United States Patent [19]

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Carlson

[54] **WAFER BREAKER**

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[21] Appl. No.: **121,886**

[52] U.S. Cl. **225/2,** 225/96.5
[51] Int. Cl. **B26f 3/00**
[58] Field of Search 225/2, 93, 96.5; 29/413

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Primary Examiner—Frank T. Yost
Attorney—John J. Leavitt

[57] **ABSTRACT**

Presented is a machine for breaking a semiconductor wafer that has been scribed into the individual dies described by the scribe lines.

25 Claims, 18 Drawing Figures

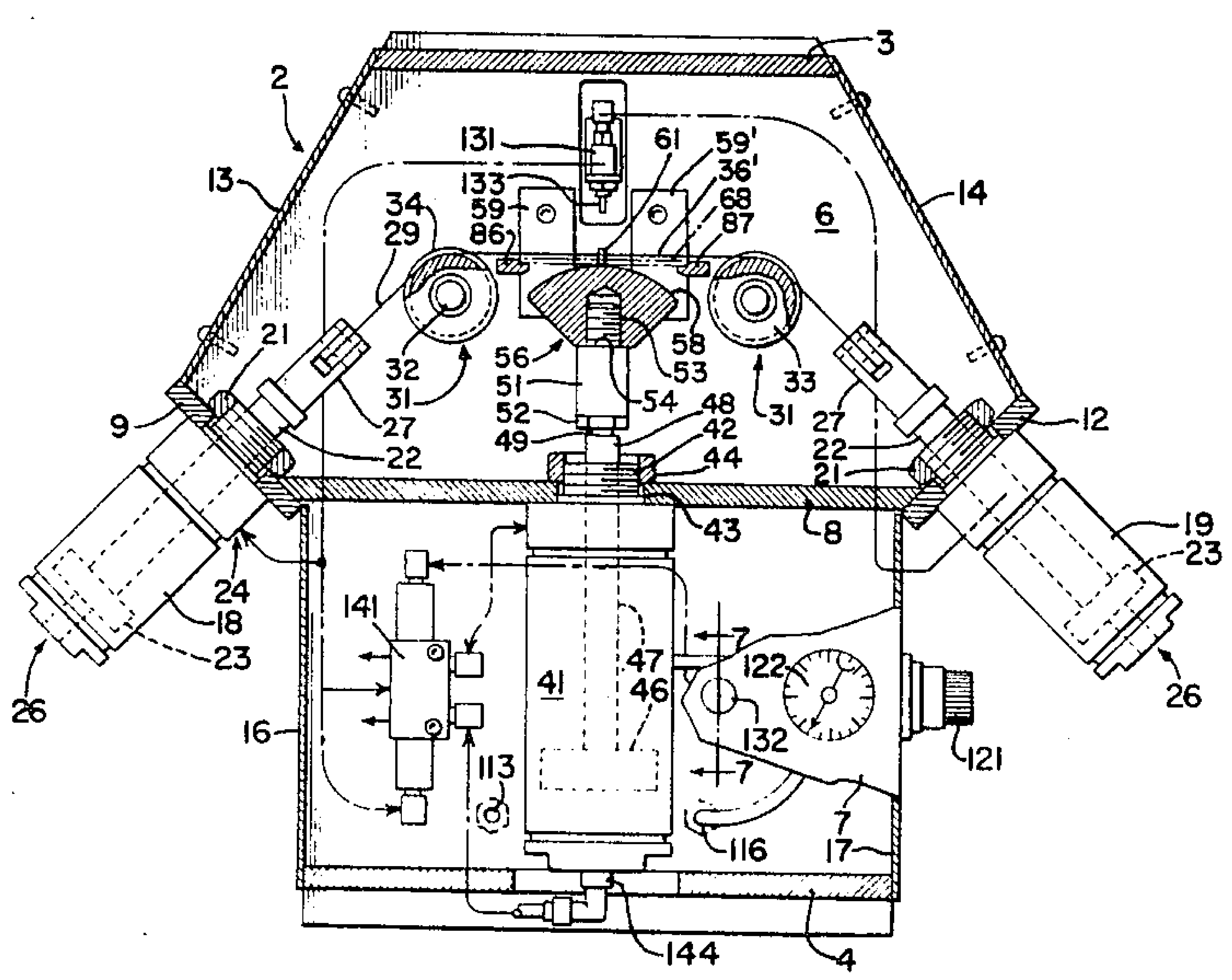


FIG. 1.

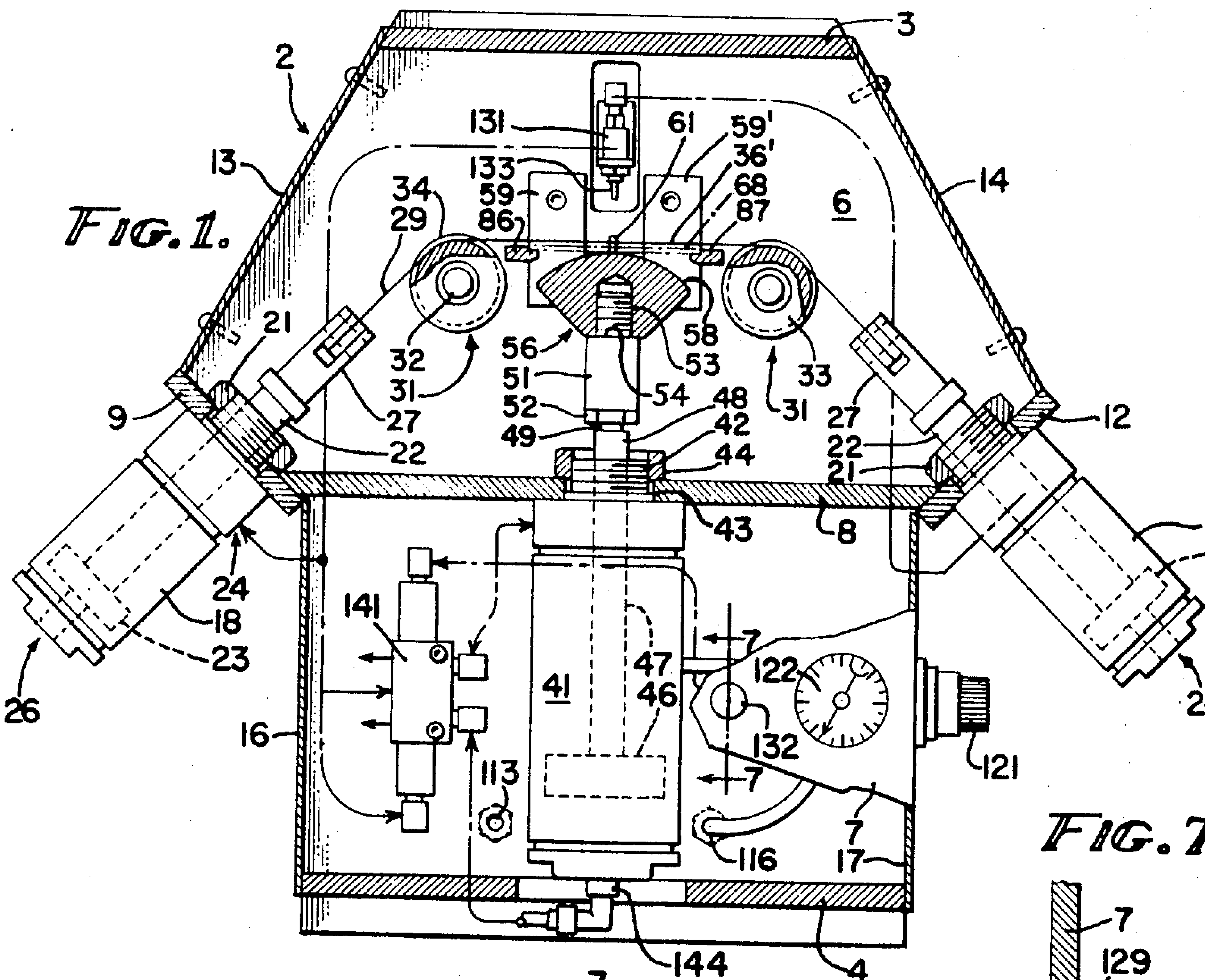


FIG. 7.

