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## (54) Machine suitable for automatically transforming bands of metal sheet into beams that are bent longitudinally according to electronically programmable profiles, as well as punched, drawn and bent transversally.

(57) The machine comprises two prisms (9, 10) having a vertical axis and a polygonal cross-section with lateral faces which support respective half-dies cooperating with one another in twos to bend, draw, punch or otherwise process a band of sheet metal placed between them. Means (13, 14) are provided for causing the rotation of said prisms (9, 10) with respect to their vertical axes for the positioning of the half-dies in respective operating positions opposite to one another and means (15, 16) for causing said prisms (9, 10) to move reciprocally closer and further away in a vertical plane comprising said axes. There are further provided means (109-124) for causing a further limited rotation of one (10) of the two prisms after said operating position has been reached and during a bending operation of the band of sheet metal. There is associated a manipulator (18) provided with a replaceable grasping clamp (36) suitable for vertically supporting from above a band of sheet metal and provided with the possibility of movement along a first horizontal axis passing between the above prisms (9, 10) and perpendicular to said vertical plane of movement of the prisms, along a second horizontal axis perpendicular to the former and along and on a vertical axis of rotation (37). There is lastly provided a clamp magazine (19) accessible by the manipulator (18) for the replacement of said clamp (36) between one process and the other.

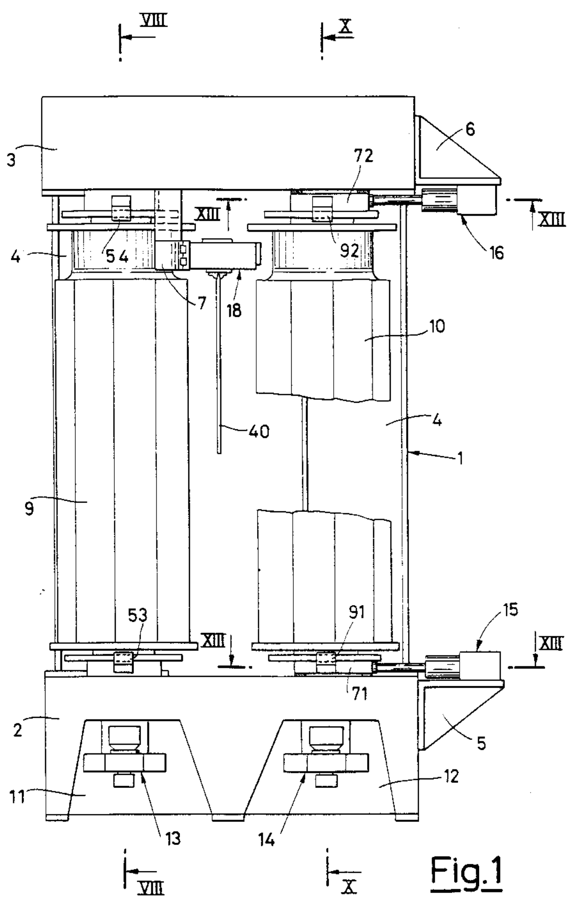


Fig.1

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The present invention relates to a machine suitable for automatically transforming bands of metal sheet into beams that are bent longitudinally according to electronically programmable profiles, as well as punched, drawn and bent transversally.

The known techniques for bending strip of sheet metal, several times and in various directions so as to obtain beams of various shapes, are substantially three: the shaping of continuous bands by means of the so-called roller forming machines, in which the profile is formed by the gradual adaptation of the band to the profiles of the numerous pairs of rollers in line which, rotating synchronously, move the band itself; the bending by means of so-called press brakes, in which the bends are executed one at a time on strips with a length of a few meters with the action of a rectilinear and acute blade which penetrates into the groove of a fixed counterblade obstructed by the sheet metal to be bent; the forming by means of common presses, wherein a half-die integral with the movable ram, penetrating into a half-die integral with the base, executes several bends simultaneously.

Each of the three preceding techniques has serious drawbacks, if it is required to produce bent beams in small series, having many different lengths with the same profile, if it is required to go automatically from one shape to another completely different one or from one section length to another and if in addition to longitudinal bends it is also required to execute on the strips punches, drawings, and transversal bends.

In fact the first technique can only be used in the manufacture of large quantities of sections having the same profiles and different lengths, because the process for designing and manufacturing the profile forming rollers and for replacing them on the machine at the start of each new production run is long and expensive; in addition, it is not possible to execute drawing operations and transversal bends on the sections during the profile forming process.

The second technique uses a single die wherein during the bending operation no point of the sheet metal strip is stationary with respect to the base of the machine; it follows that:

- the man or robot moving the strip to the die must follow the displacements of one edge of the strip durign the bending operation, the man with effort and danger, the robot only after being instructed with complicated programming procedures; both are in any case not very efficient;
- in order to execute any section it is necessary to replace the die with another having a different shape and this implies a loss of time which reduces the productivity of the machine.

The third technique generally uses several dies simultaneously, located on the same press and a transfer device which grasps the extremities of the strips at each forming station and makes them advance by one step; this technique is highly productive, but it is rigid, because the section which can be produced and the length of the strips are only those for which the die has been manufactured.

The main object of the present invention is to accomplish a machine which, at one and the same time, is highly productive, very flexible and can be automated completely to produce beams which are in any case punched, drawn and bent and of any length shorter than a maximum pre-set value.

A second object of the present invention is to allow the easy handling of the strips of sheet metal being processed, using tools which leave one edge of the sheet metal immobile during the bending operation.

A third object of the present invention is to have a large number of bending, punching and drawing dies arranged in a limited space and always ready for operations so that, with the same configuration of the machine, it is possible to produce sections having a complex form or several different profiles.

A fourth object of the invention is to accomplish a machine which may be supplied directly with one or more bands of sheet metal wound in coils.

According to the invention such objects are attained with a machine which may be used not only for bending bands of sheet metal longitudinally but also for punching, drawing and bending them transversally, characterised in that it comprises two prisms having a vertical axis and a polygonal cross-section with lateral faces which support respective half-dies co-operating with one another in twos to bend, draw or punch a band of sheet metal placed between them, means for causing the rotation of said prisms with respect to their vertical axes for the positioning of said half-dies in respective operating positions opposite to one another, means for causing said prisms to move reciprocally closer and further away in a vertical plane comprising said axes, and a manipulator provided with a grasping clamp suitable for vertically supporting from above a band of sheet metal and provided with the possibility of movement along a first horizontal axis passing between the above prisms and perpendicular to said vertical plane of movement of the prisms, along a second horizontal axis perpendicular to the former and along and on a vertical axis of rotation.

There are also preferably provided means for causing a further limited rotation of one of the two prisms after said operating position has been reached and during a bending operation of the band of sheet metal. This has the purpose of allowing the formation of bends having an angle greater than 90 degrees.

Going into greater detail, the present invention provides that on the flat faces of the two prisms having a polygonal cross-section with vertical and parallel axes there are arranged pairs of bending, drawing or punching half-dies which, interacting with one another by one drawing closer to the other, due to the rotation and then the translation of the above prisms, with a force sufficient to cause the required deformation of the sheet metal, execute the desired operations.

The extremities of said prisms are supported so that the prisms themselves with the half-dies applied to them can rotate on their vertical axis due to the effect of a numerically controlled motor and of a suitable transmission of motion and that each face of a prism with a half-die con stop firmly in a position so as to be facing and parallel to the face of the other prism, to which a homologous half-die is applied.

The axes of the two prisms are made to move in a direction parallel to one another, causing the two half-dies applied to the two opposite faces of the prisms themselves to move closer together and to compenetrate one into the other. As a particular case, one of the two prisms can have the axis fixed with respect to the base. Movable horizontal carriages supporting the end pivots of the prisms are coupled for translation to a strong rectangular frame, whose middle vertical plane is parallel to the plane of the axes of the prisms and which constitutes the fixed structure of the machine.

In the central part of the machine's upper horizontal beam there is a manipulator with a clamp as the grasping organ. Said clamp moves according to three numerically controlled axes: a horizontal rectilinear axis of translation orthogonal to the plane of the frame, a horizontal axis perpendicular to the preceding one and a vertical axis of rotation. In addition, the clamp has the possibility of assuming two positions not far from one another in a vertical direction.

The clamp can thus reach any point of a horizontal rectangle, whose long sides are perpendicular to the plane passing through the axes of the die-holding prisms, and at any of such points it can assume any angular orientation and execute a small vertical displacement. Said clamp has the jaws which open and close by rotating on a horizontal axis and is therefore suitable for grasping the strip of sheet metal being processed along a segment of a straight line which is parallel and close to a short side of the strip itself and for holding the strip in a vertical plane.

Since the clamp on occasion must have narrow jaws so as to grasp very short rectilinear edges of the bent strip and sometimes must have wide jaws so as to grasp wider edges, and this so as to be able to move the strip under all circumstances with the maximum acceleration, the clamp is automatically interchangeable with other clamps deposited in a magazine forming part of the same machine.

With its motion the clamp can go to withdraw a strip issuing vertically from a shearing unit mounted in front of the frame or from a sheaf of strips arranged in a container, to arrange the strip in a well-defined position between two half-dies applied to the prisms for each of the operations of deformation of the strip and, at the end of the process, move the finished beam to a vertical container arranged on the opposite side of the frame.

The advantages deriving from the present invention with respect to the known techniques recalled above are manifold:

- the feeding with sheafs of strips already cut elsewhere, which is impossible with the roller forming machine, or,as an alternative, the feeding with coils of metal band, which is impossible with the bending press;
- the maneuverability of the strip between the half-dies by means of a single clamp, thanks to the fact that the strip is vertical and held from above and it is thus not bent by gravity towards one of the two half-dies;
- the capacity of the manipulator to handle very long strips, grasping them at only one end, again thanks to the vertical arrangement of the strip;
- the absence of the need of the manipulator's programmed movements to execute the displacements of the edges of the strip during the bending operations, thanks to the fact that the dies allow the area of the strip grasped by the manipulator clamp to remain immobile;
- the possibility of grouping several dies in a limited space and of moving them quickly to an operating position, so that it is possible to go instantaneously from the shape of one bend to another;
- the mobility on two orthogonal axes of the two half-dies, so that it is possible to program different bending angles and radii for each bend, something that is not possible with traditional presses, whose dies have only one direction of reciprocal movement.

One possible embodiment of the present invention is illustrated, as a non-limiting example, in the enclosed drawings, wherein:

Fig. 1 shows an overall front view of the machine, with no dies, from the feed side;

Fig. 2 is a top plan view of the machine with no dies;

Fig. 3 shows an axonometric view of a particular embodiment of the strip manipulator associated with the above machine;

Fig. 4 shows a clamp suitable for the execution of non parallel bends, seen in a horizontal sectional view taken along the line IV-IV of Fig. 5;

Fig. 5 shows said clamp in a vertical sectional view taken along the line V-V of FIg. 4;

Fig. 6 shows the magazine of the clamps and the manipulator during the clamp changeover step;

Fig. 7 shows the manipulator in a sectional view taken along the line VII-VII of FIg. 10;

Fig. 8 shows a vertical sectional view, taken along the line VIII-VIII of FIg. 1, of the prism having a fixed axis with its organs controlling the rotation;

Fig. 9 shows a horizontal sectional view, taken along either of the two lines IX-IX of Fig. 8, of the prism having a fixed axis with its organs controlling the angular position;

Fig. 10 shows a vertical sectional view, taken along the line X-X of Fig. 1, of the prism having a movable axis with its organs controlling the rotation and guiding the translation;

Fig. 11 shows a horizontal sectional view, taken along either of the two lines X-X of Fig. 10, of the prism having a movable axis with its organs controlling the rotation;

Fig. 12 shows a vertical sectional view, taken along the line XII-XII of Fig. 11, of a part of the organs controlling the rotation of the prism having a movable axis;

Fig. 13 shows a horizontal sectional view, taken along either of the two lines XIII-XIII of Fig. 1, of the prism having a movable axis with its organs controlling the translation;

Fig. 14 shows the horizontal sectional view of a bending die with two co-operating half-dies supported by the movable prism and by the fixed prism, respectively, of the machine;

Fig. 15 shows an overall plan view of the machine, including a pair of half-dies;

Fig. 16 shows a collection of some examples of beams which can be produced with the machine according to the preceding figures and, more in general, with that according to the present invention.

