned by means of a hand wheel **8**. This device serves for turning the drum **3** and the work piece holder slide **4** into an angular position which depends on the angular helix angle of the grinding worm **9** as well as on the helix angle of the work piece when grinding helical gears. The angular position of the drum **3** and of the work piece slide **4** can be fixed by the aid of screws **11**. For the driving of the work pieces a motor **12** is provided—in the present case a synchronous motor—which is fixed to the drum **3**. In a bore of the drum **3** the rotatably mounted cage **13** of a differential gearing is centered coaxially to the axis of the aforesaid motor. This cage **13** is locked when grinding spur gears. On the shaft end of the motor **12** a pinion **14** is mounted which is in mesh with a spur gear **15**. The latter is mounted on a shaft **16** which is rotatably journalled in the cage **13** and is provided with a further spur gear **17**. The latter is in mesh with a spur gear **18** which transmits rotary motion through the shaft **19** and the change gears **20**, **21**, **22**, **23** on to the pinion **24**. The four change gears are selected and fitted in accordance with the number of teeth of the work piece. The pinion **24** is rotatably journalled in two bores of the drum **3**.

A spur gear **25** in mesh with the pinion **24** is keyed on a driving shaft **26** rotatably mounted in the work piece carrier slide **4**. This shaft carries a further spur gear **27** which in turn meshes with a spur gear **29** mounted on the working spindle **28**. The rotary movements of the working spindle **28** are transmitted by the aid of a dog **120** to the mandrel **30** and to the work piece mounted thereon. The mandrel **30** is centered between the centre point of the working spindle **28** and the centre point of the tail stock sleeve **31**. As mentioned hereinabove the cage **13** of the differential gearing is kept at a standstill when grinding spur gears. A toothing **1311** (Fig. 5) provided on the said cage **13** is in mesh with a spur gear **42** which is keyed to a rotatably journalled shaft **43** together with a bevel gear **44**. The bevel gear **44** meshes with a bevel gear **45** which is mounted on a shaft **46**. On the end of the shaft pointing away from the bevel gear **45** a disc **47** is mounted (see Fig. 2). The latter is provided with a pin **48** projecting into a bore **301** provided in the drum **3**. By this measure the cage **13**, the spur gear **42**, the shaft **43** the pair of bevel gears **44**, **45** and the shaft **46** are locked.

When grinding helical gears an additional rotary movement has to be imparted to the work piece which is effected with the aid of the differential gearing by turning the cage **13**. For this purpose the disc **47** designed for locking the said cage **13** is removed, and a spur gear **49** is fitted to the shaft end concerned (Fig. 5). The spur gear **49** together with three further spur gears **50**, **51**, **52** forms a train of change gears, which is determined in accordance with the helix angle to be produced on the work piece. The change gear **52** is mounted on a shaft

53 which is rotatably journalled in the drum 3 and is provided with a spur gear 54 (Fig. 1a). The latter is in mesh with a toothed rack 55 which is screwed to the work piece carrier slide 4.

Below the toothed rack 55 a template 38 is pivotally mounted. The same is held by two screws 39, 40 of which the upper one serves as a pivot axis. A scale 41 arranged below the template 38 facilitates the adjusting thereof into the position desired. When grinding conical gears and crowned gears the control face 381 is in contact with the rod 851 of a piston 85 which is guided in a cylinder 302 on the drum 3. The chambers 852, 853 located on the left hand side and right hand side, respectively, of the piston 85 are closed by the covers 86, 87, respectively.

The portion of the drum 3 extending into the work piece carrier slide 4 is designed as the cylinder of a piston. The piston 56 (Fig. 2) guided therein is fixed to the work piece carrier slide 4. The cylinder 561 for the piston in the drum 3 is provided with a lid 57. The movement of the work piece carrier slide 4 is effected by the aid of control oil. The speed when grinding is determined by the controllable output volume of a so-called variable delivery (pump 58 Fig. 2) of a conventional type. The latter is attached to the drum 3 and is driven by the aid of a spur gear 59 from the pinion 24. Two adjustably mounted abutments 60, 61 on the work piece carrier slide 4 (Fig. 1a) serve for adjusting the stroke required when grinding. A switch 62 is mounted on the drum 3 between these abutments 60, 61.

GRINDING SLIDE, INFEED MECHANISM

The grinding slide 70 is mounted horizontally slidably on the base 1. The grinding worm 9 is mounted cantilever fashion on that end of the grinding spindle 72 which projects towards the service side of the machine. The grinding spindle 72 is rotatably journalled in the grinding slide 70 and is directly coupled to the driving motor 73. The latter is connected by flanges to the grinding slide 70 and is constructed, like the work piece driving motor 12, as a synchronous motor. For the shifting of the grinder slide two mutually independent infeed devices are available. The manual infeed device comprises a shaft 74 rotatably journaled in the base 1, which is provided with the hand wheel 75 and a bevel gear pinion 76. The latter is in mesh with another bevel gear 77. The hub 771 (Fig. 2) of the latter is journalled in a bearing bracket 1002 of the base 1. A ring 78 fitted to the end of the hub prevents axial displacements thereof. The bore of the bevel gear 77 is designed for receiving that portion 791 of the spindle 79 which has a splined profile. When turning the hand wheel 75 accordingly the rotary movements are transmitted through the shaft 74 and the pair of bevel gears 76, 77 on to the spindle 79. The spindle 79 is arranged between the two guide ways 80, 81 of the grinding slide 70.