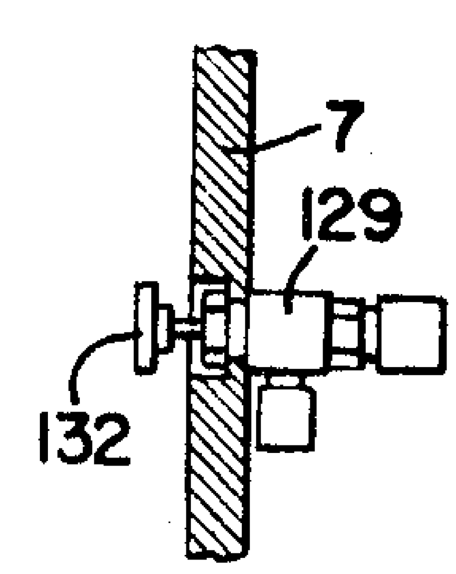
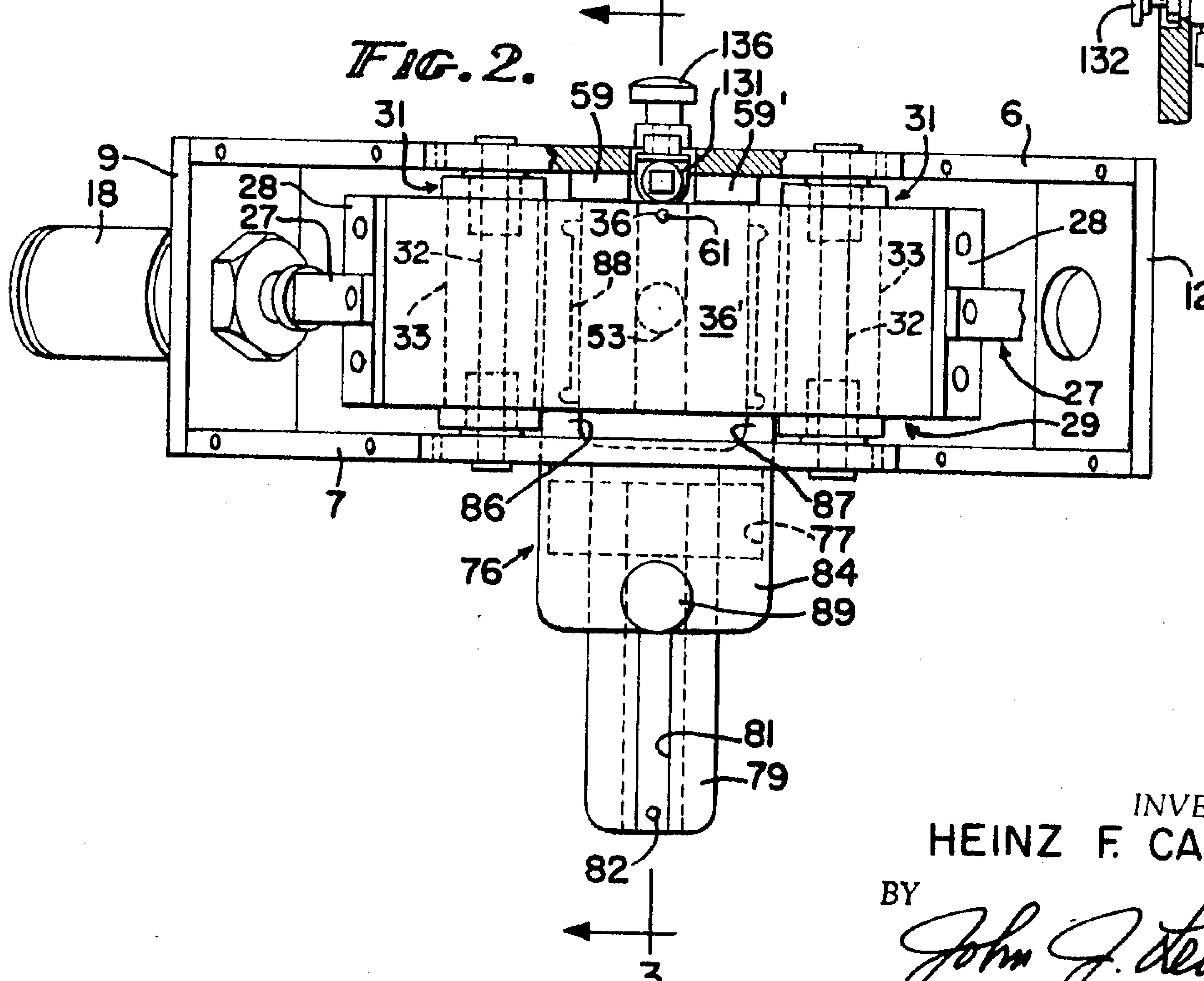


FIG. 2.



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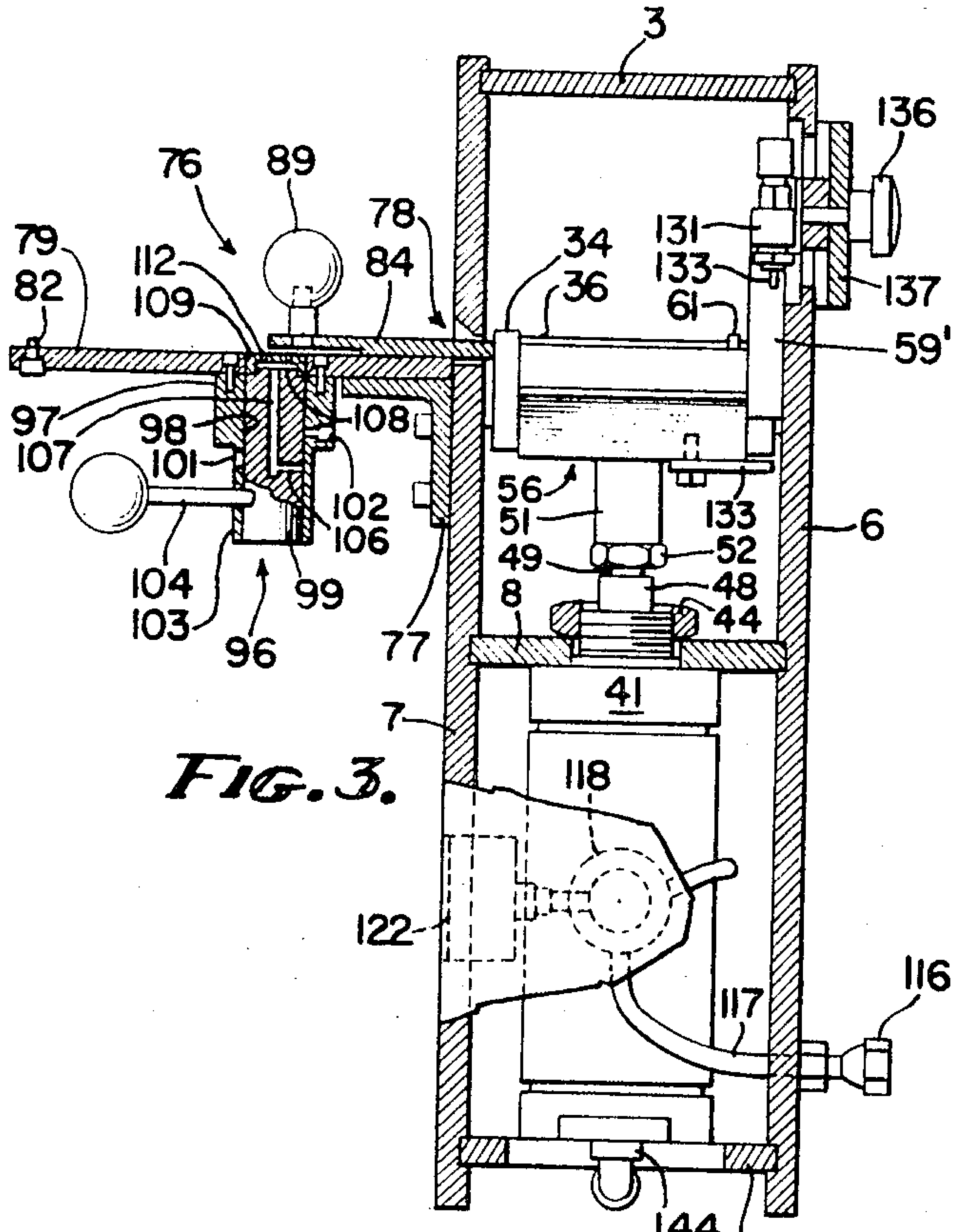


FIG. 3.

FIG. 8.