Fig.s 1 and 2 give a schematic representation of the general architecture of the machine.

There is seen in Fig.s 1 and 2 a supporting structure 1, which, independently of the material with which it is accomplished (steel casting, welded sheet metal, etc.) and of the particular sub-division into smaller parts suitable for making it easier to produce and/or to transport, has the form of a closed portal with a base 2, cross-beam 3 and uprights 4, with projections 5 and 6 on the right hand side, 7 on the front and 8 on the rear, which support some of the machine's active organs.

A left hand prism 9, having a fixed vertical axis, can rotate on its axis. A right hand prism 10, having a movable vertical axis, in addition to rotating on its axis, can also translate so that its axis remains in the vertical plane also holding the axis of the left hand prism 9. Both prisms 8 and 9 are suitable for supporting on their faces respective half-dies for processing (bending, drawing, punching) a sheet metal. There are no mechanical guides which compel the axis of the right hand prism 10 to remain vertical, while still in the above vertical plane, but the tilting of that axis in that plane is determined by the hydraulic organs which move the extremities of the axis itself. It is thus possible to obtain and check both parallelism and non-parallelism of the active edges of the homologous half-dies applied to prisms 9 and 10 and, as a consequence, it is possible to execute bends both with a constant and with a variable angle on a strip of sheet metal 40 being processed.

Inside the base 2, accessible through wide openings 11 and 12, there are control organs 13 and 14 of the rotation of the prisms 9 and 10. On the lateral projection 5 of the base 2 and on the lateral projection 6 of the cross-beam 3 there are installed control organs 15 and 16 for the translation of the right hand prism 10. On a horizontal beam 17, which extends along the front of the structure 1 with the projection 7 and along the back of the structure 1 with the projection 8, there slides a manipulator 18 which supports and moves the strip of sheet metal 40 being processed. At the rear extremity of the same beam 17 an automatic clamp magazine 19 is applied.

With reference to Fig. 3, the manipulator 18 slides on beam 17 along precision guides 20 and 21, operated by a motor 22 which, through a possible reduction unit 134, rotates a toothed pinion, not visible in the figure, which engages a rack 23. For safety, at the extremities of the stroke of the manipulator 18 on the beam 17, there are suitable shock absorbers 24 and 25 (Fig. 2), capable of absorbing the kinetic energy of the manipulator erroneously not braked by the motor 22.

The manipulator 18 has a carriage 26, slidable along the beam 17, which supports an overhanging beam 27, along which, on precision guides 29 and 30, there moves another carriage 28 operated by a motor 31, which acts through pulleys 32 and 33, a toothed belt 34 and a screw 35.

On carriage 28 there is hinged a clamp 36, which is made to rotate on a vertical axis 37 by a motor 38, which transmits motion to it by means of a worm screw and a helical pinion of which Fig. 3 shows the casing 39. The clamp 36 is provided with two jaws 41 and 42, which are held open by springs and closed by a hydraulic cylinder not visible in the figure. The clamp 36 is also moved vertically by a hydraulic cylinder (not shown) between two fixed positions very close to one another. The clamp 36 is fastened to a support shaft rotating on axis 37 so that it can be automatically removed and changed with a clamp having a different size, contained in the magazine 19 (Fig. 2).

With reference to Fig.s 4 and 5, one of the clamps 36 furnished with the machine contains inside a jaw 41 provided with a grasping pawl 139 and with a clamping edge or lip 137 a cylindrical/conical pin 135 provided with a tip 136 which protrudes by a few tenths of a millimeter from the clamping lip 137 of the jaw 41, said pin being held in position by a very rigid spring 138; when said clamp is completely closed against the strip of metal sheet 40, the tip 136 of the pin 135 and the grasping pawl 139 of the jaw 41 are embedded in the sheet metal 40 and the spring 138 is compressed more than when the clamp is open; following a small movement of the jaws 41, 42 away from each other the clamping lip 137 is no longer in contact with the sheet metal 40, while the tip 136 of pin 135 is still embedded in the sheet metal 40 under the action of the spring 138. Under these conditions the strip of sheet metal 40 can rotate on the axis of the pin 135, sliding against a flat surface 140 of the jaw 42. This allows the execution on the strip of sheet metal 40 of bends which are not parallel to one other, by making an angle between the strip and the half-dies, which are vertical, of which further details shall be given later. The inclination, always of a few degrees, is obtained by a small displacement of the carriage 26 along the beam 17, while the clamp 36 is arranged with its clamping lip 137 parallel to the beam 17 and while the lower extremity of the strip of sheet metal 40 is prevented from moving by a protrusion of the half-dies. Once the inclination of the strip has been obtained, the clamp 36 is closed again and the strip 40 returns under the control of the manipulator.

With reference to Fig. 6, the changeover of clamp 36 of the manipulator 18 (Fig. 3), which is indispensable for the active expansions 157 and 158 (Fig. 7) of the jaws 41 and 42 of the clamp 36 be extended to a greater or lesser degree in the direction of the clamping lip so as to adapt themselves to wider or narrower flat edges of the strip being processed, occurs for example with a mechanism such as that described below. Spare clamps 36', 36'', etc. with expansions 157 and 158 extended to a greater or lesser degree or with special jaws such as, say, those illustrated by Fig.s 4 and 5 are deposited in appropriate seats 159, say, six, of a flat spider 160 of the magazine 19.

Each spare clamp is inserted in the spider 160 by the sliding of the lateral edges of the seats 159 in grooves 161 and 162 obtained in the sides of each clamp.

The withdrawal of each clamp 36 from its seat 159 is hindered by a spring-operated dog 163.

The spider 160, which is flat and arranged in a horizontal plane, can rotate on a vertical axis 200 passing through its centre and can stop accurately in the positions opposite which a seat for a clamp is in the position of Fig. 7, which is that wherein there occurs the passage of the clamp from the manipulator 18 to the spider 160 and vice versa.

The fastening of the clamp 36 to a terminal part 164 of the manipulator 18 is obtained by a swallow-tail coupling, whose clearance is eliminated and the sliding prevented by a wedge 165 pushed to wedge itself by a spring 166. The closing organs of the clamp 36, that is, a hydraulic cylinder 167 and its accessories, which act on the hinged jaw 41 are incorporated in the terminal part 164 of the manipulator 18.

A small pneumatic or hydraulic cylinder 168 integral with a supporting structure 169 (Fig. 2) of the spider 160 is in line with the wedge 165 and can push it up against the spring 166 to release the clamp 36 from the terminal part 164 of the manipulator 18.

Going back now to Fig.s 1 and 2 and making specific reference to Fig. 8, the left hand prism 9 is rotatably constrained with its lower extremity to the base 2 and with its upper extremity to the beam 3. The lower extremity extends downward with a shaft 43 which terminates with a gear 44 engaging a pinion 45 operated by a motor 46. Two toothed polygonal plates 47 and 48 with teeth 65 (Fig. 9) are integral with the lower extremity and with the upper extremity, respectively, of the left hand prism 9.

In Fig. 9, which simultaneously represents the two distinct but substantially identical cross-sections IX-IX of Fig. 8, the lower seen from above and the upper seen from below, both toothed polygonal plates 47 and 48 are seen. Between the toothed plate 47 and the base 2 and between the toothed plate 48 and the beam 3 there are two levers 49 and 50, identical one with the other. Each of these two levers, remaining in its horizontal plane because held there by sliding surfaces belonging to the adjacent casings, can slide with respect to a small parallelepiped block 51 (Fig. 9) in turn rotating on a pivot 52 integral with the base 2 and with the beam 3, respectively. The sliding action of the levers 49 and 50 on the small blocks 51 is operated by small hydraulic cylinders 53 and 54, having the casing hinged on supports 55 and 56, integral with the base 2 and with the beam 3, respectively, and having the stem hinged with respective extremities of the lever 49 and of the lever 50. Opposite extremities 57 and 58 of the levers 49 and 50 move between a pair of hydraulic shock absorbers 59 and 62 and a pair of hydraulic shock absorbers 60 and 61, respectively, whose casings are integral with the structure 1 and whose stems are, on the other hand, movable and suitable for absorbing the kinetic energy transmitted to them by the extremities 57, 58 of the levers 49, 50. When the small cylinders 53, 54 are expanded, the levers 49, 50 have respective teeth 63, 64 outside the space traversed by the teeth 65 of the toothed plates 47, 48 and thus, under these conditions, the left hand prism 9 can rotate freely on its axis moved by motor 46. But if the small cylinders 53, 54 are contracted, as in Fig. 5, the teeth 63, 64 interefere with the teeth 65 and stop the rotation of the toothed plates 47, 48 and of the left hand prism 9, with which they are integral, discharging the kinetic energy on the pair of hydraulic shock absorbers 59, 60 or 61, 62. Pairs of hydraulic cylinders 66, 67 and 68, 69 set the lever 49 and the lever 50, respectively, against the shock absorbers opposite those which shall execute the next braking of the rotation of the prism 9.

Between a casing 70 (Fig. 8) which is integral with the base 2 and which encloses the pair of gears 44, 45 and the shaft 43 there are some sealing gaskets not shown in the figure, which, in combination with some conduits made in the casing 70 and in the shaft 43, constitute a rotating coupling, through which oil under pressure is brought on board the prism 9, where some dies may require hydraulic operations.#

With reference to Fig.s 10 and 11, the right hand prism 10, as opposed to the left hand prism 9, is not rotatably constrained directly to the base 2 and to the beam 3, but with its lower extremity to a carriage 71 and with its upper extremity to a carriage 72. The carriage 71 can only translate horizontally on the base 2 towards the prism 9 under the action of the driving organ 15 (Fig. 1), being guided by precision guides 73, 74, 75. The carriage 72, on the other hand, is constrained to the beam 3 only by a precision guide 76 so that, under the action of the driving organ 16 (Fig. 1), it can execute translations which are parallel and equal to the translations of the carriage 71, but so that it can also rotate on a horizontal axis perpendicular to the plane of the axes of the prisms 9 and 10. Rolling bearings 77 and 78 between the lower pivot of the right hand prism 10 and the carriage 71 are spherical with a common centre, and thus allow the oscillation of the axis of the prism 10 with respect to the carriage 71, while the bearings 79 between the upper pivot of the right hand prism 10 and the carriage 72 do not allow oscillations between prism and carriage. Thus the carriage 72 follows the right hand prism 10 in its oscillations in the only vertical plane in which it can oscillate and the carriage 71 remains constantly parallel to the base 2.

As for the left hand prism 9, the right hand prism 10 is also made to rotate on its axis by a motor 80, whose shaft carries a toothed pinion 81 which engages with a wheel 82 integral with a pivot 83, extension of the prism 10. A casing 84, which encloses the pair of gears 81, 82 and which supports the motor 80, remains always coaxial with the pivot 83, as it is spherically coupled with the lower face of the carriage 71 and being constrained to the base 2 only to the extent of not being allowed to rotate. Between the casing 84 and the shaft 83 there are some sealing gaskets, which, in co-operation with some conduits made in the casing 84 and in the shaft 83, constitute a rotating coupling, through which oil under pressure is brought on board the prism 10, where some dies require hydraulic operations.