On the left hand end of the spindle 79 a piston 90 is fixed which is slidably guided in the base 1. The cylinder 901 thereof is closed by a lid 91. In the latter and in the bore 903 of the piston 90 the control pin 92 is slidably inserted. The same is provided with a feeler 93 which by the aid of a compression spring 94 abutting on the end face 931 of a collar and on the lid 91 is biased permanently against the control face 951 of a piston 95. The latter is guided in a cylinder 96 which is closed by the two lids 97, 98 (see Fig. 6). The lid 98 is provided with an eye 981 rotatably mounted on a shaft 99 which is in turn journalled in the base 1. On the lid 98 there is moreover provided an arm 982. The latter reaches into the range of a piston 100 which is guided in a bore 1003 of the base 1. The stroke of the said piston is determined by the end face 1004 and by a lid 101. A tension spring 102, which is attached by means of two eyes 103, 104 to the cylinder 96 and to the base 1, respectively, has the effect that the arm 982 constantly contacts the piston 100.

CONTROL DEVICES

For the control of the machine, in addition to the control members mentioned hereinabove when describing the infeed device and the drive of the work piece, the following devices are provided:

The pressure oil required for the hydraulic control is fed from a sump provided in the base 1 by the aid of three gear pumps 110, 111, 112 (Fig. 8b). The pressure oil delivered by the gear pump 110 serves for controlling the machine, i. e. for automatically manoeuvring the work piece carrier slide 4 and the grinding slide 70 in respect of the direction of movement of the work piece carrier slide 4. The gear pump 112 supplies pressure oil, which is needed for the actuation of the hydraulically controlled infeed device for the grinding slide 70. The pressure oil supplied by the third gear pump 111 is used when grinding crowned gears. The pressures in the pressure zones associated with the three gear pumps 110, 111, 112 are adjusted and controlled by the aid of associated pressure regulator valves 113, 114 and 115 and pressure gauges 116, 117, 118.

For the distribution of the pressure oil a control block 119 provided with two pistons 124, 125, and three cocks 121, 122, 123 are provided. The cock 121 which is adjustable by means of a lever 126, can be turned into three positions marked A, B, C, respectively. The position A finds application in the first place when setting the machine, when the work piece carrier slide 4 has to be moved quickly up-and-down. The position B is to be adjusted to when operating, while the position C permits the arresting of the work piece carrier slide 4 in any position desired.

The position of the cock 122 which is fixed by the aid of a lever 127 determines the working method. When the position D is selected, gears having a cylindrical circumference can be ground. The position E comes in question when conical gears are to be machined. The position F is required when crowned gears are to be produced.

A lever 128 serves for adjusting the cock 123. The latter can be adjusted to two different positions G, H. When the cock 123 is turned into the position G, the grinding slide 70 is shifted from a rear position (e. g. after the setting of the machine) into the working position and is retained there. On the other hand the position H is selected, when e. g. at the end of a working process the grinding slide 70 is to be restored rearward immediately, in order that the work pieces may be exchanged.

For the feeding of the control network a grid having the two conductors 129, 130 (Fig. 16) is provided. On the control block 119 (Fig. 8b) two magnet coils 131, 132 are attached. The same are arranged on both sides of the pivot axle 133 of a control lever 134 which is likewise pivotally mounted on the control block 119. This lever is connected to the control piston 125.

At the front end face of the base 1 a cylinder 135 (Fig. 1) is mounted which contains a slidably mounted piston 136. A guide bushing 138 inserted in the cylinder 135 and fixed by a screw 137 is penetrated by a piston rod 1361. In the latter there is provided an annular groove 1362 which is engaged by a cylindrical pin 139. The same is screwed into a plate 140. The latter is inserted slidably into the guide track formed on top of the cylinder 135 by the base surface 1351 and two longitudinal ledges 1352 (Fig. 7). The plate 140 carries a template 141 which is adjustably mounted, and has a slot 1411 (Fig. 17) and a screw 142 therein, by means of which it can be arrested in any position desired.

A feeler pin 143 arranged horizontally at right angles to the guide tracks 1351, 1352 is slidably mounted in the two bores 1006 of the base (see Fig. 7).

The horizontal axis of the feeler pin **143** runs at the same level as the surface of the plate **140** and the underside of the template **141**. When grinding crowned gears, i. e., when the plate **140** in question and the template **141** mounted thereon are to be shifted, the vertically positioned sensing edge **1431** (Fig. 17) of the feeler pin **143** slides either on the side face **1401** of the plate **140** or on the control surface **1412** of the template **141**. A guide pin **144** which projects into a longitudinal groove **1432** (Fig. 7) assures the correct position of the feeler pin **143**. The latter is moreover constantly in contact with the end face of a collar **1451** of the copying piston **145**. The latter slides in the lid **148**, and is fitted into a bore **1471** of the piston **147**. A compression spring **149** inserted between the lid **148** and the collar **1451** of the piston **145** assures a constant contact without play of the feeler pin **143** on the plate **140** or on the template **141**. The lid **148** is screwed to a cylinder **150** which is in turn fixed on the right hand side wall of the base. It houses the piston **147** and is provided with two arms **1501** (Fig. 1*a*). The latter serve as bearings for the shaft **36**, which is provided with the control lever **37** and the eccentrically mounted disc **35** (Fig. 2). The bearing portions and the bore of the lever **37** run co-axially to one another, and the journal pin **361** for the disc **35** is arranged eccentrically thereto by an offset *e* (see Fig. 7). The nose **371** of the lever **37**, which is guided between the two arms **1501**, contacts a pin **151** which is screwed fast into the piston **147**.