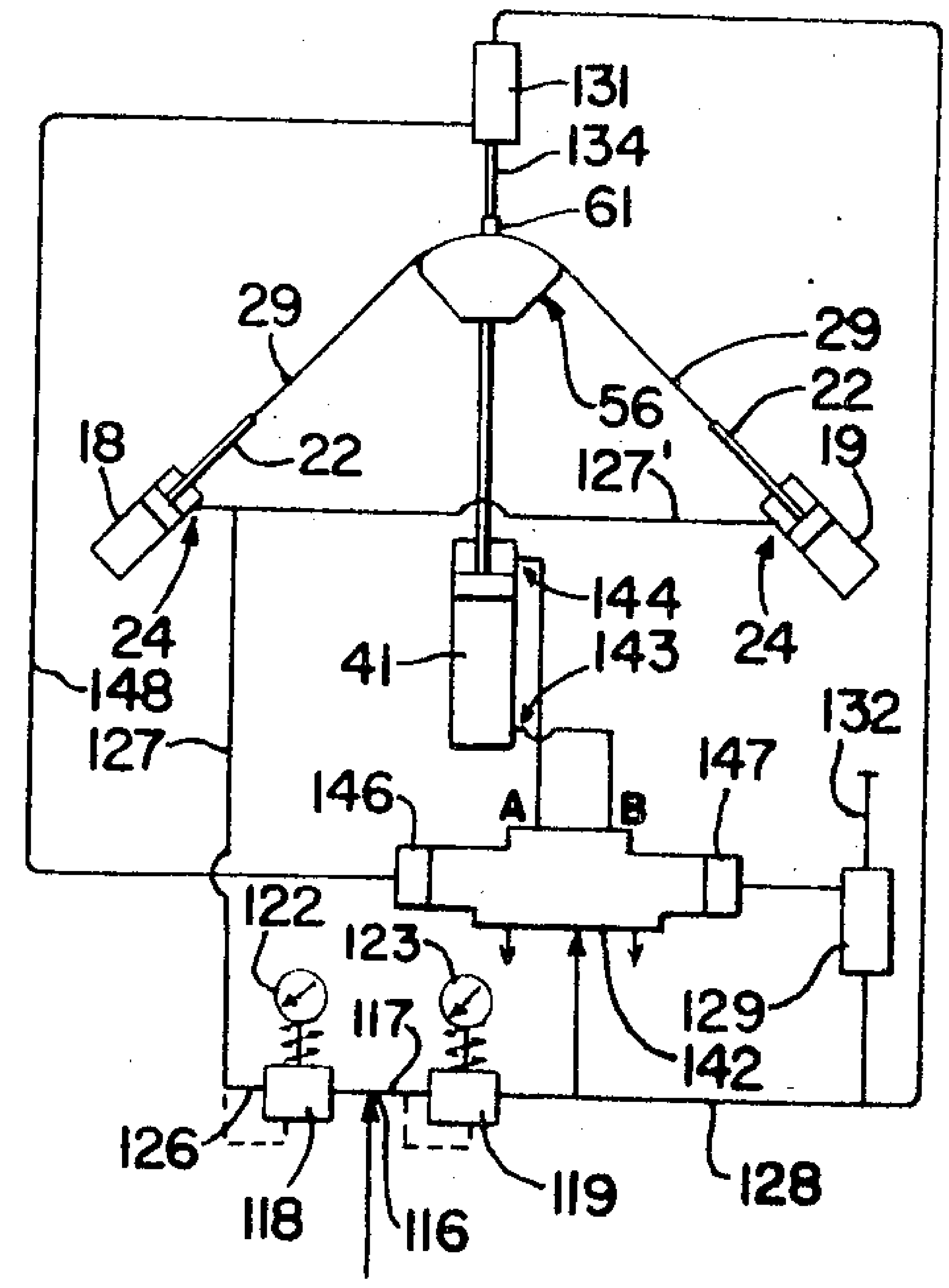


FIG. 4.

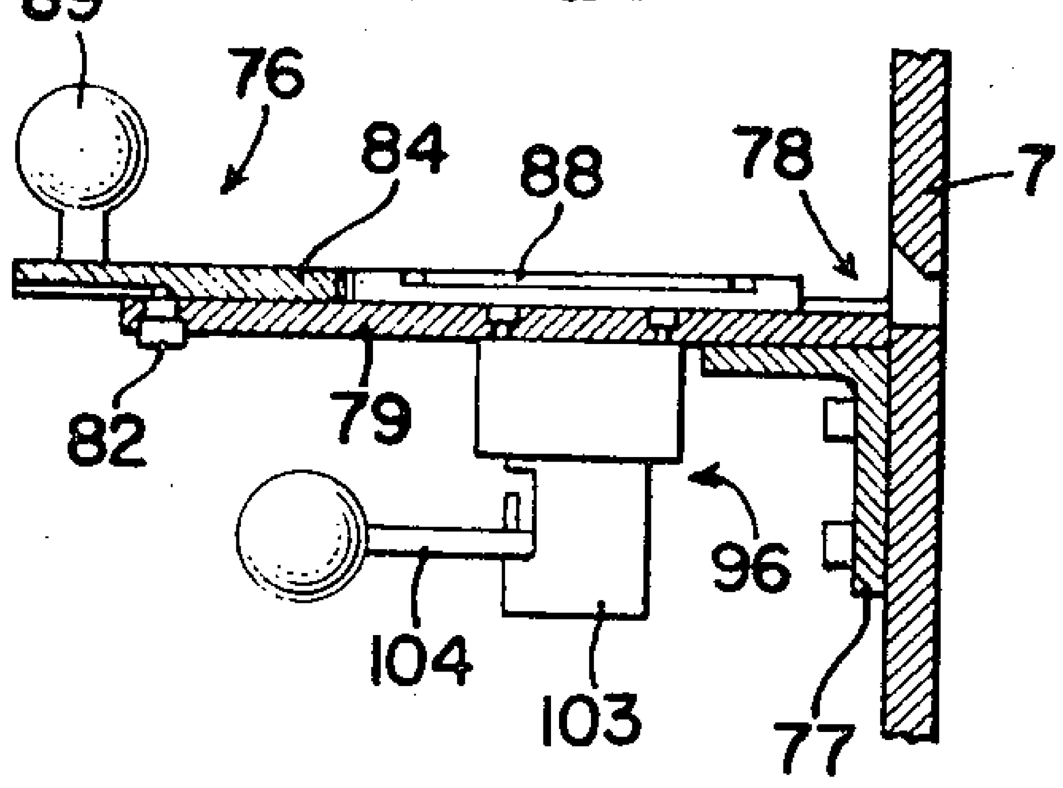


FIG. 6.

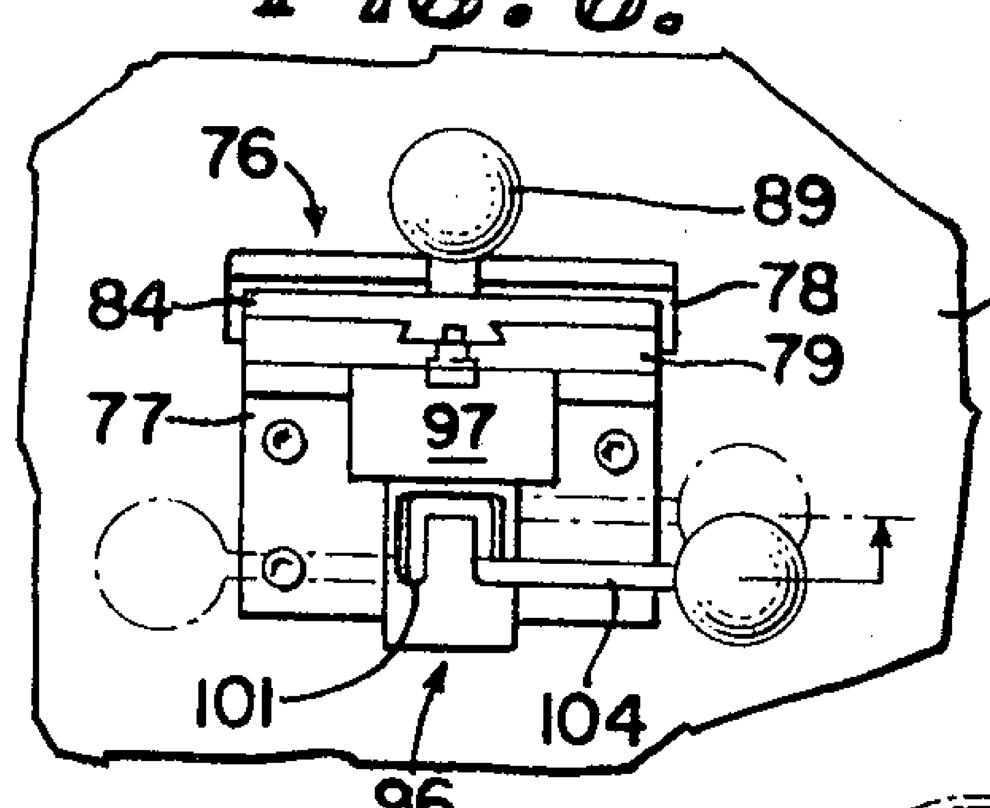
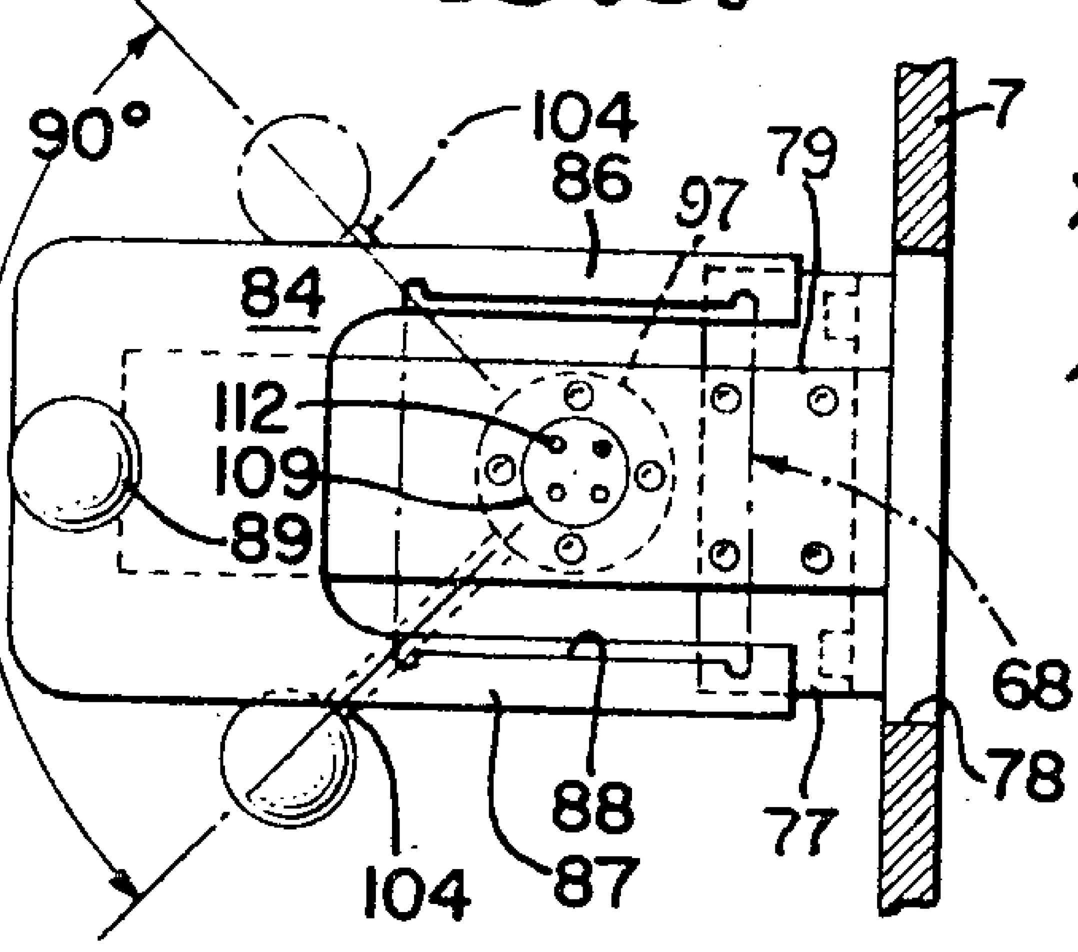