Two toothed polygonal plates 85 and 86 with teeth 103, 104 having different radial extensions are integral with the lower extremity and with the upper extremity, respectively, of the right hand prism 10. In Fig. 11, which simultaneously represents the two distinct but substantially identical sectional views XI-XI of Fig. 10, the lower seen from above and the upper seen from below, both toothed polygonal plates 85 and 86 are seen. Under the toothed plate 85 and above the toothed plate 86 there are two levers 87 and 88. Each of these two levers, remaining in its horizontal plane, can slide with respect to a small parallelepiped block 89 (Fig. 11) in turn rotating on a pivot 90, integral with the carriage 71 and with the carriage 72, respectively. The sliding action of the levers 87 and 88 on the small blocks 89 is operated by small hydraulic cylinders 91 and 92, having the casing hinged on supports 93 and 94, integral with the carriage 71 and with the carriage 72, respectively, and having the stem hinged with respective extremities of the lever 87 and of the lever 88. Opposite extremities 95, 96 of the levers 87, 88 move between a pair of hydraulic shock absorbers 97, 99 and a pair of hydraulic shock absorbers 98, 100, respectively, whose casings can be adjusted with respect to the structure 1 and whose stems are suitable for absorbing the kinetic energy transmitted to them by the extremities 95, 96 of the levers 87, 88.

When the small cylinders 91, 92 are expanded, the levers 87, 88 have respective teeth 101, 102 outside the space traversed by the teeth 103 of the toothed plates 85, 86, but not outside the space traversed by the tooth 104 of each toothed plate, which protrudes more than the others. It follows that, under these conditions, the right hand prism 10 can perform almost one revolution but no more.

This is to avoid breaking the electrical cables, which enter the right hand prism 10 along the shaft 83, which is hollow, as a result of an undefined rotation in the same direction. But if, on the other hand, the small cylinders 91, 92 are contracted, the teeth 101, 102 also interfere with the teeth 103 and stop the rotation of the toothed plates 85, 86 and of the right hand prism 10, discharging their kinetic energy on the pair of hydraulic shock absorbers 97, 99 or 98, 100. The pairs of hydraulic cylinders 105, 106 and 107, 108 set the lever 87 and the lever 88, respectively, against the shock absorbers opposite those which shall execute the next braking of the rotation of the prism 10.

The left hand prism 9 rotates to move quickly to one of the positions, which in the figures are, for example, nine, wherein one of the half-dies applied to the faces of the prism is exactly in the operating position, facing the corresponding half-die carried by the prism 8. Once one of these positions has been reached, wherein the motor 46 with its pinion 45 continues to push against the teeth of the wheel 44, which in turn pushes a tooth 65 of each toothed plate 47, 48 against the teeth 63, 64 and thus the extremities 57, 58 of the levers 49, 50 against the stems of the two shock absorbers 59, 61 or 60, 62, one lower and one upper, and these against the end abutment of the corresponding casing, the prism 9 remains immobile throughout the duration of the bending operation.

The prism 10 also rotates with an identical mechanism to take the correct die to the operating position, but this can rotate, through a small angle, even during the bending operation, to execute possible bends with an angle greater than 90 degrees. The amount of the operating rotation is a function of the thickness of the metal sheet, of the quality of the metal sheet, of the bending angle and of the shape of the die and it must be set with great accuracy. In addition this rotation requires a large force, because it is necessary to overcome the resistance of the metal sheet to be bent.

Fig. 12, which is a sectional view taken along the line XII-XII of Fig. 11, illustrates the mechanism with which the small operational rotation of the right hand prism 10 is attained with a large force and great precision. The same mechanism is installed both at the lower extremity and at the upper extremity of the right hand prism 10, but Fig. 12 illustrates only that installed at the lower extremity. Two motors 109 and 110 rotate two small shafts 111 and 112, with each of which two toothed pinions 113, 114 and 115, 116 are integral. Each of said pinions engages with an externally toothed and internally threaded ring 117, 118, 119, 120, which is screwed onto the cylindrical casing 97, 99 of one of the shock absorbers, which is prevented from rotating by a small key 125, 126. The extremity of the casing of each shock absorber, opposite to that from which the stem protrudes, terminates with a piston 121, 122, which penetrates into the chamber of simple-action hydraulic cylinder 123, 124. The extremities of the stroke of each of said pistons 121, 122 are determined by the positions at which the corresponding rings 117, 119 or 118, 120 are set by the motors 109, 110. In this way the small operational rotations of the prism 10 are executed by hydraulic cylinders 123, 124 but set in their amplitude by rotative motors 109, 110.

With reference to Fig. 13, which represents the organs 15 operating the translation of the lower carriage 71 of the right hand prism 10, installed on the projection 5 of the base 2 (Fig. 1) which are repeated exactly (16) on the projection 6 for the carriage 72, the translation of the carriages is operated in the direction of operations by two pairs of single-action hydraulic cylinders 127, 128 and 129, 130 which push only against the carriages, through spherical and flat surfaces, which allow misalignments and inclinations.

The motion in the opposite direction of the same carriages, which requires a much smaller force, is operated by two hydraulic traction cylinders 131, 132.

The motion of said cylinders is operated by electro-hydraulic servovalves.

While in all the preceding figures the prisms 9 and 10 are shown with no dies, in Fig 14 there is shown a horizontal sectional view of a typical bending die and of a hydraulic metal sheet holder associated with the right hand prism 10. The die is divided into two half-dies 143 and 144, the first applied to a face 145 of the left hand prism 9 and the second to a face 146 of the right hand prism 10. In fig. 14 the two half-dies 143 and 144 are represented in the position at the start of the bending operation, that is, with the faces 145 and 146 of the left hand prism 9 and of the right hand prism 10, respectively, parallel to one another, both prisms are held by their respective motors 46 (Fig. 8) and 80 (Fig. 10) against the abutments of the shock absorbers 60, 62 (Fig. 9) and 98, 99 (Fig. 11), which obstruct their rotation, clockwise if seen from above, and the right hand prism 10 has moved toward the left hand prism 9 enough to bring the active face 147 of a metal sheet holder 148 belonging to the half-die 144 against the strip of metal sheet 40, taken by the clamp 36 (Fig. 3) to the face 149 of a counterblade 150 belonging to the half-die 143. The half-die 144 also comprises a blade 151. The metal sheet holder 148 and the blade 151 are mounted on a die holder 152 and this is in turn held by means of quick-action holding means 153 on the right hand prism 10. A series of hydraulic cylinders 154 incorporated in the right hand prism 10 oppose a force adjusted with known devices to the sliding action of the sheet metal holder 148 in the die holder 152. The counterblade 150 is mounted in a die holder 155 and this in turn is held by means of quick-action holding means 156 on the right hand prism 9.

The construction features and the operation of the die constituted by the half-dies 143 and 144 and co-operating with the cylinders 154 are the object of the application for the Italian invention patent No. 19330 A/90 dated 9 February 1990.

With reference to Fig. 15, if the sheet metal to be transformed into sections having various profiles and various lengths is available in a continuous strip wound in a coil, the machine described up to now is completed by an unwinding reel 190 with two coaxial and opposite chucks 191 and 192, each of which, expanding and rotating, supports and causes to rotate a coil 193, 194 of band 196, the first shown in line with the position wherein the strip 40 arranged vertically shall be grasped at its upper extremity by the clamp 36 and the second in a position such as to be easily replaced by a third coil. The unwinding reel 190 is rotatable on a vertical axis 195 passing through its centre. The band 196, which unwinds from the coil 193, forms a downward loop, which falls even below the lower face of the base 2 (Fig. 1) and then rises vertically with its free extremity just on the vertical line of the clamp 36, taken by the manipulator 18 to the grasping position, as in Fig. 2.

In said vertical portion the band 196 passes through a straightening/feeding unit with rollers 197, which, in addition to removing from the band the curvature due to its having been wound on the coil, advances the front of the band along a suitable vertical guide by an amount sufficient to make it penetrate some millimeters between the jaws of the clamp 36. Above the straightening/feeding unit 197 there are three shears: one shear with horizontal blades not represented in Fig. 15, which cuts the strip transversally, removing the strip 40, and two shears with circular blades, 198 and 199, which may be moved away from one another to a greater or lesser degree according to the width required for the strip 40, which trim the edges of the band 196, before the tranversal cut. The twin unwinding reel 190, the straightening/feeding unit 197 and the shears 198, 199 are all within the scope of the known art and are not therefore described in detail, but only outlined to give an example of a possible solution to the problem of automatically generating the strip 40. The straightening and shearing unit is movable vertically and must, on each occasion, be positioned at the height corresponding to the length of the strip 40.

The operation of the machine represented in the drawings can be described as follows.

The coil of band of sheet metal 193 is unwound due to the effect of the synchronised motion of the chuck 191, of the reel 190 and of the straightening/feeding unit 197, maintaining the amplitude of the loop and preparing a vertical part of band as wide and as long as the strip 40 which will have to be bent according to a given profile, described by a suitable program introduced into an electronic controller of the machine, built and instructed according to known techniques.

The trim scrap, that is, the two narrow strips removed from the edges of the original band 196 to reduce it to the required width, must be cut into small pieces by the same circular blades and allowed to fall into a container. As soon as the processing of the preceding strip is over and after the automatic changeover, if any, of the clamp 36 has been effected, the manipulator 18 moves the clamp 36 to the position at which it can grasp the top of the straightened and trimmed band and the clamp closes. The transversal shears separate the strip 40 from the band 196 and the manipulator, by moving along the beam 17, takes the strip to the correct position between the half-dies 143 and 144, which are moved away from one another, thanks to a suitable translation of the prism 10, enough for the strip 40 to slide in between them. The manipulator 18 moves the strip 40 close to the face 149 of the counterblade 150, causing the acute corner of the counterblade 150 to coincide with the straight line along which the strip is to be subjected to the first bend. The prism 10 translates, first moving the face 147 of the sheet metal holder 148 close to the strip 40 and then, while the cylinders 154 engaged along the length of the strip 40 keep the strip 40 tightly up against the counterblade 150, making the active edge of the blade 151 advance beyond the corner of the counterblade 150 and thus causing the strip 40 to be bent. If the bending angle is less than 90 degrees, this is obtained with an appropriate translation of the prism 10; if, on the other hand, the angle is equal to or greater than 90 degrees, after the translation a small rotation must also be executed, anti-clockwise if seen from above, of the prism 10, obtained by means of the pushing action of the lower and upper hydraulic cylinders 123 until the rings 118 are moved against the abutment, after their adjustment on the part of the motor 109. The opposite rotation thanks to the motor 80 and the opposite translation thanks to the cylinders 131 and 132 release the bent strip, still held by the clamp 36, which has not moved during the bending operation. If the next bend is to be executed in the same direction as the first, the same die is used and thus the operation may be repeated in exactly the same way, after the translation of the clamp in a direction parallel to the face 149 of the counterblade 150 and after the adjustment, if any, of the ring 118, if the new bending angle is not less than 90 degrees and different from the preceding one.

If, on the other hand, the next bend is to be executed in the opposite direction, a die which is the mirror image of that illustrated in Fig. 14 must be brought automatically into the operating position and the half-dies of the mirror-image die are applied to two faces of the prism 9 and of the prism 10, adjacent to those visible in Fig. 14.

The changeover of the two half-dies in the operating position is made by the simultaneous rotation, anti-clockwise if seen from above, of the two prisms 9 and 10 on the part of the respective motors 46 and 80, braked by the respective shock-absorbers 60, 62 and 97, 100.