At the beginning of this description it has been already mentioned, that the support **2** is pivotally mounted on top of the base **1**. The centre line X of the semicircular guide rail **33** serves as the fulcrum axis thereof.

The weight distribution resulting from the support **2** and from all the components guided thereon and fitted thereto in relation to the fulcrum axis X is such, that there is permanently a moment in the anti-clockwise direction.

Accordingly a force P is applied constantly to the disc **35**. The same has the tendency of turning the lever **37** in the counterclockwise sense (see Fig. 7). The rotational movement is stopped by the aforesaid pin **151** whereby a constant contact is safeguarded between the latter and the nose **371**.

COURSE OF THE WORKING PROCESS

As a starting point and basis for the following considerations the conditions are to be chosen which are met when grinding gear wheels having a cylindrical circumference. Subsequently explanations of the functioning of the control members and the course of the working process when grinding conical gears and crowned gears will be given.

(*a*) *The grinding of gears having a cylindrical circumference*

The conditions underlying the following description are illustrated in Figs. 8 and 9:

The lever **126** and cock **121** are in the position B as prescribed for grinding. The lever **127** and the cock **122** connected therewith are in the position D, i. e., the control is adjusted for the grinding of gears having a cylindrical circumference. The grinding slide **70** assumes the position relevant for grinding since the lever **128** and the cock **123** have been turned into the position denoted G. In these circumstances the following conditions prevail on the side of the grinder disc:

As mentioned herein before, the grinding slide **70** and and the piston **90** are in the working position. Both chambers **901**, **902** are under pressure. The chamber **901** is supplied with pressure oil from the pressure line **160** through the groove **1231** and the line **161**. The chamber **902** is in communication with the pressure line **163** through the line **162**. The two chambers **901**, **902** form together with the piston **90** and control pin **92** a copying system. The position of the piston **90** depends on that of the control pin **92**. The pressure fluid contained in the chamber **902** has the tendency of pushing the piston **90** to the left. At the same time the pressure fluid present in the chamber **901** acts in the opposite direction. The chamber **901** is in communication with the drain line **186** through the annular groove **921** (Fig. 2) the radial bores **922**, the bore **925**, the radial bores **923** and the annular groove **924**. The magnitude of the aperture formed by the edge **905** and the annular groove **921** determines the pressure in the chamber **901**. With a stationary position of the control pin **92** and with conditions in the control system as illustrated in Figs. 8*a*, *b*, *c*, the pressure in the chamber **901** and the aperture formed between the edge **905** and annular groove **921** adjust themselves automatically so that in respect of the piston **90** there prevails a state of equilibrium.

The position of the spindle **79** has been altered by turning the handwheel **75** to such an extent that under the conditions of the control system as illustrated in Figs. 8*a*, *b*, *c* the grinder helix **9** is in engagement with the work piece **10**, and machines the same.

When grinding gears with a cylindrical circumference, the piston **95** remains constantly in the position shown in Fig. 8*a*, i. e. it contacts the lid **98**. The chamber **961** is connected by a flexible pipe **164** to the pressure line **162** referred to hereinabove. The chamber **962** on the other hand is in communication with the drain hole **1225** in the cock **122** (Fig. 8*b*) through the flexible pipe section **165** and the line **159**. The piston **100** (Fig. 8*a*) is forced by the arm **982** against the lid **105** by the bias of the tension spring **102**. This is possible because the chamber **1005** is not under pressure, but is connected to the drain pipe **169** by the lines **166**, **167**, **168** and the annular groove **1251** (Fig. 8*b*).

In the circumstances assumed, i. e. when the lever **126** and the cock **121** are in the position B, the following conditions prevail on the side of the work piece:

Pressure oil flows into the chamber **562**. This oil flows from the pressure pipe **163** into the regulator pump **58**. The oil delivered by the latter flows through the pipe **170** to the control block **119** into the chamber **1243** and from there into the pipe **172**. The latter passes the pressure oil through the groove **1211** and the pipe **173** into the chamber **562** referred to hereinabove. As a consequence the work piece carrier slide **4** moves upwards at working speed, because the oil flowing per unit time into the chamber **562** must pass the variable delivery pump (see the direction of the arrows). The oil contained in the chamber **561** can return through the pipes **174**, **167**, **168**, the annular groove **1251** and the drain pipe **169** into the sump. The cylinder **302** fitted to the drum **3** is not under pressure when grinding gears with a cylindrical circumference. The chamber **853** is in communication with the drain hole **1228** in the cock **122** through the pipe **175**. The position of the control template **38** is irrelevant. It has not to fulfil any task when grinding gears having a cylindrical circumference.

The control aggregate arranged on the right hand side of the machine is subject to the following conditions: the chamber **1501** in the cylinder **150** is under pressure. It is permanently connected to the pressure line **163** through the line **176**. The other chamber **1502** has discharged itself through the pipe **177** into the drain hole **1227** provided in the cock **122**. Consequently the end face **1472** of the piston **147** abuts constantly on the lid **148**. The position of the lever **37** and of the eccentric shaft **36** connected therewith and of the disc **35** mounted on the latter associated with this situation, results in a position of the support and of all components connected therewith as required for the grinding of gears with a cylindrical circumference (and as will be explained later also for the grinding of conical gears).