FIG. 5.



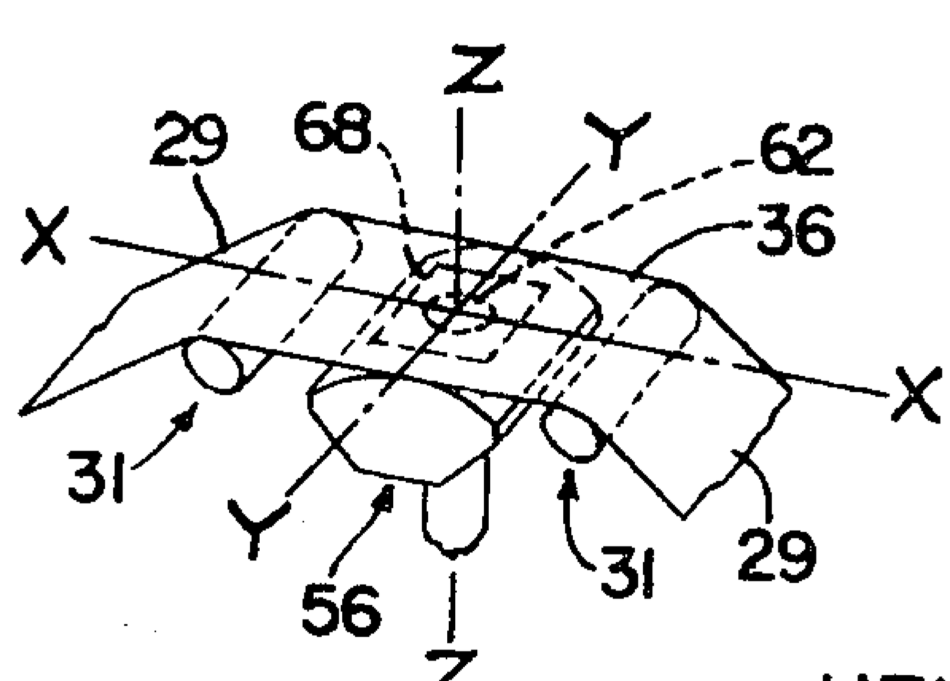


FIG. 17.

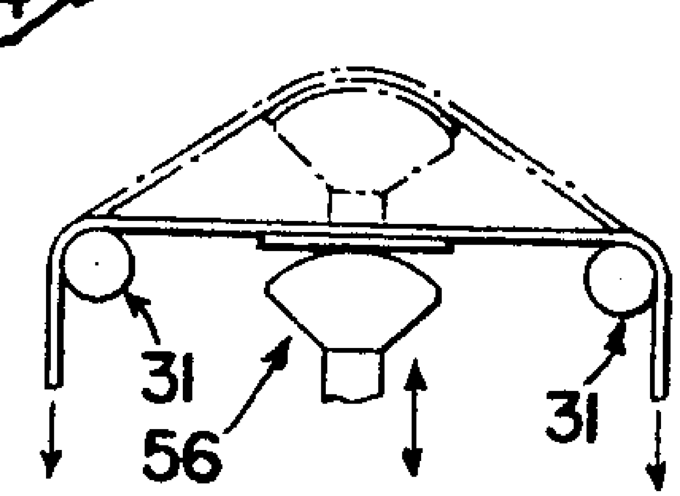


FIG. 18.

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FIG. 16.

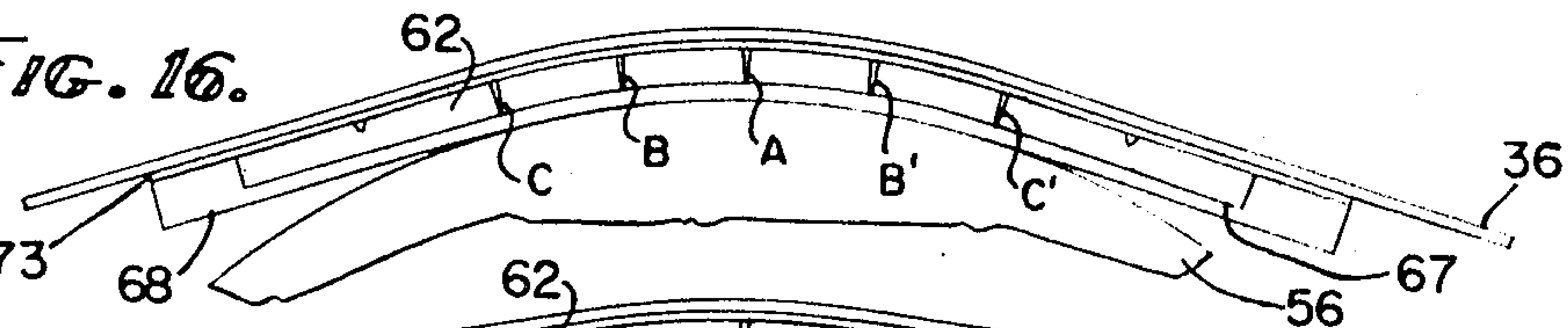


FIG. 15.

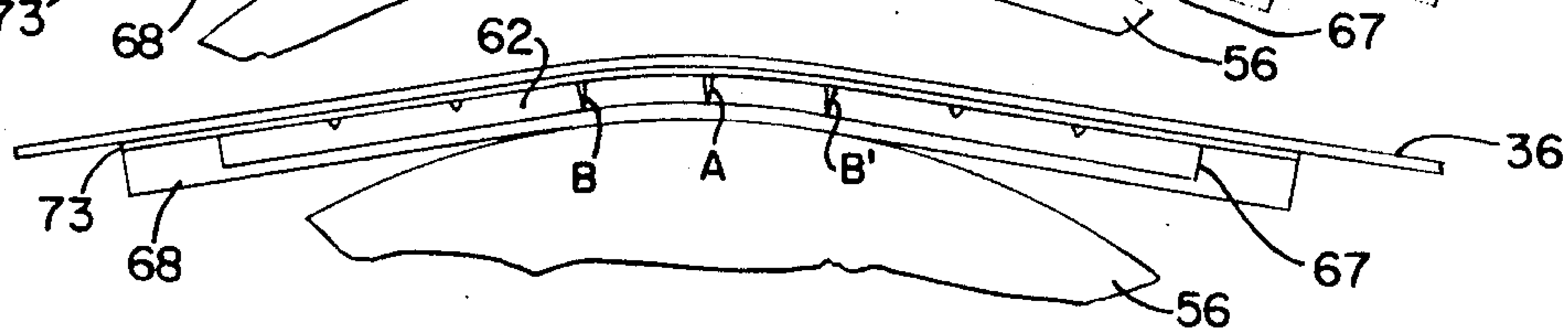


FIG. 14.