The seven faces of the prism 9 not occupied by the half-die 143 and by its mirror-image 144 can be occupied by half-dies that are similar but which have a counterblade with a different profile, compatible with profiles of the strip 40 impossible to obtain with the counterblade 150 and its mirror-image blade 151.

The same faces of the prism 9 and the homologous faces of prism 10 can be occupied by half-dies designed for operations other than the longitudinal bending of the strips 40, such as, say, transversal bending at different levels, punching, drawing, markings, etc..

If the changeover of a half-die in the operating position requires a rotation of more than one ninth of a revolution and in a direction opposite to that of the last rotation, the levers 49, 50 of the prism 9 and the levers 87, 88 of the prism 10 must be displaced radially by the small cylinders 53, 54 and 91, 92, respectively, to allow the passage of teeth 65 and 104, and then moved back to the initial position to await the arrival of the teeth to be held.

If the changeover of a half-die in the operating position requires a rotation in the same direction of the last rotation, in addition to the radial displacement of the levers 49, 50 and 87, 88 their tangential repositioning must also be executed by means of the small cylinders 66, 68 or 67, 69 and 105, 107 or 106, 108, as well as the expansion of the shock absorbers which dissipate the prisms' kinetic energy.

To shorten the time of the bending operation it is convenient to use the clamp 36 with the largest jaw width compatible with the width of the edge of the strip to be grasped and thus in the passage from one lot of strips to another and on occasion during the bending operation of any one strip the clamp must be changed.

For this changeover the spider 160 rotates so that one of the empty seats 159 is in the position which can be reached by the clamp on board the manipulator 18; the manipulator 18 causes its clamp 36 to slide into the empty seat; the small cylinder 168 pushes up against the wedge 165, releasing the clamp from the terminal part 164 of the manipulator 18; the manipulator 18 moves away from the spider 160, leaving the old clamp on it and the small cylinder 168 moves back; the spider 160 rotates on its vertical axis and moves the new clamp to the changeover position; the manipulator 18 aligns itself with the new clamp and then the small cylinder 168 goes to push up against the new wedge 165 to prepare the entry into the new clamp of the terminal part 164 of the manipulator 18; the manipulator 18 moves into the clamp; the small cylinder 168 moves back allowing the new clamp to lock itself onto the manipulator; lastly the manipulator takes the new clamp along with it, sliding it out of its seat 159 of the spider 160.

A pre-determined sequence of bending operations and of possible other processes with dies different from the standard ones provided with the machine, of automatic changeover of dies, of clamps and of sheet metal coils, generates a highly varied production of sheet metal articles, impossible with known machines.

Some examples of beams which can be produced with the machine described are indicatively illustrated in Fig. 16.

**Claims**

**1.** Machine for transforming bands of sheet metal in bent, drawn, punched or otherwise processed beams, characterised in that it comprises two prisms (9, 10) having a vertical axis and a polygonal cross-section with lateral faces which support respective half-dies co-operating with one another in twos to bend, draw, punch or otherwise process a band of sheet metal placed between them, means (13, 14) for causing the rotation of said prisms (9, 10) with respect to their vertical axes for the positioning of said half-dies in respective operating positions opposite to one another, means (15, 16) for causing said prisms (9, 10) to move reciprocally closer and further away in a vertical plane comprising said axes, and a manipulator (18) provided with a grasping clamp (36) suitable for vertically supporting from above a band of sheet metal and provided with the possibility of movement along a first horizontal axis passing between the above prisms (9, 10) and perpendicular to said vertical plane of movement of the prisms, along a second horizontal axis perpendicular to the former and along and on a vertical axis of rotation (37).

**2.** Machine according to claim 1, characterised in that it comprises means (109-124) for causing a further limited rotation of one (10) of the two prisms after said operating position has been reached and during a bending operation of the band of sheet metal.

3. Machine according to claim 1, characterised in that one (9) of said prisms is rotatable on a fixed vertical axis and the other (10) of said prisms is rotatable on a vertical axis which is translatable with respect to the first in the vertical plane which comprises the above axes.

4. Machine according to claim 1, characterised in that at each extremity of said prisms (9, 10) there is fastened a respective toothed plate (47, 48; 85, 86) and there is associated a respective lever (49, 50; 87, 88) for holding/releasing the rotation of the prism, which can be displaced radially between a holding position wherein a tooth (63, 64; 101, 102) of said lever (49, 50; 87, 88) is in the path of the movement of teeth (65, 103) of said toothed plate (47, 48; 85, 86) to prevent the rotation of the latter and a release position wherein said tooth (63, 64; 101, 102) of said lever (49, 50; 87, 88) is outside the path of the movement of the teeth (65, 103) of said toothed plate (47, 48; 85, 86) to allow the rotation of the same.

5. Machine according to claim 4, characterised in that said lever (49, 50; 87, 88) is also rotatable in its horizontal plane so that its said tooth (63, 64; 101, 102) can be made tangentially movable between two extreme positions defined by a pair of shock absorbers (59-62; 97-100).

6. Machine according to claim 5, characterised in that it comprises means (109-124) for varying the position of the shock absorbers (59-62; 97-100) of one of said prisms (9, 10) during a bending operation of the band of sheet metal.

7. Machine according to claim 6, characterised in that said means (109-124) for varying the position of the shock absorbers (59-62; 97-100) of one of said prisms (9, 10) comprise hydraulic cylinders (121-123) to operate the displacement of the casing of the shock absorber, and adjustable limit switches (117-120) for limiting said displacement.

8. Machine according to claim 1, characterised in that said clamp (36) of the manipulator (18) is fastened to the same in a removable and replaceable way.

9. Machine according to claim 1, characterised in that it comprises a clamp magazine (19) accessible to the manipulator (18) for replacing the previously mounted clamp with a spare clamp (36', 36'', etc.) contained in said magazine (19).

10. Machine according to claim 9, characterised in that said clamp magazine (19) comprises a flat rotatable spider (160) provided with housing seats (159) for spare clamps displaceable in turn to a position where it can be accessed by the manipulator (18) by the rotation of said spider (160).