A plane placed through the axis of rotation of the

work piece 10, which runs parallel to the axis of the grinding spindle, includes in the present case an angle $\alpha=90°$ with the horizontal axis of the grinding worm 9. The piston 136 in the cylinder 135 is likewise retained in an end position when grinding gears with a cylindrical circumference. The chamber 1353 is connected through the pipe 178 to a pipe 176 constantly carrying fluid under pressure. The chamber 1354 is empty since the oil which had been contained therein could flow off into the sump through the pipe 179 and the drain groove 1224 with a drain hole provided in the cock 122. The piston 136 is therefore constantly in contact with the guide bushing 138, and is not subject to translations during the grinding of gears with cylindrical circumference.

When the work piece carrier slide 4 reaches the upper end position at the end of its upward movement, the abutment 60 forces the switch lever 621 in the counter-clockwise direction (see Fig. 8) which has the consequence of closing the switch 622. Consequently the magnet coil 132 is energized, because a connection is then established between the two conductors 129, 130 through the line 180, the switch 622 (now closed), the line 181, the magnet coil 132 and the line 183.

Consequently the double lever 134 turns in the clockwise direction and carries along the piston 125 connected therewith towards the right (Fig. 9*b*). After this displacement, pressure fluid can flow from the pipe 176 through the pipe 184, the annular groove 1251 and the pipe 168 into the chamber 1245. Although the chamber 1241 is likewise under pressure, the piston 124 moves towards the left into its end position, because the effective pressure area on the side of the chamber 1245 is larger than in the chamber 1241. Pressure fluid then flows also through the pipe 167, connected to the pipe 168, and through the pipe 166 into the chamber 1005, which results in an immediate displacement of the piston 100 coming to an end when the same abuts on the lid 101. The arm 982 and all the components 98, 96, 95 and 97 connected therewith are subject to a rotary motion in the counter-clockwise sense, the extent of which depends on the stroke of the piston 100. The shaft 99 serves as axis of rotation; owing to this displacement, also the feeler 93 and the control pin 92 connected therewith change their positions and move towards the left, since the spring 94 keeps up constantly the contact with the control face 951. With the displacement of the control pin 92, the hydraulic copying device formed by the same, the piston 90 and the two chambers 901, 902 is brought into action as such. As soon as the control pin 92 moves towards the left, an increase of the aperture between the edge 905 and annular groove 921 occurs. Consequently a pressure drop takes place in the chamber 901. This in turn leads to a displacement of the piston 90 and of the grinding slide 70 towards the left, since the pressure in the chamber 902 is then high enough to overcome the reduced resistance on the side of the chamber 901. As soon as the control pin 92 comes to a standstill, the displacement of the piston 90 and grinding slide 70 comes to an end immediately. The force acting from the chamber 902 tends to shift the piston 90 to the left as far as possible. Thereby, however, the aperture formed between the annular groove 921 and the edge 905 becomes progressively narrower. Consequently at the same time the pressure in the chamber 901 and the force applied to the piston 90 from that side increase. This increase in pressure and force continues until again equilibrium is established between the two chambers 901, 902.

The result of the displacement of the piston 100 as just described, of the rocking movement of the cylinder 96 as well as of the components connected therewith, and of the movement of the control pin 92 towards the left consists in that the grinding worm 9 is automatically lifted off the work piece 10'' by a certain amount, immediately after the switching-over. At the same time the pipe 174 connected to the pipe 167 carries pressure oil which flows into the chamber 561. The work piece carrier slide 4 accordingly reverses its direction of movement and slides downward (see direction of arrows in Fig. 9*c*). The oil contained in the chamber 562 is expelled, and escapes into the sump through the line 173, the groove 1211, the line 172, the chamber 1243 and the drain pipes 1192, 1191, 1193, 169.

The downward run of the work piece carrier slide 4 takes place quickly, since the chamber 562 can discharge itself without any resistance worth mentioning. The positions of the pistons 136, 145, 147 remain unchanged during this phase of operations.

The downward movement of the work piece carrier slide 4 comes to an end when the upper abutment 61 bears on the switch lever 621 and turns the same in the clockwise sense (see Fig. 8*c*). Thereby the switch 623 is closed. The circuit established consequently between the two conductors 129, 130 through the line 180, the switch 623 now closed, the line 182, the magnet coil 132 had been interrupted already at the beginning of the downward stroke of the work piece carrier slide 4 when automatically opening the switch 622, the energised magnet coil 131 can now turn the lever 134 in the counterclockwise direction, which has the consequence of a displacement of the piston 125 towards the left into the position shown in Fig. 8*b*. As soon as this is done, communication is established between the chamber 1245 and the drain pipe 169 through the pipe 168 and the annular groove 1251. Since the chamber 1241 is constantly under pressure, the piston 124 moves at once into the right hand side end position as shown in Fig. 8*b*. Moreover the work piece carrier slide 4 starts moving upward since the oil delivered by the variable delivery pump 58 must flow into the chamber 562 over the path described hereinbefore, while the oil contained in the chamber 561 is expelled into the sump through the pipes 174, 167, 168, the annular groove 1251 and the drain pipe 169. Since, as just shown, the pipe 166 is in communication with the drain pipe 169, the pressure drops also in the chamber 1005. The force applied by the tension spring 102 through the arm 982 to the piston 100 is now capable of expelling the oil from the chamber 1005, and of displacing said piston into the position shown in Fig. 8*a*. During this displacement of the piston 100 and the simultaneous rotary movement of the cylinder 96 and of all the components connected therewith in the clockwise direction, the control pin 92 is forced to the right hand side.