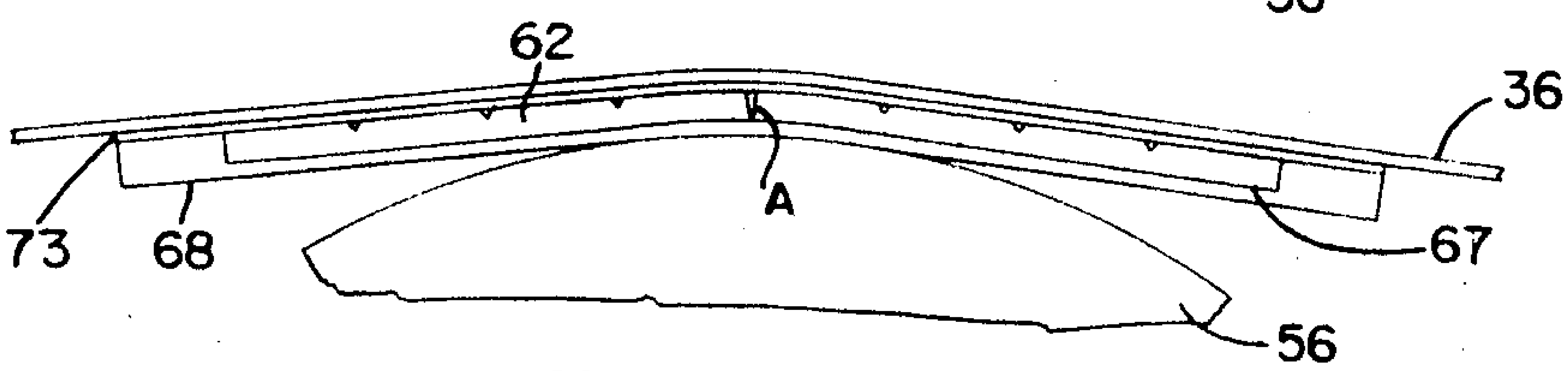


FIG. 13.

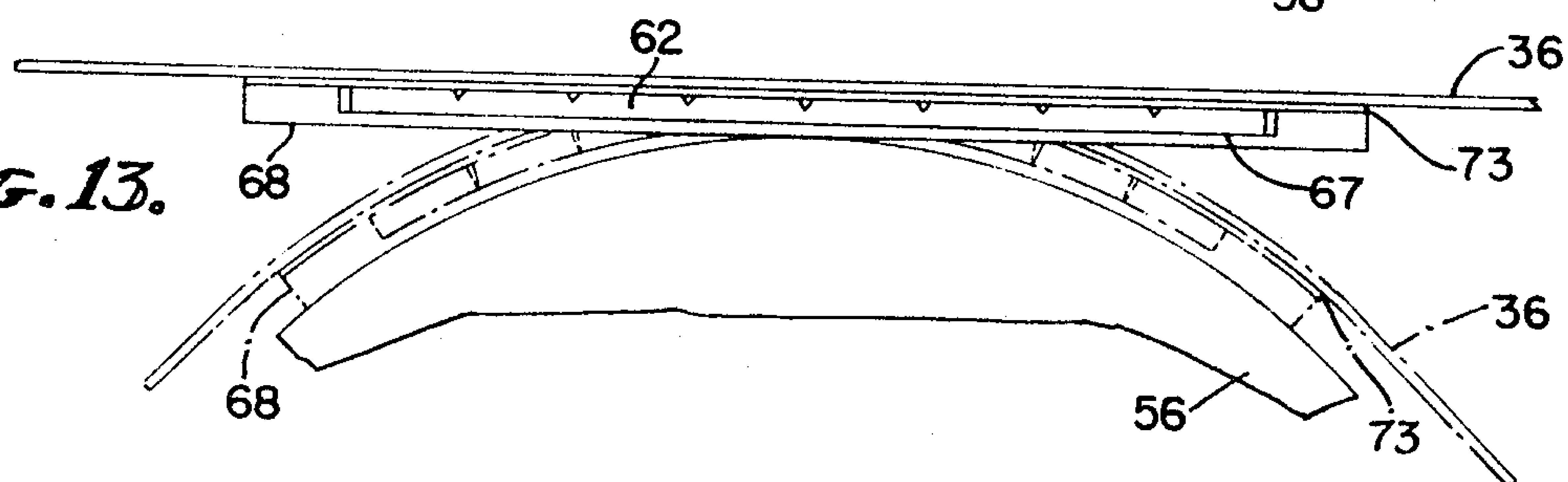


FIG. 11.

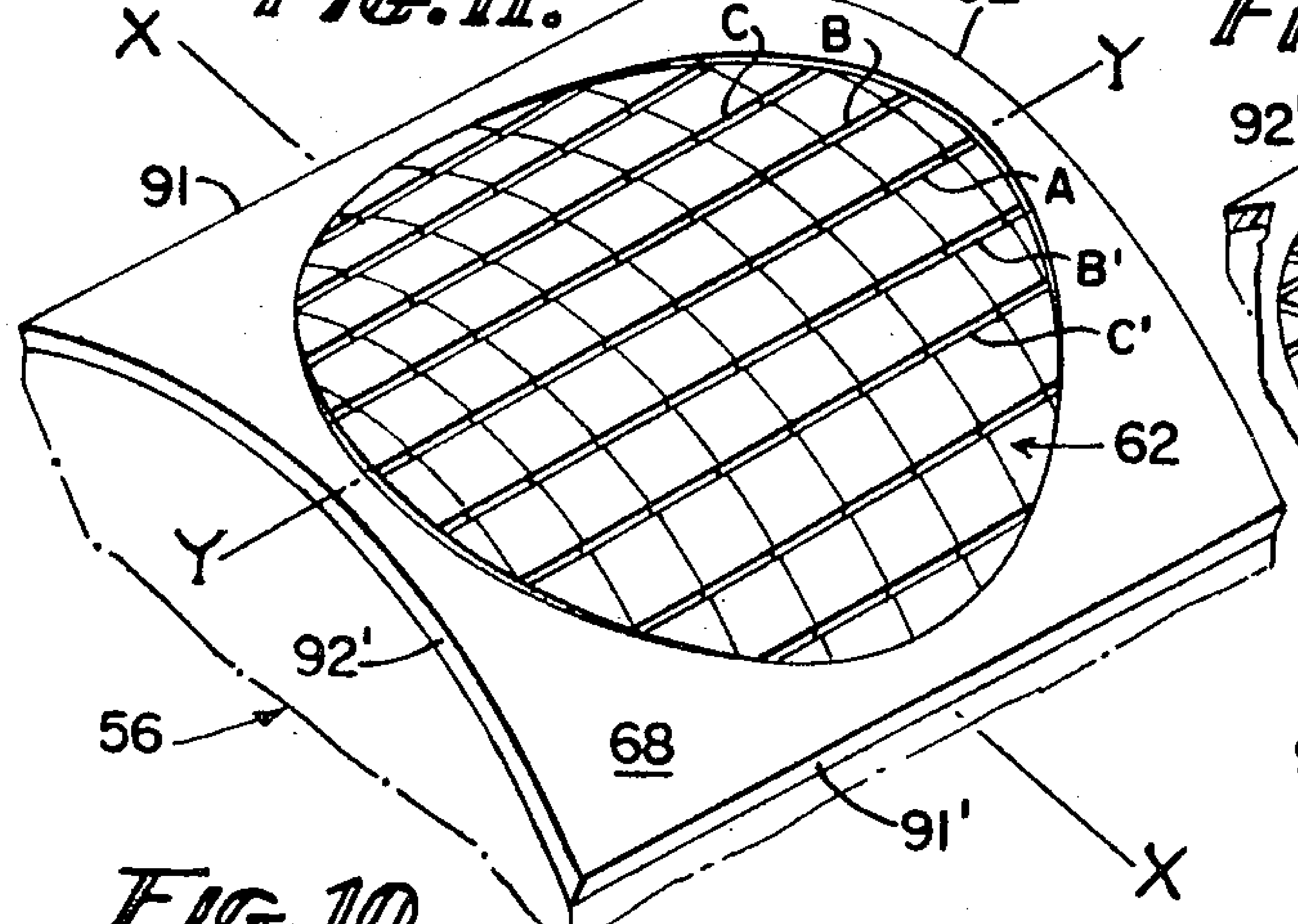


FIG. 12.