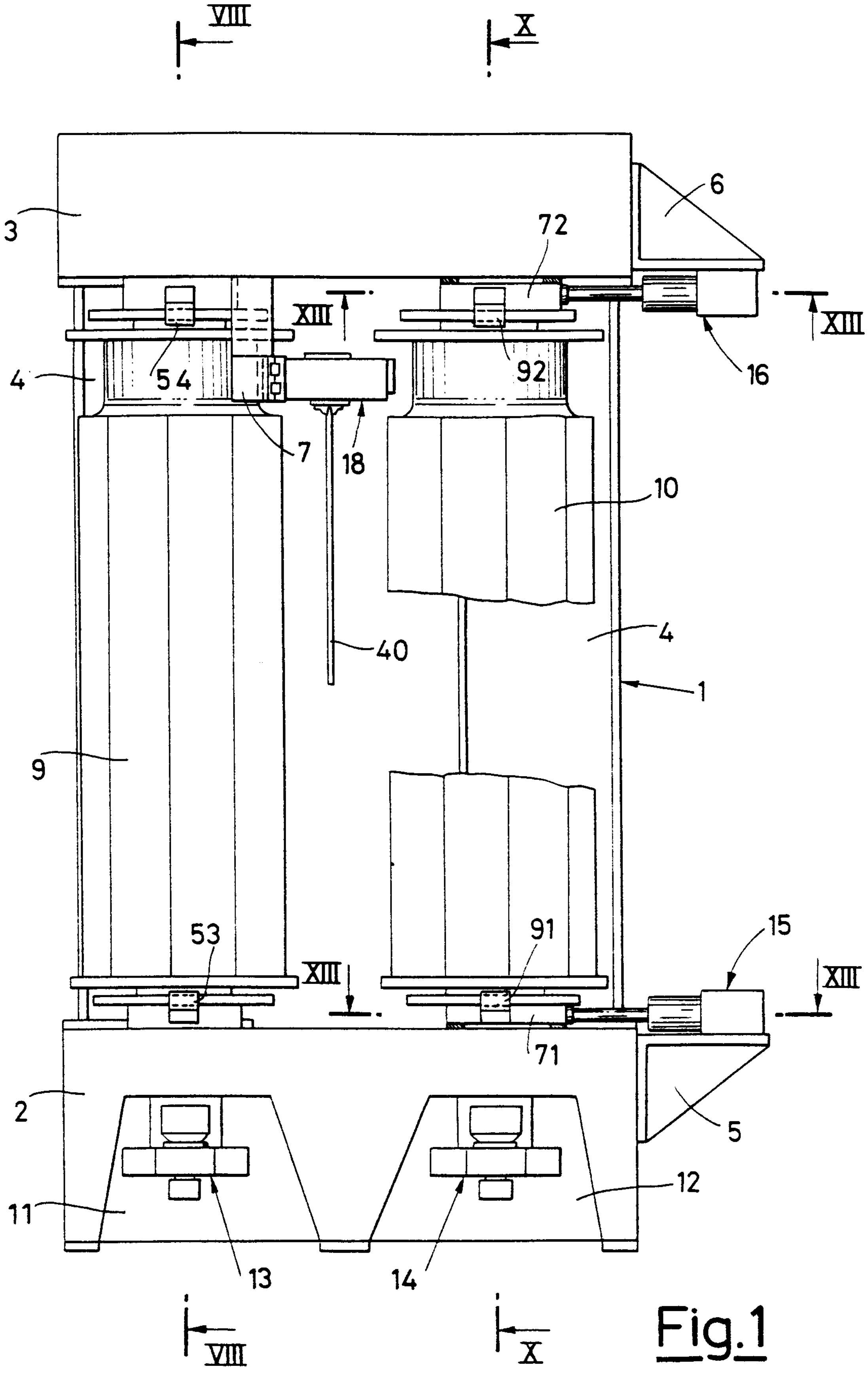

VIII
X
6
72
3
XIII
XIII
4
54
92
16
7
18
10
40
4
1
9
15
53
91
XIII
XIII
71
2
5
11
12
13
14
VIII
X

Fig.1

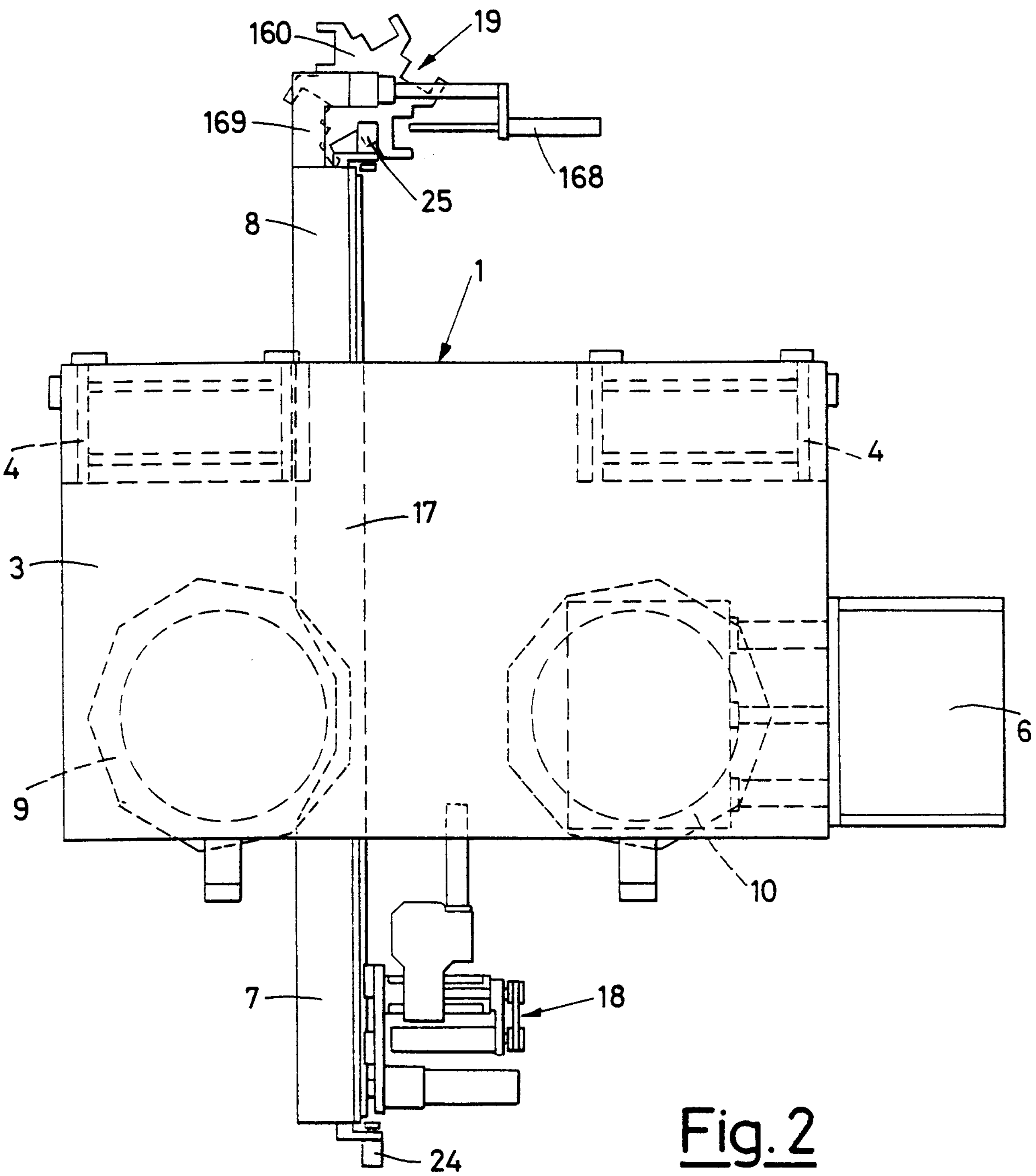



Fig. 2

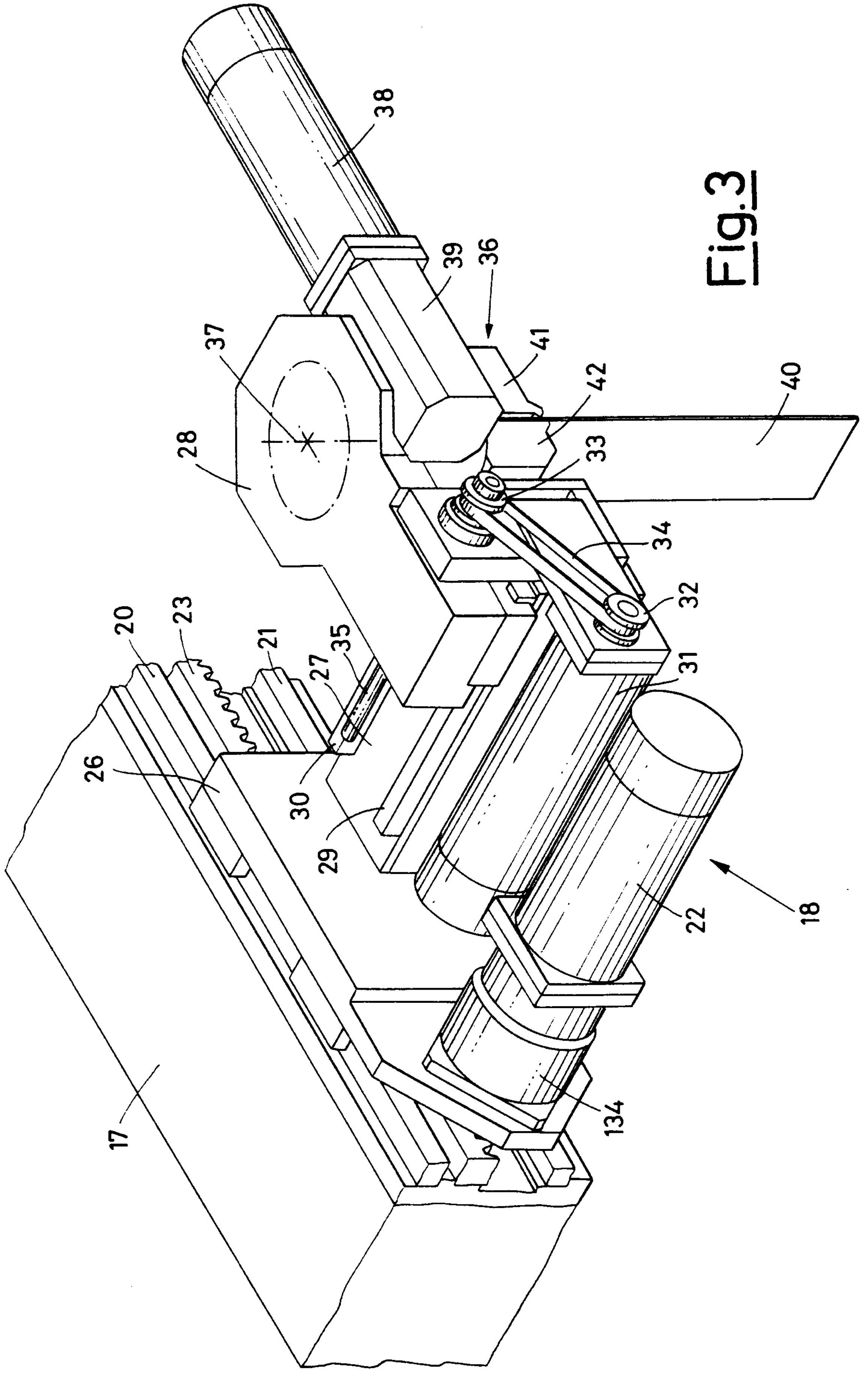



Fig.3

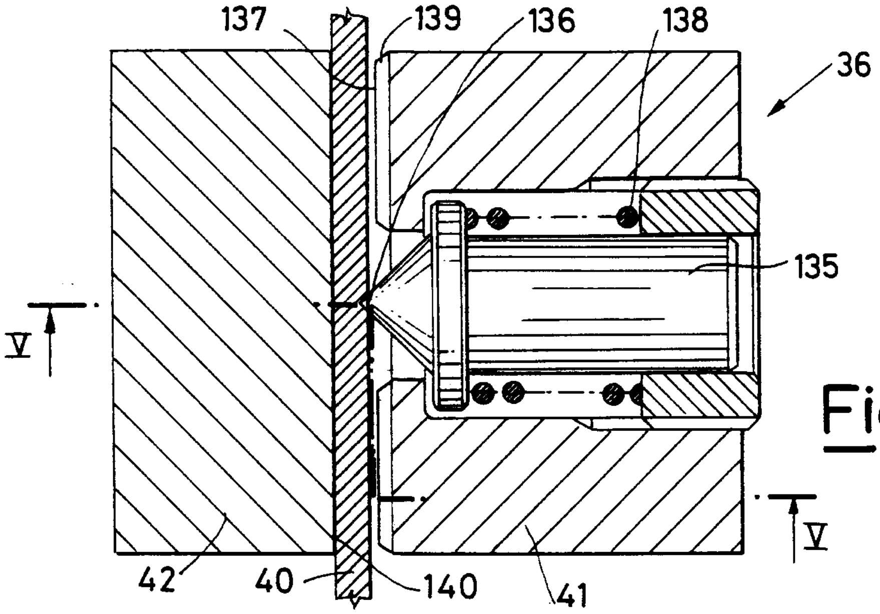



Fig. 4

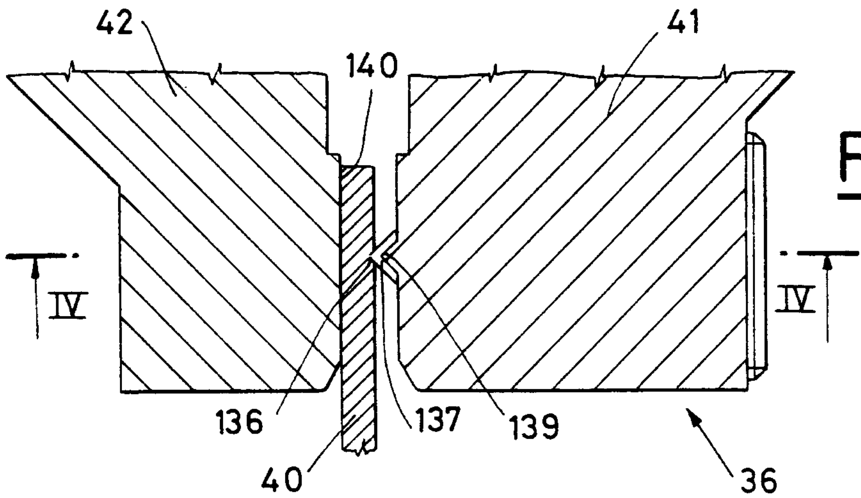
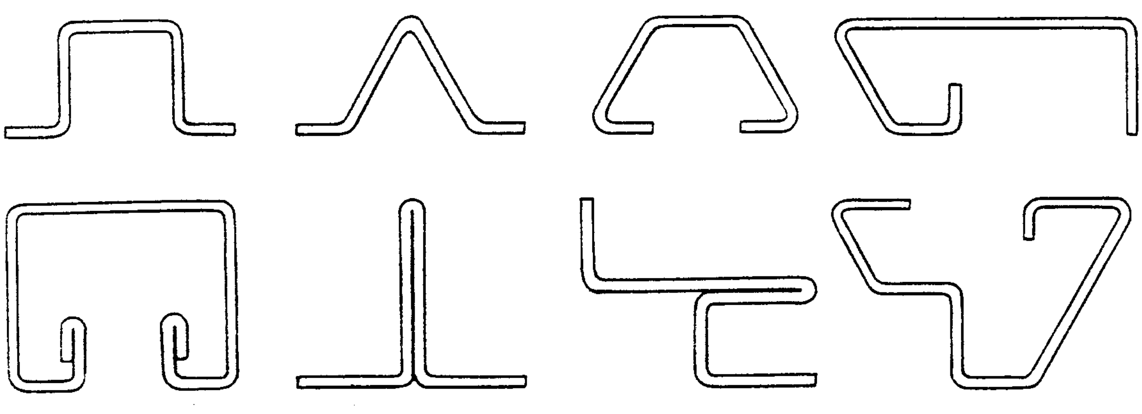