The movement of the latter involves a movement of the grinding slide 70 towards the right. As soon as the control pin 92 performs a displacement towards the right, the gap formed between the edge 905 and the annular groove 921 in the equilibrium condition is reduced. This change causes an immediate pressure rise in the chamber 901, which means a disturbance of the equilibrium condition previously prevailing, and results in a displacement of the piston 90 and grinding slide 70 towards the rigth. This movement comes to an end, and equilibrium is restored between the two chambers 901, 902, as soon as the control pin 92 has reached the rest position illustrated in Fig. 8*a*, i. e. when the grinding slide 70 is in the working position.

In the control system then the same conditions prevail again as those chosen as the starting point of these explanations. It has been shown, how in the grinding of gears with cylindrical circumference the up-and-down movements of the work piece carrier slide 4 and the to-and-fro movements of the grinding slide 70 follow one another automatically. During the working stroke, i. e. during the upward movement of the work piece carrier slide 4, the distance between the axes of the work piece 10 and of the grinding worm 9 remains permanently constant, as required by the geometrical shape of the work piece 10.

The variations in the distance between the axes which

can be effected by means of the hand wheel 75 are here not under discussion. The same are merely provided in order for example to effect at the beginning an upward movement of the work piece carrier slide 4, and infeed movements of the grinding slide 70, which have the object of performing a removal of material from the work piece 10, or of bringing the grinding worm 9 into contact with the gear to be ground, when setting the machine.

When the grinding slide 70 is to be lifted off the work piece a larger distance, such as required for example for exchanging or for measuring the said work piece, the lever 128 and the cock 123 connected with the same are turned into the position H. In these circumstances the supply of pressure fluid to the pipe 161 is interrupted, and the latter is brought into communication with the drain hole 1232. In the chamber 901 a pressure drop occurs immediately. Consequently the pressure oil flowing into the chamber 902 pushes the piston 90 at once towards the left, until it abuts on the lid 91. The oil contained in the chamber 901 is expelled through the pipe 161 and the drain hole 1232. When turning the lever 128 back and the cock 123 into the position G, the chamber 902 is again supplied with oil under pressure, and the condition described hereinbefore is restored.

When the work piece carrier slide 4 is for example arrested for the purpose of exchanging a work piece, or when it has to be moved quickly up and down for adjustment when setting the abutments 60 and 61, the two positions C and A, respectively, of the lever 126 and cock 121 are used. When turning the same into the position C, the communication between the line 172 and 173 is interrupted i. e. the inflow and outflow of control oil of the chamber 562 is blocked. Consequently the work piece carrier tool 4 remains in the position in which it is after performing the turning movement of the lever 126.

When the turning into the piston C is effected during the up-stroke of the work piece carrier slide 4, the oil delivered by the regulator pump 58 can flow off through the safety pressure regulator valve 187 into the overflow pipe 188 and from there into the sump.

When turning the lever 126 and the cock 121 into the position A, communication is established between the pipes 189, 173. At the up-stroke of the work piece carrier slide 4 the pressure oil flowing into the chamber 562 is not delivered in dosed quantities by the variable delivery pump 58, but reaches it directly from the pressure line 163 through the chamber 1241, the control block 119, the line 189, the groove 1212 and the line 173. Accordingly the work piece carrier slide 4 also moves upward at a higher rate than when grinding. The downstroke takes place quickly anyway, as described already hereinabove. In the circumstances contemplated, the chamber 562 can discharge itself at the downstroke of the work piece carrier slide 4 through the pipe 173, the groove 1212, the pipe 189, the chamber 1242 and the two drain lines 1193, 169.

(b) The grinding of conical gears

The conditions in the control system when grinding a conical work piece are illustrated in Figs. 10*a, b, c*. The lever 126 and the cock 121 are then in the position B. The work pieec carrier slide 4 moves upward at operational speed. The lever 128 and the cock 123 occupy the position designated G, i. e. the grinding slide 70 is in the working position and the grinding worm 9 is in engagement with the conical work piece 10'.