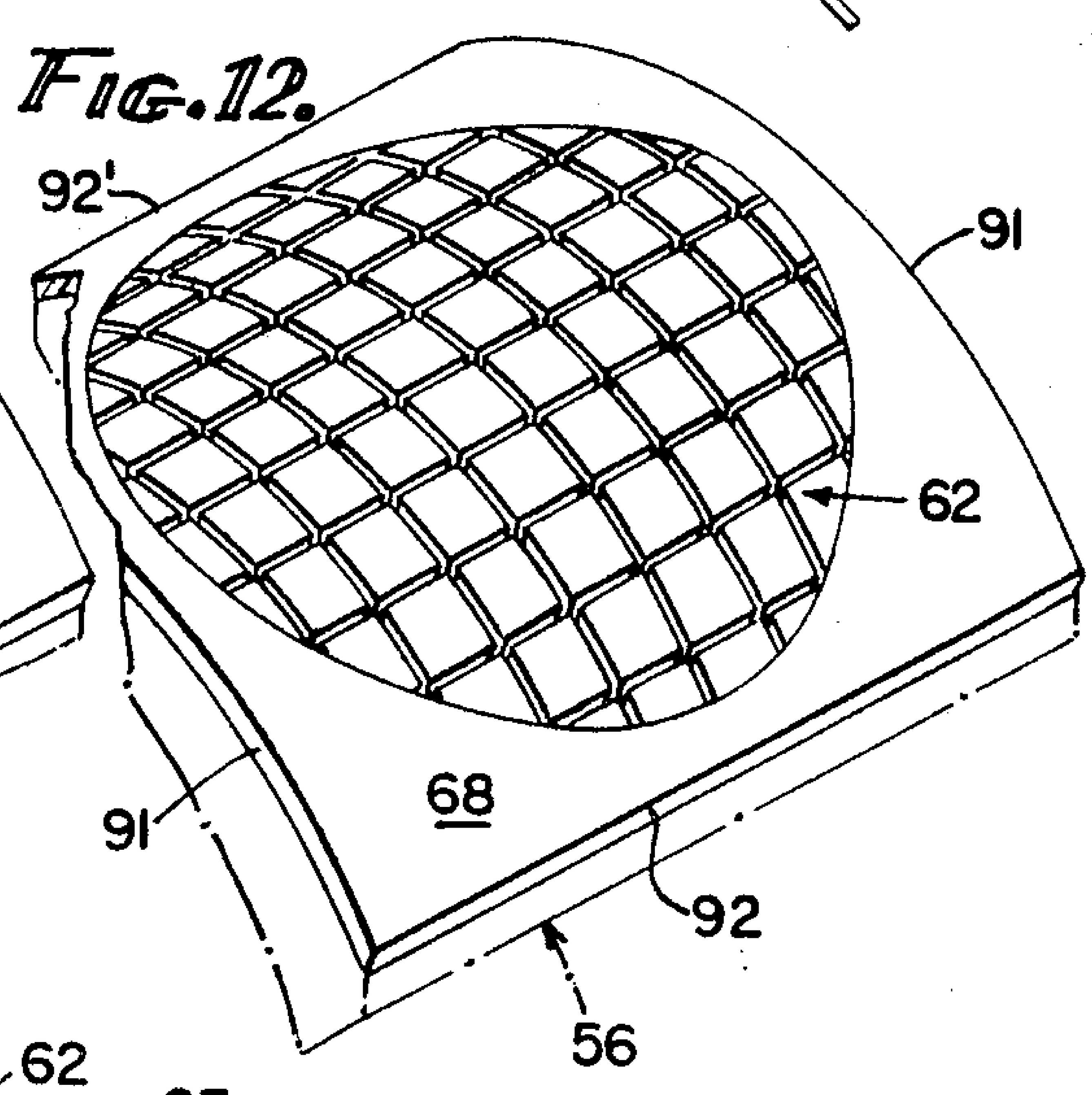
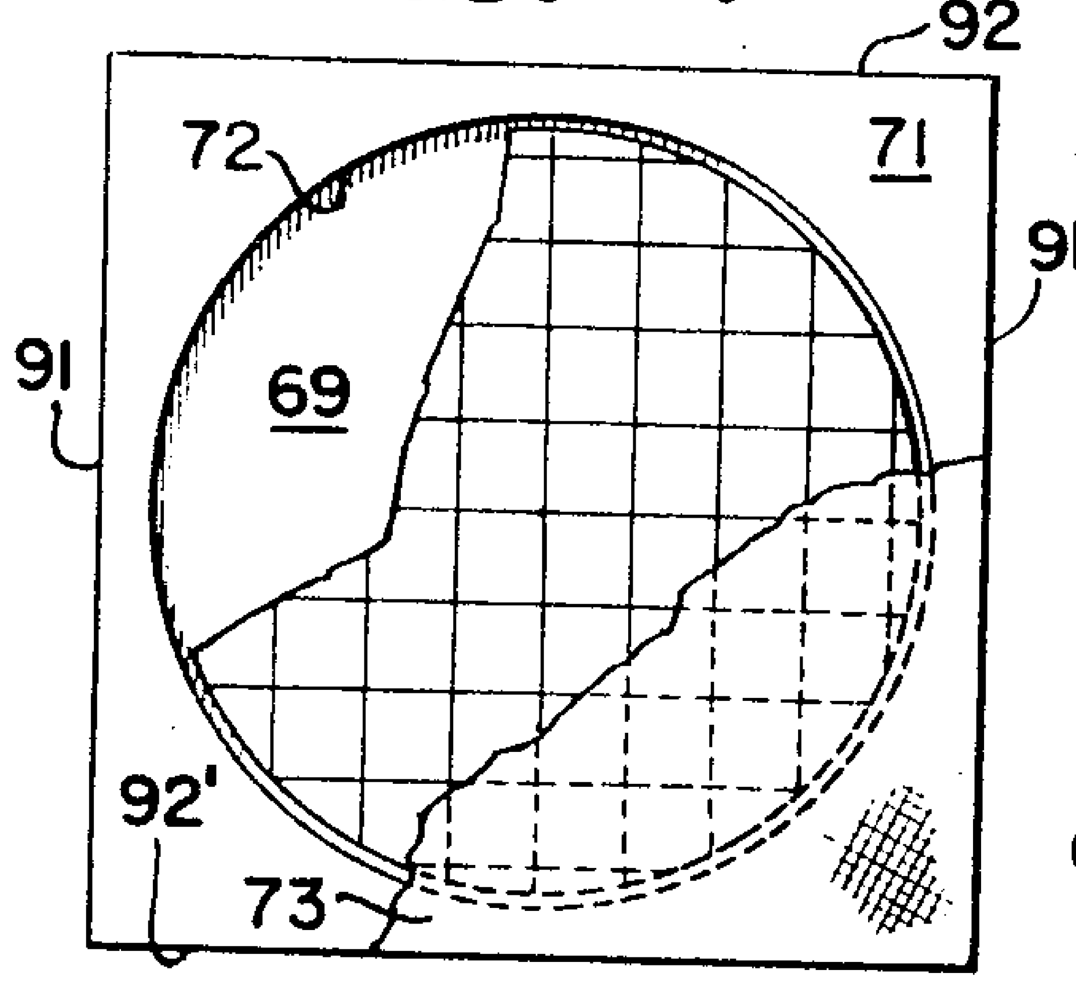


FIG. 10.



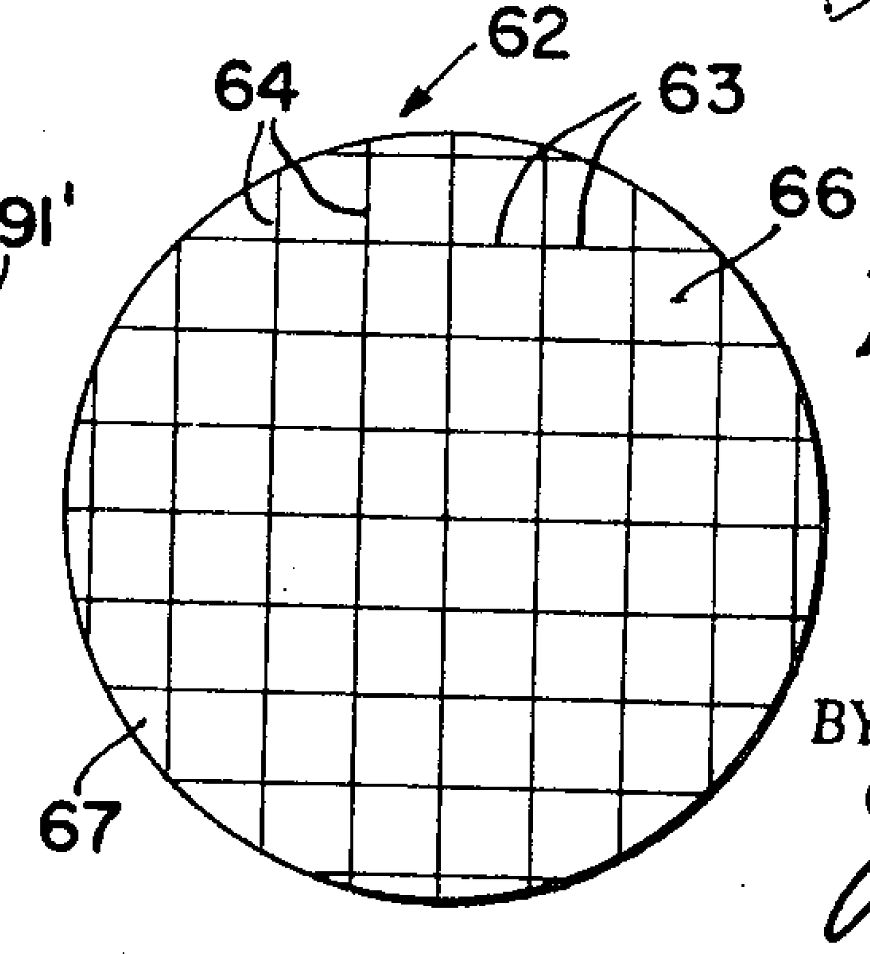


FIG. 9.

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WAFER BREAKER

BACKGROUND OF INVENTION

With the advent of microminiature electronics such as integrated circuits in which the semiconductor chip forming the integrated circuit is so small as to create problems in handling the chip, one of the problems has been in producing the chip in the first place. One of the methods that is commonly used is to manufacture a wafer of relatively large size, individual areas of the wafer including the separate integrated circuits being defined by scribe lines cut into one surface of the wafer in a grid pattern comprising sets of parallel lines at right angles to each other. Such scribe lines are usually no more than scratches having a depth of approximately 0.001 of an inch and a width as narrow as can be provided by appropriate cutting means such as a diamond scribe or a laser.