Fig. 5

Fig 16



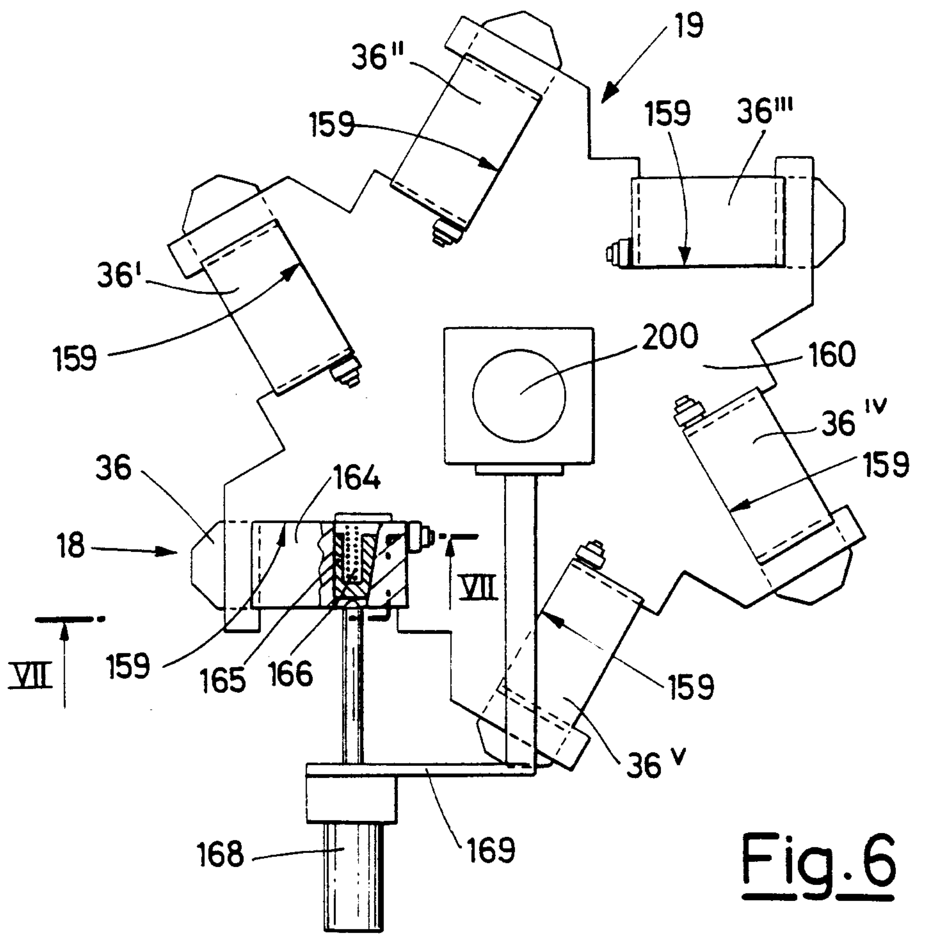

19
36''
159
36'''
36'
200
160
36 IV
36
164
18
VII
VII
159
165
166
36 V
168
169

Fig.6

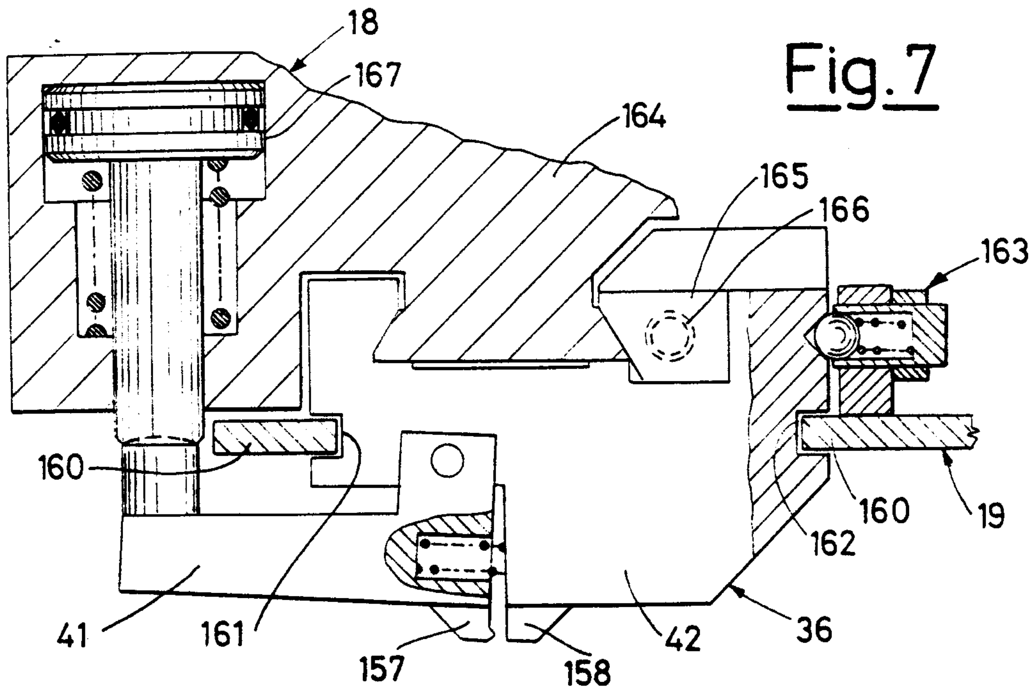

18
167
164
165
166
163
160
160
19
162
41
161
157
158
42
36

Fig.7

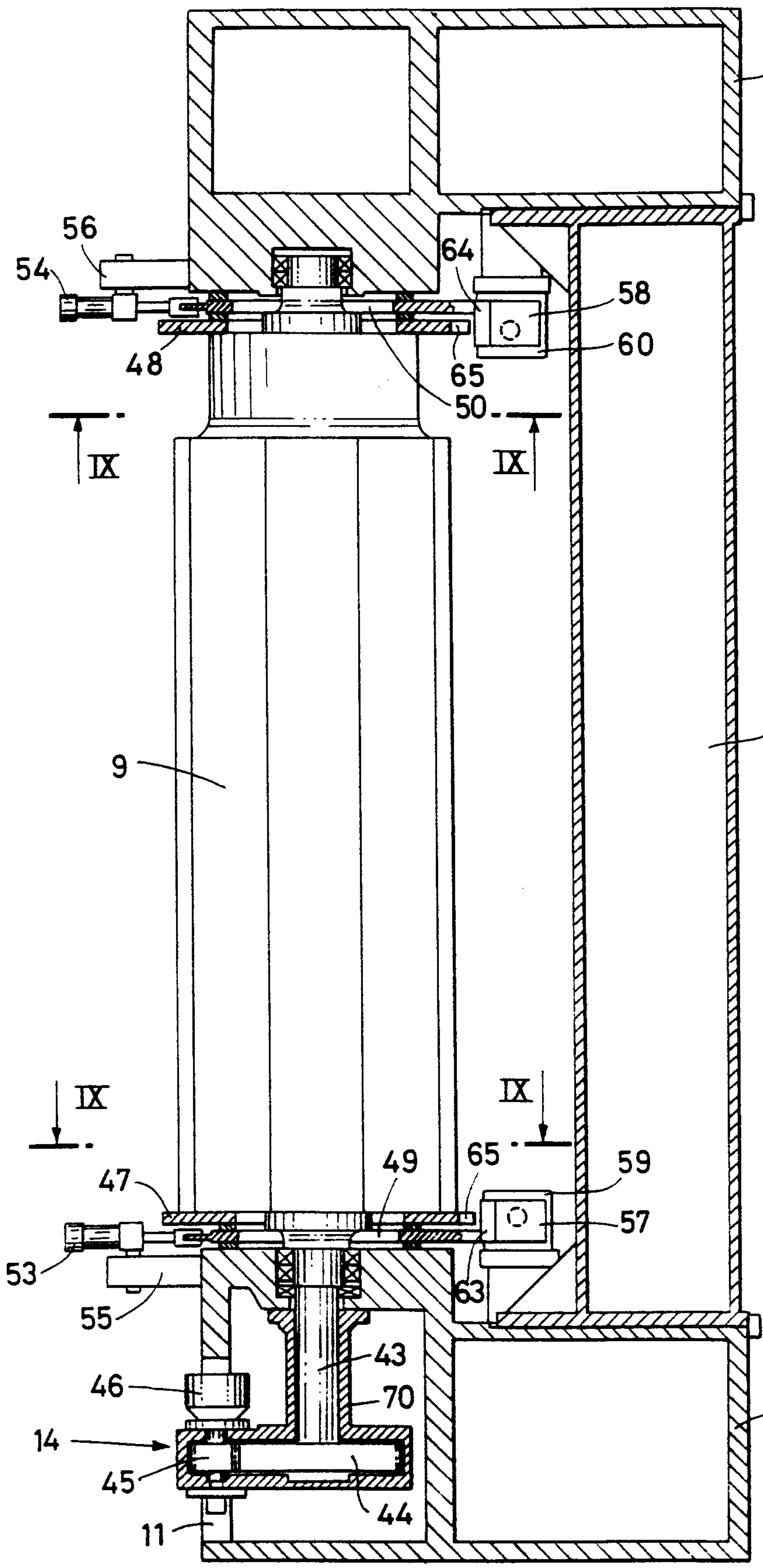

3
56
54
64
58
60
48
65
50
IX
IX
4
9
IX
IX
59
49
65
47
57
53
63
55
43
46
70
2
14
45
44
11

Fig. 8

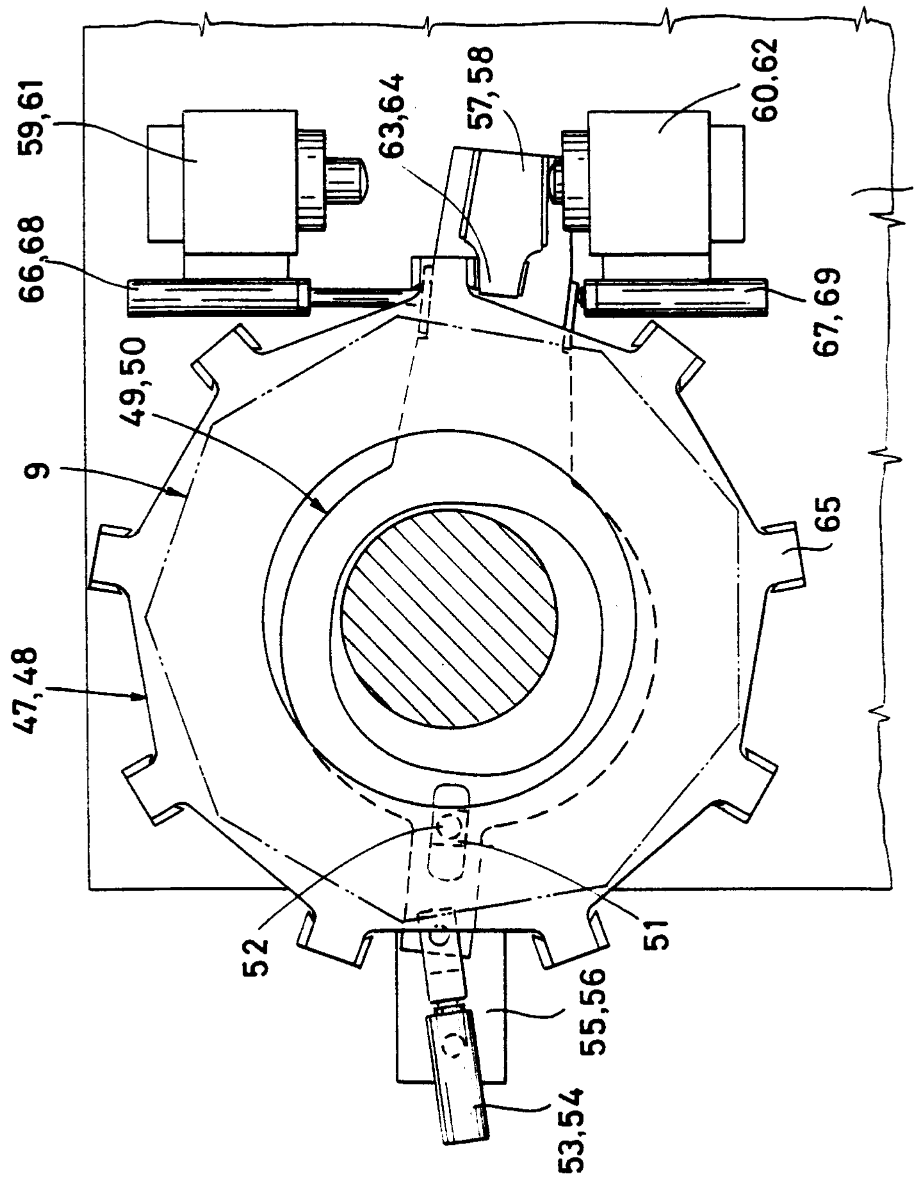



Fig.9