The lever 127 and the cock 122 are in the position E which is relevant for the grinding of conical gears. This new situation does not cause any alteration of the conditions in the chambers 1353, 1354, 1501, 1502. The chambers 1353, 1501 are filled with oil under pressure, while the chambers 1354, 1502 are in communication with the drain grooves 1224, 1227 through the associated pipes 179, 177. Consequently the lever 37, the disc 35 and the support 2, and all the devices connected therewith maintain their position unaltered, i. e. the angle α amounts likewise to 90° when grinding conical work pieces, the same as it is the case when grinding gears with cylindrical circumference. On the other hand there exists now communication between the two chambers 962 and 853, which is established through the flexible pipe 165, the line 159, the longitudinal groove 1223 in the cock 122, and the line 175. During the downstroke of the work piece carrier slide 4 preceding the up-stroke contemplated, pressure oil flowed from the line 163 through the lines 176, 184 into the annular groove 1251 and from there through the line 190 into the groove 1221. From there the pressure fluid passed on the one hand through the line 175 into the chamber 853 and forced the piston 85 with the piston rod 851 permanently against the control face 381, on the other hand the pressure oil passed through the longitudinal groove 1223, the line 159 and the flexible pipe 165 also into the chamber 962. This had the consequence that the piston 95 was moved into the other end position, since the force applied to it from the side of the chamber 962 exceeded the force component acting on the side of the chamber 961. When switching-over to working speed the communication between the pressure oil line 184 and the line 190 was interrupted by the cylindrical portion 1252. However, the connection between the two chambers 962, 853 was maintained. The control oil contained therein and in the pipeline section lying between them can escape nowhere. It is under a pressure which is applied to this closed system from the chamber 961 through the piston 95. Accordingly the piston 85 is constantly forced to the left during the up-stroke of the work piece carrier slide 4, and the rod 851 slides constantly on the control face 381 of the template 38 which is put into an oblique position when grinding conical gears. This oblique position has the consequence that the piston 85 may move a certain distance to the left during the up-stroke of the work piece carrier slide 4. At this displacement to the left a corresponding quantity of liquid flows into the chamber 853 which is expelled at the same time from the chamber 962 by the piston 95. The latter accordingly moves in the direction towards the lid 98 during the up-stroke of the work piece carrier slide 4. During this movement of the piston 95 the control pin 92 is forcibly moved to the right by the control face 951. For reasons which have been explained already hereinabove, this movement towards the right is also carried out by the piston 90 and by the grinding slide 70. Accordingly an infeed movement is performed automatically by the grinding slide 70 during the up-stroke of the work piece carrier slide 4, as required for the grinding of the conical work piece 10'. Of cours the infeed movement to be performed automatically by the grinding slide 70 has to be accurately adapted to the dimensions of the work piece 10' to be ground. For example this can be effected in that the scale 41 is calibrated in such a manner that an adjustment angle δ on the template is associated to an angle γ on the work piece 10', so that the displacement of the pistons 85, 95 resulting therefrom during grinding effects a displacement of the control pin 92 as well as of the piston 90 and grinder slide 70, as required for the accurate production of the conical work piece 10' under consideration.

At the end of the upstroke the abutment 60 operates the switch lever 621, and the reversing process is initiated in the manner already described. The piston 125 is pulled to the right, which has the consequence of a displacement of the piston 124 to the left. Accordingly the work piece carrier slide 4 reverses its direction of movement and slides downwards at an increased rate. Pressure oil moreover passes into the chamber 1005 and forces the piston 100 against the lid 101. This leads to a rocking movement of the arm 982 and of all compo-

nents connected therewith, and results, as known, in that the control pin **92** is displaced to the left and that the grinding worm **9** is lifted off a certain amount from the work piece **10'**.

At the same time pressure oil flows again from the line **184** through the annular groove **1251** and the line **190** into the groove **1221** of the cock **122**, and from there on the one hand through the line **175**, on the other hand through the longitudinal groove **1223** and the line **159**, **165** into the associated chambers **853** and **962**, respectively. The piston **95** moves at once into its other end position whereby the control pin **92** contacting the oblique control face **951** performs a displacement to the left. The piston **85** guided in the cylinder **302** on the work piece carrier slide **4** is forced against the control face **381** of the template **38**. The two chamber **962** and **853** and the whole pipe line system lying between them are filled with pressure fluid during the downstroke of the work piece carrier slide **4**. The conditions prevailing in the control system at the moment contemplated correspond to those chosen as the starting point of the preceding chapter. After the reversing of the work piece carrier slide **4** the operations in the control system are repeated in the sequence described.

(c) The grinding of crowned or barrel-shaped gears

The conditions in the control system during the working operation on the work piece carrier slide **4** are illustrated in Figs. 11*a, b, c.*

The lever **126** and the cock **121** are accordingly in the position B. The lever **128** and the cock **123** connected therewith are in the position denoted G, i. e. the grinding slide **70** is in the working position and the grinding worm **9** is in contact with the work piece **10''** to be ground. The latter is intended to have crowned teeth. The lever **127** and the cock **122** are accordingly in the relevant position F.

In these circumstances on the side of the grinding worm **9** the same conditions prevail as when grinding gears having a cylindrical circumference. The position of the grinding slide **70** is not subject during the up-stroke to any variation controlled by the hydraulic control. The chamber **962** is now in communication with the drain groove **1224** through the lines **159**, **165**, and the piston **95** abuts on the lid **98**. Accordingly the position of the control pin **92** remains likewise stationary. On the other hand there exists now communication between the chambers **853**, **1354** which is maintained through the line **175**, the groove **1221**, the longitudinal groove **1222** and the line **179**. During the preceding down-stroke of the work piece carrier slide **4** the two chambers **853**, **1354** just mentioned and the aforesaid pipe line system were connected to the pressure line **184** through the pipe **190** and the annular groove **1251**. In this condition the pressure oil penetrating into the chamber **1354** was capable of shifting the piston **136** into the left hand side end position, since the effective component force acting from the side of the chamber **1354** is larger than that on the opposite side. At the same time the pressure oil forced the piston **85** during the operational phase contemplated against the control face **381** of the template **38** which is likewise arranged at a slope when grinding crowned gears. When switching over, the supply of pressure oil to the two chambers **853**, **1354** was interrupted; the communication between the latter remained however, and the liquid trapped in this pipe line section cannot escape anywhere. It is under the pressure applied by the piston **136** since the chamber **1353** is permanently in communication with the pressure oil pipe lines **176**, **178**. For this reason the piston rod bears continuously on the control face **381** even after the switching over. When turning the lever **127** and the cock **122** into the position F moreover a connection was established which allowed the pressure oil delivered by the gear pump **111** to flow from the line **191** through the groove **1226** into the line **177**, and from there into the chamber **1502**. In the condition illustrated in Figs. 11*a, b, c,* i. e. when grinding crowned gears the two chambers **1501**, **1502**, the piston **147** and the copying piston **145** form a copying system, which functions similarly to that which is formed by the piston **90**, the control pin **92** and the two chambers **901**, **902**, and which has already been described in detail. Between the edge **1473** of the piston **147** and the annular groove **1452** there exists a small gap, which connects the chamber **1502** with the drain pipe **192** through the radial bores **1453**, the longitudinal bores **1454**, **1471**, the radial bores **1474** and the annular groove **1475**.