Wafers from which semiconductor chips are cut to provide integrated circuit components or semiconductor dies come in various sizes in various thicknesses. In general, however, it is necessary to break the wafer into individual "chips" of much smaller size. Frequently, individual chips or dies constituting a complete integrated circuit are no more than 0.025 to 0.050 of an inch in transverse dimension, with a thickness of perhaps 0.010 or 0.012 of an inch. Under these circumstances, it will be appreciated that it is extremely difficult to break the wafer along the scribe lines without cracking the chips or dies in areas which render them useless. In general, it has been found that conventional wafer breaking equipment results in a loss factor of from 30 percent to 50 percent of the possible dies which could be secured from one wafer.

DESCRIPTION OF THE PRIOR ART

Because of the existence of this problem, many attempts have been made to produce apparatus that would effectively break wafers into the individual dies. One such apparatus is taught by U.S. Pat. No. 3,040,489. That patent teaches the conventional method of packaging a scribed wafer in an appropriate plastic envelope so as to protect the surfaces thereof from contamination. The enclosed and scribed wafer is then fastened to the surface of a table having a resilient pad upon which the enclosed wafer packet is placed. The table is movable so as to carry the wafer beneath a roller which imposes a downward pressure on the enclosed wafer as the wafer passes thereunder, causing the wafer to crack along the scribed lines. It should be noted that this apparatus causes one peripheral edge of the wafer to be first fed beneath the roller, with the roller successively imposing pressure on individual scribe lines as the wafer progresses from one peripheral edge thereof to the other beneath the roller. When the wafer has been cracked in one direction, the table is removed, replaced in a position 90° to its previous position, and the sequence of operation is repeated so as to break the wafer in the opposite direction. It will be apparent that this apparatus depends for its operation upon placement of the enclosed wafer upon the resilient support which is deformed by the downward pressure exerted by the roller. The axis of the roller must, of course, be parallel to the scribe lines, and the wafer is broken along each scribe in turn as the roller passes thereover.

Another attempt to crack wafers into separate dies is taught by U.S. Pat. No. 3,105,623. In all essential points, this patent depends for its operation upon the same principal described with respect to U.S. Pat. No. 3,040,489, i.e., placement of a scribed wafer on a resilient base which is then carried beneath a roller to apply pressure progressively across the wafer from one peripheral edge to the other so as to break the wafer in turn at each scribe line over which the roller passes.

U.S. Pat. No. 3,149,765 teaches an apparatus in which a scribed wafer is arranged in a feed channel provided with a push rod which successively advances the wafer by predetermined increments to bring a strip of the wafer defined by a pair of scribe lines into position so that the entire strip may be individually broken from the main body of the wafer. The strips so broken away are then pushed out of the way by a second push rod and main body of the wafer is again advanced and the operation repeated. As each individual strip is moved out of the path of the remaining main wafer portion, each chip in each individual strip is then caused to register with an appropriate opening in a rotatable platen where it is broken from the strip and carried away foe further processing.

A departure from the apparatus described in the previous patents is taught by U.S. Pat. No. 3,167,228. This patent, briefly, teaches the utilization of a resilient spherical surface having a radius of curvature complementary to the radius of curvature of a concave fixed platen against which the resilient spherical surface is adapted to abut. A conventionally enclosed and scribed wafer is supported on the convexly curved resilient surface in a point contact and the resilient convex surface is projected upwardly so that it is brought into conformity with the concave complementary fixed platen. As the two curved surfaces approach each other, it will be apparent that the outer peripheral edges of the wafer contact the depending peripheral edges of the concave platen, while the convex surface on which the wafer is supported imposes an upwardly directed force on the exact center of the wafer. Because of the spherically curved surface of the resilient pad on which the wafer is supported, it is proposed by the patent that the wafer is broken in both directions in a single operation.

U.S. Pat. Nos. 3,206,088 and 3,396,452 both teach the concept of placement of an appropriately scribed and packaged wafer on a deformable base and the application of pressure to the top side of the wafer by pressure devices of various kinds, including cylindrical rollers, or a breaking tool having a polygonal cross section so as to apply pressure to the wafer in the vicinity of each scribe line, causing it to be deformed into the deformable base member and broken along the scribe line. The latter U.S. Pat. No. (3,396,452) adds the refinement of converting the relatively flat deformable base member taught by the previous patents into a cylindrical deformable support rotating in unison with a pressure roller and between which the enclosed wafer is fed. Again, breaking of the wafer depends upon deformation of the cylindrical deformable roller in the vicinity of each succeeding scribe line commencing with a scribe line next adjacent the outer periphery of the wafer.

Additional methods and apparatuses for breaking wafers are taught in U.S. Pat. No. 3,461,537, which teaches packing the wafer in a vacuum-tight envelope prior to application of pressure to break the wafer, U.S.

Pat. No. 3,507,430, the main thrust of which is directed to a snapping tool adapted to snap a scribed wafer into separate parts, and U.S. Pat. No. 3,537,169 which also teaches the concept of applying pressure to the backside of a scribed wafer, causing it to be deformed into a deformable support member and thus broken along the separate scribe lines. This patent adds the refinement to the teaching of previous patents that includes attachment of the wafer to a foil responsive to application of heat to effect separation of the dies once broken.

With few exceptions, as indicated by the prior art discussed above, most wafer breaking devices utilize the concept of a deformable and resilient base upon which a wafer is supported so that the scribed side of the wafer faces the deformable base. Pressure is then applied by an appropriate roller to the back side of the wafer, causing the deformable base below the wafer to be deformed maximally along one of the scribe lines, thus causing cracking or breaking of the wafer along that scribe line. It is believed that the use of such a deformable base in the cracking or breaking procedure of wafers contributes importantly to the high percentage of rejects of dies secured from wafers. Accordingly, it is one of the principal objects of the present invention to provide a wafer breaking apparatus that eliminates the use of a deformable base.

With the exception of U.S. Pat. No. 3,167,228, it appears that most prior art devices operate by a mode which results in cracking the wafer along separate scribe lines in individual operations. In other words, it does not appear that prior art devices for breaking wafers are capable of breaking the wafer along more than one scribe line at a time. Accordingly, it is another object of the invention to provide a wafer breaking device which initially breaks the wafer along a scribe line lying in a median plane, and subsequently, simultaneously breaks separate strips from the separate halves of the wafer.

Another object of the invention is the provision of a wafer breaking device which utilizes a non-resilient platen upon which the wafer to be broken is supported, and the imposition thereon of variable pressure by a non-resilient member which progressively conforms its configuration and the configuration of the wafer to the configuration of the platen.

It has been found that when a wafer is caught between two non-deformable surfaces, one of which is flexible but non-deformable, and the wafer is caused to conform to the curved surface of one of the members, the percentage of rejects drops to approximately one-half to 1 per cent. Accordingly, it is another object of the invention to provide a wafer breaking device in which a non-resilient curved platen is utilized to initially support an unbroken wafer, which is subsequently caused to conform to the curved surface of the platen by a taut steel band.

As indicated above, diameters and thicknesses of wafers differ. Also, the sizes of the dies to be broken from such wafers differ. Such variations in diameter, thicknesses and die size require the imposition of different pressures to effect adequate breaking along the scribe lines. Accordingly, it is a still further object of the invention to provide a wafer breaking device in which the pressure applied to break the wafer may be varied in accordance to the special characteristics of the wafer being broken.

Another characteristic noted of wafer breaking devices of the prior art is that most of such devices are not portable. Accordingly, another and important object of the invention is to provide a wafer breaking apparatus which weighs approximately 50 pounds, and which is completely portable and may be operated either pneumatically, hydraulically, electrically, mechanically, or electromechanically.

SUMMARY OF THE INVENTION

In terms of broad inclusion, the wafer breaking device of the invention comprises a platen having a curved surface, in one aspect of the invention the curve being curvilinear, and on which the unbroken wafer is adapted to be supported. Preferably, the platen is movable between a first loading position and a breaking position by any suitable means such as the ram in an air cylinder. Opposed to the platen, and adapted to initially abut against the flat surface of the unbroken wafer, is a flat section of a tensioned band, preferably steel but formable from other materials, and which is adapted to conform itself to the curvature of the underlying platen as the platen advances from its loading position to the wafer breaking position. The steel band may be tensioned by any suitable means such as air cylinders having appropriate rams connected to opposite ends of the steel band, with tension being applied to the band by admitting air under pressure behind a piston in each air cylinder. Obviously, other means of tensioning the band may be utilized. Since the initial contact of the unbroken wafer with the tensioned band constitutes a flat surface-to-surface contact, it will be apparent that application of pressure by the non-resilient underlying platen will cause fracture of the wafer along a scribe line lying in a median plane of the wafer, thus initially breaking the wafer into two separate and equal halves. Continued movement of the platen in opposition to the tension band causes the band to progressively conform itself to the curvature of the underlying platen, causing opposing halves of the wafer to fracture along pairs of corresponding scribe lines, succeeding breaks progressing from the center of the wafer outwardly toward the peripheral edges. Thus, in one operation, assuming a curvilinear platen, the wafer is initially broken into individual strips collectively arranged to conform to the curvature of the underlying platen and the superposed tensioned band.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a vertical cross-sectional view of one embodiment of the invention, portions of the structure being in elevation for clarity.

FIG. 2 is a plan view of the device the top plate being removed to disclose the underlying structure.

FIG. 3 is a vertical cross-sectional view generally taken in the plane indicated by the line 3—3 in FIG. 2, portions of the structure being shown in elevation for clarity.