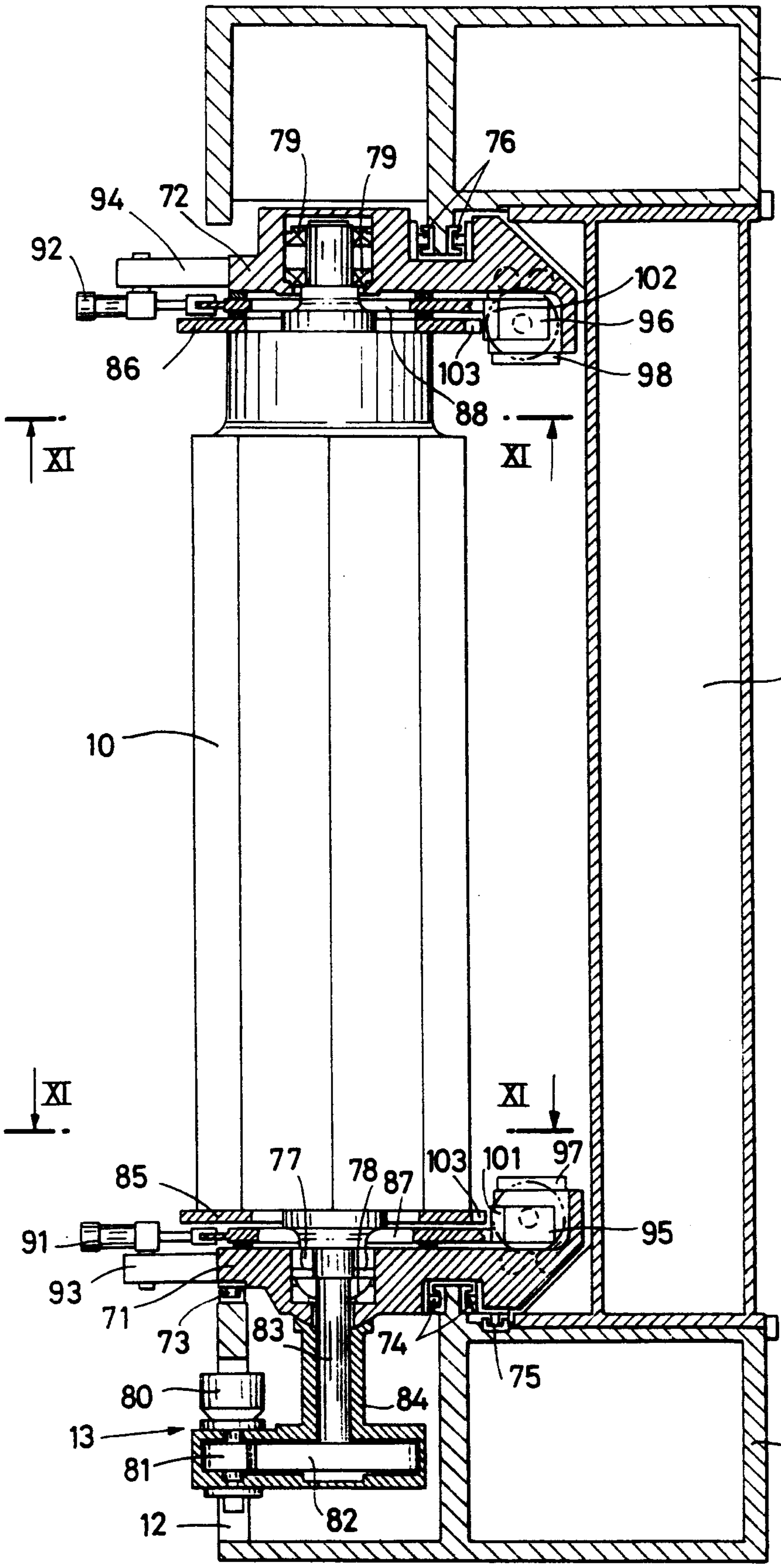
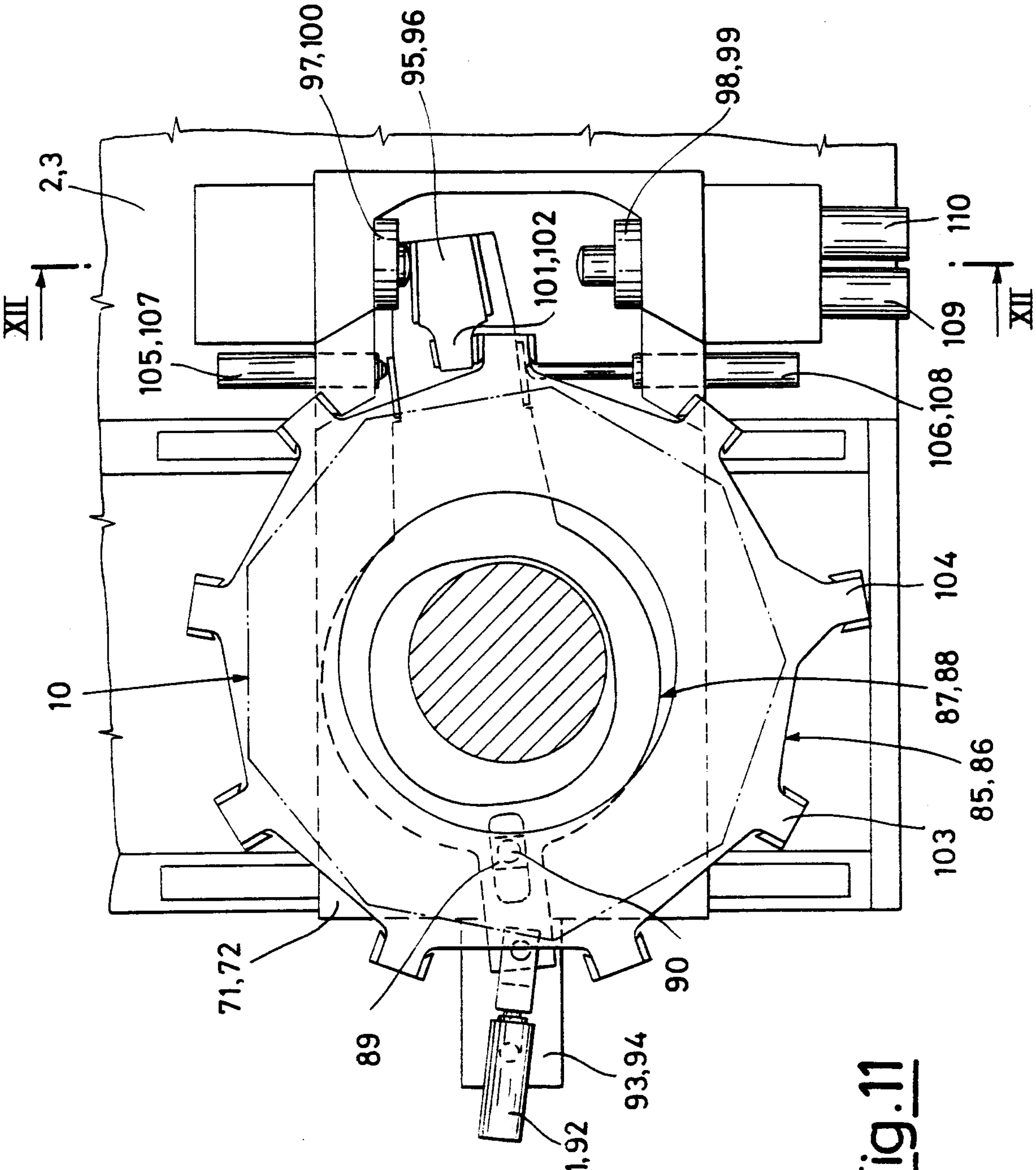

3
79
79
76
94
72
92
102
96
86
103
98
88
XI
XI
4
10
XI
XI
85
77
78
87
103
101
97
91
95
93
71
73
83
74
75
80
84
13
2
81
82
12

Fig.10



97,100
95,96
98,99
2,3
XII
XII
110
101,102
109
105,107
106,108
10
104
87,88
85,86
103
71,72
90
89
93,94
91,92


Fig.11

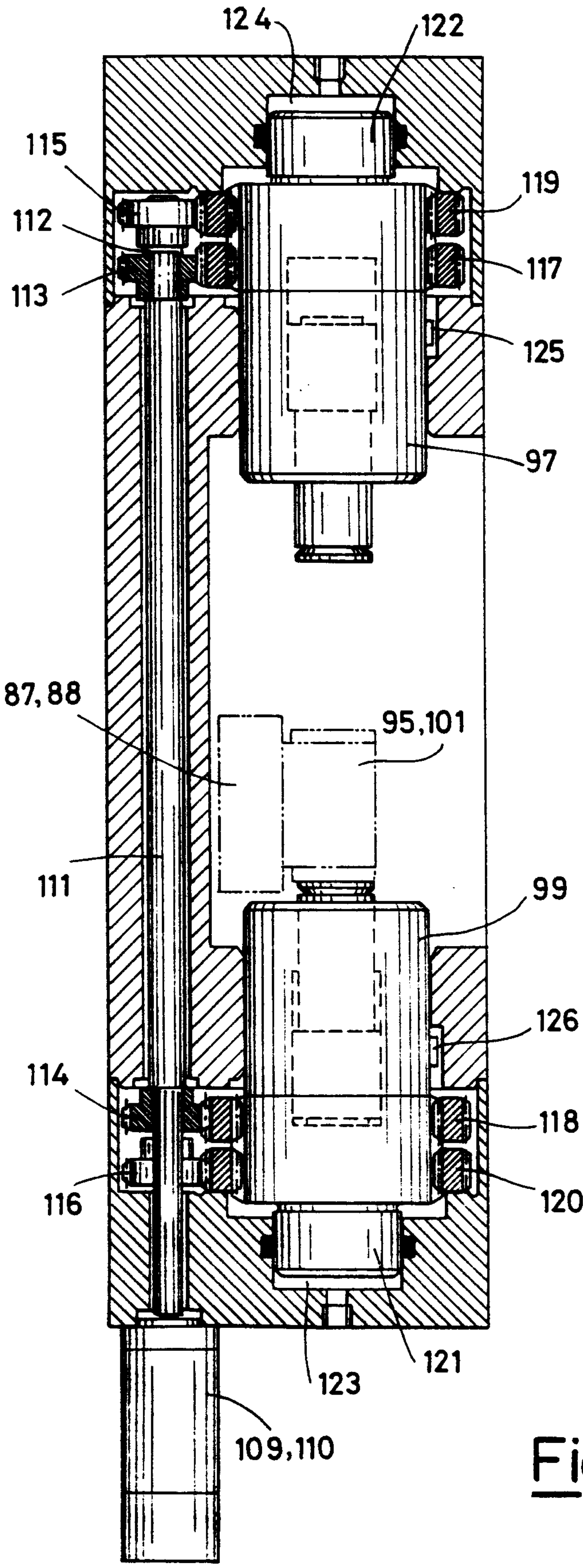

124
122
115
112
113
119
117
125
97
87,88
95,101
111
99
126
114
118
116
120
123
121
109,110