The plate **140** is provided with a template **141**, which is adapted to the requirements of the case and is appropriately placed. In Fig. 11*c* a situation is illustrated as it occurs in the course of the up-stroke of the work piece carrier slide **4**. During this phase of operations the piston rod **851** follows the control face **381** of the template **38** fitted at a slope. The piston **85** accordingly moves to the left. As a consequence thereof control oil can enter into the chamber **853**, which oil is expelled by the piston **136** from the chamber **1354**. The expulsion of control oil from the chamber **1354** causes a displacement of the piston **136** and of the plate **140** connected therewith, and of the template **141** mounted on the latter. This leads in turn to a displacement of the feeler pin **143** and of the copying piston **145** in contact therewith. Any movement thereof is immediately followed up also by the piston **147** and by the pin **151**. The longitudinal movement effects forcibly a rotational movement of the lever **37** and of the eccentric shaft **36**, which results forcibly in a displacement of the disc **35** and in a variation of the level of the point of contact between the said disc **35** and the support **2**. Any variation of the level of the contact point contemplated means, however, a rocking movement of the support **2** and of all components connected therewith including the work piece **10''**, about the fulcrum axis X. During such a rocking movement a variation of the distance between the axes of the work piece **10''** to be ground and the grinding worm **9**, which is in its working position takes place.

Fig. 11*c* shows the support **2** and all the components connected therewith including the work piece **10''** in the rocked position, i. e. the angle α exceeds in this case 90°. The work piece carrier slide **4** moves downward, and the template **38** arranged at a slope permits the piston **85** to move to the left which—as explained hereinabove—entails the transport of the piston **136** with the plate **140** and the template **141**. At the moment considered the piston **136** moves accordingly in the direction of the arrow indicated in Fig. 11*c*. The feeler pin **143** slides on the control face **1412** of the template **141** and moves from right to left until it reaches the lowest point (Fig. 11*c*). This displacement is also carried out by the copying piston **145** and by the piston **147**, and during the period contemplated the pin **151** turns the lever **37** and the eccentric shaft **36** in the clockwise sense. The disc **35** is lowered by an amount associated with this rotational movement and causes a rocking movement of the support **2** and of all the components connected thereto, including the work piece **10''** in the clockwise direction or in the direction of the arrow denoted *y*. As soon as the feeler pin **143** has passed the deepest point T, it changes its direction of movement and is then shifted from left to right by the template **141** (Fig. 11*c*). The copying piston **145** and the piston **147** then forcibly change likewise their direction of movement. Accordingly also the lever **37** and the eccentric shaft **36** change their sense of rotation. This leads to the support **2** and all the components connected to it, including the work piece **10''**, to perform a rocking movement in the direction denoted *z* as soon as the feeler pin **143** has passed the position T.

These rocking movements *y* and *z* which take place during the up-stroke of the work piece carrier slide **4**,

i. e. during the grinding process mean at the same time variations in the distance between the axes of the grinding worm 9 and the work piece 10''. In the circumstances described a crowned tooth shape results on the work piece 10'' which shape is generated while the work piece is continuously driven by the motor 12 at an accurately determined rotational speed. The slope angle of the template 38 determines the ratio of the rate of displacement of the piston 136 and template 141 with respect to the work piece carrier slide 4. When setting the machine for example by appropriate placing (see Fig. 1*a*) of the work piece 10'', care is taken that the central axis Q—Q coincides with the horizontal axis M—M of the grinding worm 9, when the feeler pin 143 passes the deepest point T. In this manner the crown shape of the teeth to be ground can be distributed symmetrically to the central axis Q—Q. The shape of the template 38 is defined by the requirements of grinding. In most cases it is demanded that the crown shape extends over the full width of the work piece 10''. In other cases, for example with very wide wheels, crowned portions are to be formed merely at the ends of the teeth (see Fig. 18) in order to prevent the formation of so-called "edge-bearers" (which as well known cause undesirable noise in operation). In order to comply with such requirements the template 141 may for example be arranged as shown in Fig. 17.

As long as the feeler pin 143 slides over the stretch *a* on the side face 1401 of the plate 140, the support 2 and the work piece 10'' remain in the vertical position ($\alpha=90°$). During this period the cylindrical middle portion *a* is ground on the work piece.

When now the edge 1431 of the feeler pin 143 leaves the side face 1401 and slides over one of the sections *b* of the control face 1412 of the templates 141, the support 2 rocks about the axis X. The angle α exceeds 90°, and on the work piece 10'' a correspondingly crowned portion *b* is generated.

The up-stroke contemplated of the work piece carrier slide 4 comes to an end, when the abutment 60 actuates the switch lever, and initiates in the manner described the switch-over process and the down-stroke of the work piece carrier slide 4. On the side of the grinding slide 70 then the same steps can be observed as described in detail with reference to the grinding of gears having a cylindrical circumference.

The chamber 1005 is provided with pressure oil. Therefrom results a displacement of the piston 100, a rocking movement of the arm 982 and of all components connected therewith, which entails a movement of the control pin 92, of the piston 90, of the spindle 79 and of the grinding slide 70. The grinding worm 9 is accordingly automatically withdrawn a certain amount from the work piece 10''. On the side of the work piece, the work piece carrier slide 4 begins to descend at an accelerated rate. At the same time pressure oil penetrates again into the chambers 853 and 1354 which causes the piston rod 851 to keep in contact with the template 38, and the piston 136 with the plate 140 and the template 141 to return into the starting position.

This condition in the control system corresponds to that which had been chosen as the starting point for the consideration of the control operations when griding crowned gears. From now on the operations described repeat themselves in the manner described.

SUMMARY

In the two working processes set forth sub (*b*) and (*c*) for the grinding of gears having a non-cylindrical circumference inter alia the problem was set to produce variations in the distance of axes in the course of a working operation. The magnitude thereof may amount to several millimetres when grinding conical gears and some microns when grinding crowned gears. In both cases, however, the desired variation in the distance of the axes had to be carried out with respect to the axial position of the work piece 10', 10'' to be ground. In spite of the fact that the two cases of application differed from one another in respect of the magnitude of the variations in the distance of the axes to an extreme extent, the control members serving for carrying out these variations in the distance of the axes are controlled from a central point. This applies to the template 38 representing the idea of the invention and adjustably attached to the work piece carrier slide 4, which in co-operation with the piston 85 influences the control members determining the performing of the variations in the distance of the axes when grinding conical gears as well as when grinding crowned gears. These control members comprise two separately arranged hydraulic copying systems which are controlled from the said template 38 and piston 85, respectively. One of them which comprises inter alia the components: piston 95, control pin 92, piston 90, comes into action when grinding conical gears. The variations in the distance of axes which may amount to several millimetres are effected by displacing the grinding slide 70. The second copying system, comprising inter alia the components: piston 136, plate 140, template 141, feeler pin 143, copying piston 145, piston 147 is in operation when grinding crowned gears and brings about the variations in the distance of the axes, which in this case are rather infinitesimal, by a rocking movement of the work piece 10''. The latter is driven forcibly and at a predetermined speed by the motor 12, and not from the grinding worm 9, even when grinding crowned gears.

When considering the hydraulic control it appears at first sight tempting to design the hydraulic copying system serving for the grinding of conical spur gears and helical gears in such a manner that it can be used also for the grinding of spur gears and helical gears with crowned toothing, the small to-and-fro movements being then imparted directly to the grinding slide. Unfortunately this idea can not be realised since the sluggishness of the hydraulic copying system is considerably larger than the maximum axial distance variations permissible when grinding crowned spur gears and helical gears. For this reason it has been found necessary to integrate the hydraulic copying system serving for the grinding of crowned spur gears and helical gears into a separate control group, and to take the aforesaid sluggishness of a hydraulic copying system into consideration. The path to be covered by the piston 147 on the control pin 143 amounts in the solution according to the present invention likewise to several millimetres. On the other hand the eccentric lever 37 serves for substantially reducing this stroke and for imparting the same as a rocking movement of the small magnitude, desired to the support 2 and eventually to the work piece. The aforegoing explanations under title (*c*) referred to the grinding of crowned gears. For this purpose e. g. a concave template 141 is required. The described means can also be used when the teeth to be ground are not crowned with regard to the direction of the teeth but are to be executed hollow. Such hollow profiles are for instance to be found on shaving cutters. In this case it is necessary to form the template 141 convexly e. g., because a decrease of the axial distance must be obtained when grinding the middle part of the teeth.

While I have herein described and illustrated in the accompanying drawings what may be considered a typical and particularly useful embodiment of my said invention I wish it to be understood that I do not limit myself to the particular details and dimensions described and illustrated, for obvious modifications will occur to a person skilled in the art.

What I claim as my invention and desire to secure by Letters Patent, is:

1. A machine for the grinding of cylindrical, conical and crowned spur and helical gears by the generating

principle, comprising in combination: a base, a grinding slide mounted slidably on the said base, a grinding worm rotatably journalled in the said grinding slide about an axis perpendicular to the direction in which the said grinding slide is slidable, a support mounted on the said base tiltably about a fulcrum axis parallel to the axis of the said grinding worm, a work piece carrier slide mounted slidably on the said support, centering means mounted on the said work piece carrier slide and adapted to center a work piece rotatably about an axis parallel to the direction in which said work piece carrier slide is slidable, a hydraulic network including one hydraulic copying system operatively connected to the said base and to the said grinding slide and adapted to impart to the said grinding slide sliding movements of a comparatively large order of magnitude as required for the grinding of conical spur and helical gears, and another hydraulic copying system operatively connected to the said base and support and adapted to impart to the said support rocking movements of a comparatively small order of magnitude as required for the grinding of crowned spur gears and helical gears, a control template fixed to the said work piece carrier slide

and controlling either of the said two hydraulic copying systems, and selector means operatively connected to the said hydraulic network having one position putting both the said hydraulic copying systems out of action for the grinding of cylindrical spur gears and helical gears and a second and third position putting alternatively one of the said two hydraulic copying systems in operation.

2. A machine as claimed in claim 1 comprising a rotatable and longitudinally slidable spindle operatively transmitting control movements from the first mentioned hydraulic copying system to the said grinding slide.

3. A machine as claimed in claim 1, comprising linkage transmitting control movements from the second mentioned hydraulic copying system to the said support, rocking the same with a reduction ratio as required for the small order of magnitude of variations in the distance of the said axes.

References Cited in the file of this patent

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