Fig.12

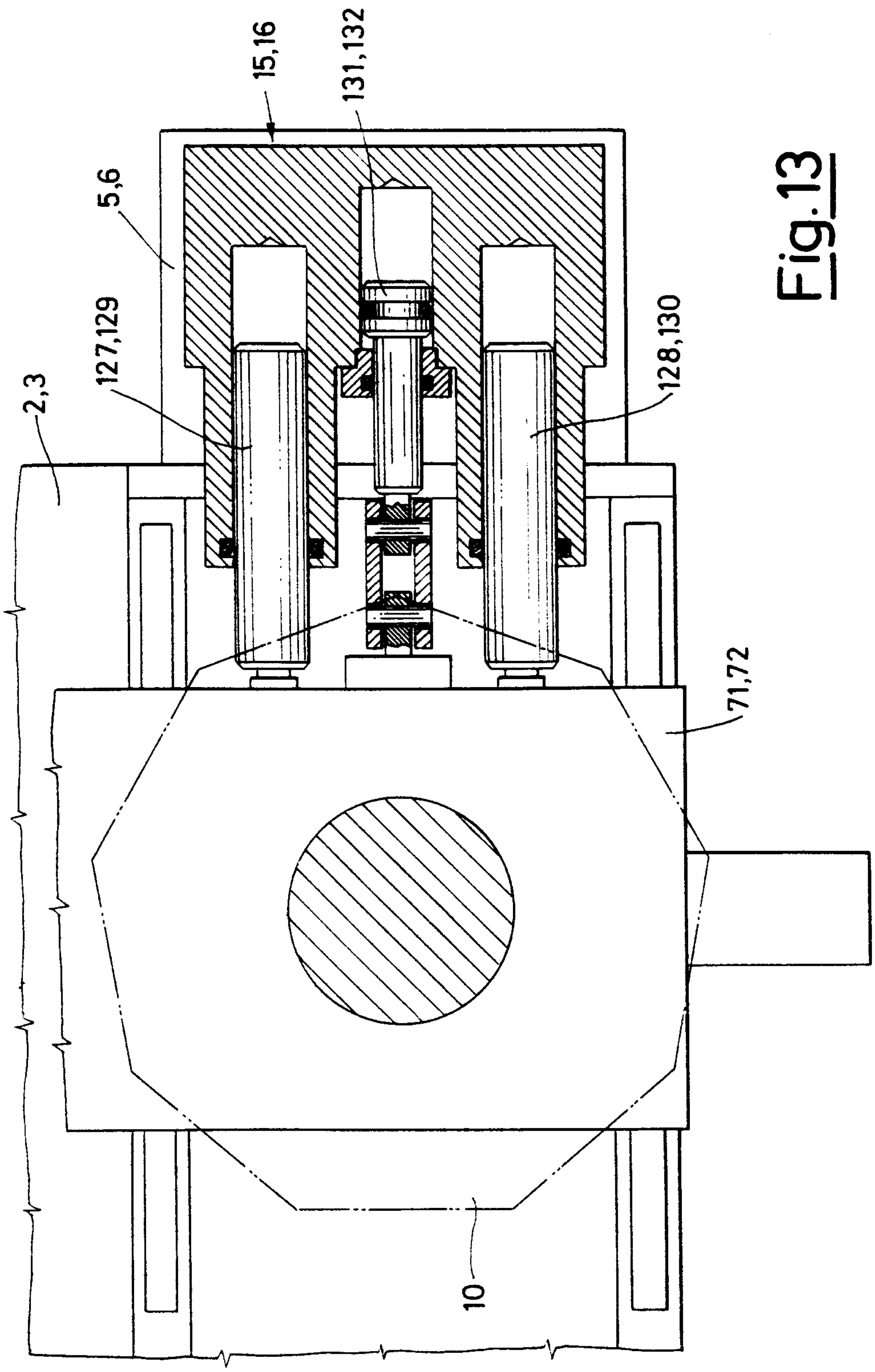



Fig.13

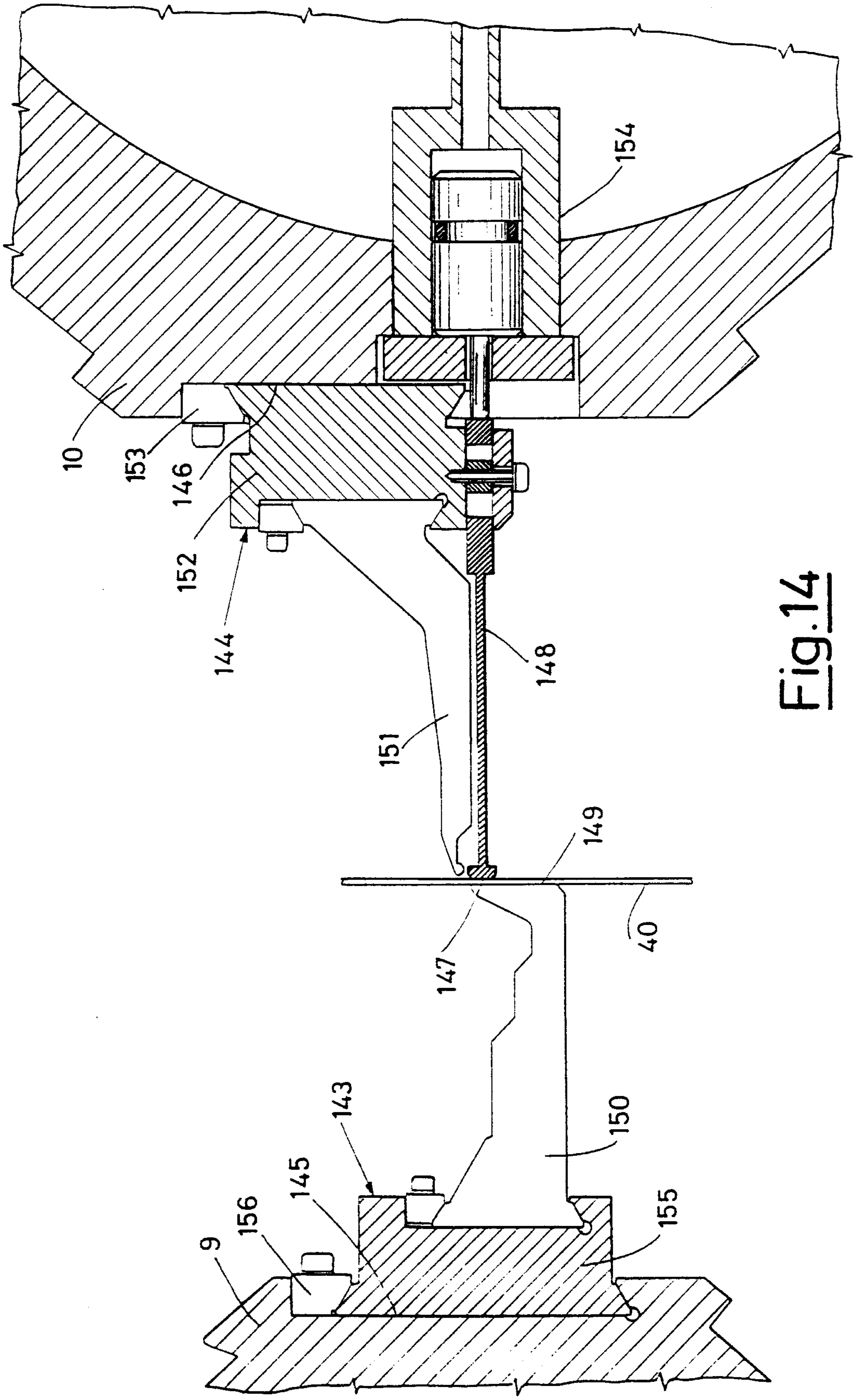



Fig.14

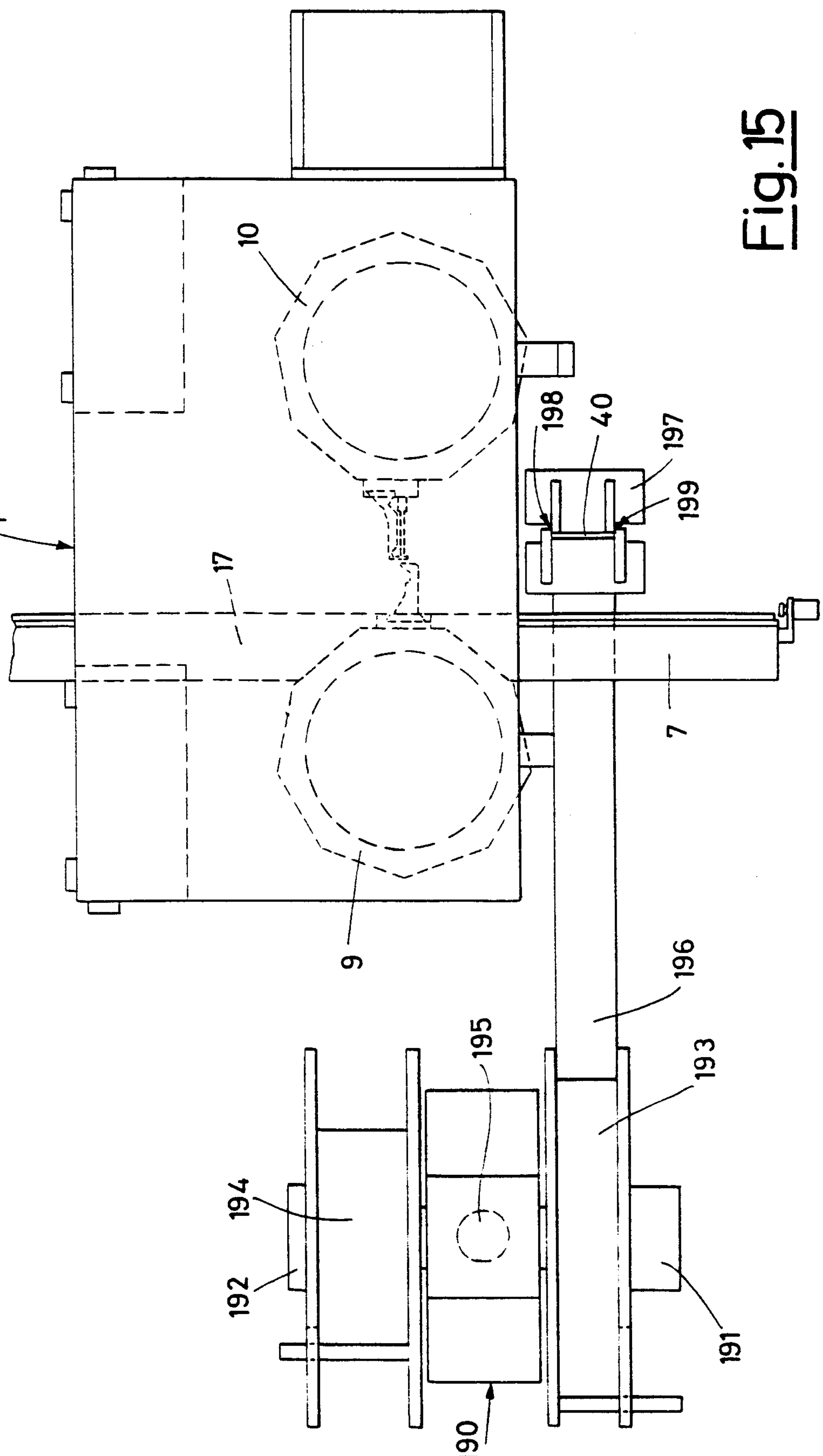



Fig.15