FIG. 4 is a fragmentary vertical sectional view illustrating the feed and rotating apparatus for the wafer.

FIG. 5 is a plan view of the feed mechanism illustrated in FIG. 4.

FIG. 6 is a front elevational view of the wafer feed and rotating mechanism.

FIG. 7 is a fragmentary sectional view taken in the plane indicated by the line 7—7 of FIG. 1.

FIG. 8 is a schematic view of the control circuit for a pneumatically operated wafer breaking device.

FIG. 9 is a plan view illustrating the scribed face of a wafer, the scribe lines being spaced apart a considerable distance for purposes of clarity.

FIG. 10 is a plan view illustrating the wafer of FIG. 9 mounted in a flexible wafer carrier adapted to be used in conjunction with the apparatus illustrated in FIGS. 1–3.

FIG. 11 is a schematic view in perspective illustrating the effect on the wafer of forcing it to conform to the curvilinear surface of the platen on which it is supported.

FIG. 12 is a schematic perspective view of the same wafer rotated to 90° and caused to conform to the curvilinear surface of the platen in accordance with this invention.

FIG. 13 is a schematic view in cross section indicating the relationship between the non-resilient underlying curvilinear platen, the unbroken scribed wafer contained in its carrier, and the superposed tensioned flat section of the steel band illustrated in FIG. 1.

FIG. 14 illustrates schematically the first break that is made along a scribe line in the wafer lying in a median plane so as to divide the wafer into two equal and opposed halves.

FIG. 15 is a schematic view in cross section illustrating the breaking simultaneously of two separate strips from the two opposed halves upon progressive conformation of the tensioned steel band to the curvature of the underlying platen.

FIG. 16 is a view similar to FIG. 15 and illustrates the manner in which the next two strips are simultaneously broken from opposed major wafer sections upon continued conformation of the tensioned steel band to the curvature of the underlying platen.

FIG. 17 is a diagrammatic view illustrating the curvilinear platen, the wafer and the tensioned steel band in relation to a system of XYZ axes.

FIG. 18 is a diagrammatic view illustrating the curvilinear platen in relation to the tensioned steel band superposed thereover and the directions in which the platen moves and the direction in which tension is applied to the steel band.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In the interest of brevity in this description, the wafer breaking apparatus of the invention will be described as a pneumatically operated device, as opposed to any of the other several ways in which it may be operated, namely, hydraulic, electrical, electromechanical and mechanical.

Referring to FIG. 1, the pneumatically operated embodiment of the invention is designated generally by the numeral 2 and includes a housing formed by top wall 3, bottom wall 4, rear wall 6, and front wall 7. Approximately midway between the top and bottom walls, there is provided a transversely extending horizontal intermediate wall 8, the ends of which are provided with outwardly extending sections 9 and 12 inclined to the intermediate wall 8 at approximately 45° and secured thereto by appropriate screws. As indicated best in FIG. 1, the front and back walls in general follow the outline provided by the laterally extending upwardly inclined intermediate wall extensions 9 and 12.

The section of the housing above the intermediate wall 8 may be categorized as the wafer breaking section, while the section of the housing below the intermediate wall 8 may be categorized as the power section. As shown, the end edges or sides of the housing are closed by side plates 13 and 14 associated with the wafer breaking section of that housing, and side plates 16 and 17 associated with the power section of the housing. In general, the front and rear walls follow the configuration of the side walls so as to form a completely enclosed two-chamber housing in one chamber of which is effected the cracking or breaking of the wafer and in which is included a minimum of control or power components, thus maintaining this section of the housing relatively free from contaminants, while the power section of the housing is isolated from the wafer breaking section, and contains most of the control and operating components.

Suitably mounted on the intermediate wall 8, here shown as being specifically mounted on the upwardly inclined extensions 9 and 12 of such intermediate wall, are a pair of pneumatic cylinders, each preferably being of the type that accommodates a nose-type mounting secured to the associated transverse wall section by an appropriate nut 21, having an extensible shaft 22 connected interiorly of the cylinder to an appropriate air driven piston 23. Each air cylinder is provided with a port 24 in the usual manner which admits air under pressure above the piston, tending to drive the piston into its lower or retracted position. The volume of the cylinder behind the piston is vented to the outside air through appropriate exhaust ports 26 formed either in the end wall as shown or in a side wall of the cylinder.

The shaft 22 of each air cylinder is provided with clevis 27, in which is pivotally mounted a bracket 28 in the nature of a U-shaped clamp having transversely extending apertures therethrough and within which opposite ends 29 of a tensioned steel band 29 may be caught.

As clearly shown in FIG. 1 the steel band 29 passes over a pair of laterally spaced rollers 31 journaled on an appropriate axle 32 extending horizontally between the front and back walls of the housing. Each of the rollers is provided with a central body section 33 defined by upstanding flanges 34 adjacent opposite ends of the rollers. It will thus be seen that as the band 29 passes over the rollers and is supported on the body section 33 thereof, the upstanding flanges provide a guide and a limit for the edges of the band, preventing displacement of the steel band in a fore and aft direction. In the embodiment illustrated, the steel band is provided with an aperture 36 (FIG. 2) adjacent one edge thereof and the steel band is preferably fabricated from stainless steel having a thickness of approximately 0.010 of an inch. The width of the bank in the embodiment illustrated is preferably approximately 3¼ inches. It is important to note that the working section 36 of the band in the attitude illustrated in FIG. 1 is horizontal across the housing, and tangent to the upper periphery of the two spaced rollers 31. It is important that irrespective of the attitude of the working section 36', that the end portions of the steel band connected to clevises 27 extend tangentially from each of the associated rollers. In this manner, there is never imposed on the shafts 22 a transverse loading which would have the tendency to wear seals and bearings.

It should be noted that while the air cylinders **18** and **19** have been illustrated and described as mounted on the obliquely extending wall sections **9** and **12**, such cylinders could just as easily be mounted on the intermediate wall section **8** within the lower power section of the housing. In such event, the housing would be more rectangular in its configuration, the inclined end walls **13** and **14** being in such an embodiment a continuation of the side walls **16** and **17**.

Mounted in the power section of the housing below the intermediate wall **8** is a power cylinder **41** having a threaded nose section **42** extending through an appropriate aperture **43** in the intermediate wall **8** and being detachably secured thereto by appropriate nut **44** as shown. The power cylinder **41** in the embodiment illustrated is preferably a pneumatic double-acting type in which air under pressure may be admitted selectively to opposite sides of a piston **46** appropriately connected to a shaft **47** the outer end **48** of which extends above the intermediate wall **8** into the wafer breaking section of the housing and is equipped with a threaded end portion **49** engaging a complementarily threaded interior bore formed in the mounting sleeve **51** locked to the threaded section of the shaft by a nut **52**. The upper end of the mounting section **51** is provided with a reduced-in-diameter stub shaft portion **53** which at its union with the larger diameter mounting portion **51** provides a shoulder **54** on which is detachably supported a platen designated generally by the numeral **56**.

The platen **56** in the embodiment illustrated is provided with vertical end walls **57** extending parallel and spaced from the adjacent front and back walls of the housing. The platen is preferably in the form of a solid non-deformable steel block having a curvilinear surface **58**, chrome plated for extreme smoothness and hardness for reasons which will hereinafter be explained. It is important that the platen **56** not rotate on the stub shaft **53**. To prevent such rotation, the stub shaft **53** may, of course, be formed with a cross section that would prevent such rotation, and the shaft **48** of the air cylinder may be appropriately keyed so that it does not rotate. However, in the interest of fabricating an economical unit, it is advantageous that the double-acting cylinder **41** not be of such special construction as to increase its cost. Accordingly, to prevent rotation of the platen **56**, about the vertical axis of the shaft **48**, stop blocks **59** and **59'** are mounted securely to the back wall **6** of the housing by appropriate means such as screws, and the associated end wall **57** of the platen is associated with the faces of such stop blocks so as to absorb any rotary moment that might be imposed on the platen.

As discussed above, it is important that there be no fore and aft displacement of the band **29** and to prevent such displacement, each of the spools **31** is provided with the upstanding flanges **34**. It is equally important that there be no longitudinal displacement of the band in relation to the underlying platen while permitting the flexure of the band to conform to the curvature of the curvilinear surface **58** thereof. To prevent such longitudinal displacement of the band, the platen is provided with an upstanding pin **61** adjacent one end of the platen and positioned so as to protrude snugly through the aperture **36** (FIG. 2). It will thus be seen that when the power cylinder **41** is activated as will hereinafter be explained, the platen **56** moves upwardly along the axis of the power cylinder, and after a very short travel abuts the underside of the working section **36** of the steel band. Thereafter, continued upward movement of the platen causes the midsection of the band to move upwardly with the platen, which in turn causes the band to closely conform to the curvature of the upper curvilinear surface **58** of the platen. It should be noted that such conformation is progressive, starting at the axis of the platen and progressively increasing as the platen moves upwardly.

In the device illustrated, the main power cylinder **41** constitutes a double-acting cylinder manufactured by the Bimba Manufacturing Company, Monee, Ill., and sold under the model No. 503-D. Air cylinders **18** and **19** are manufactured by the same company and carry a model No. 311-D. It has been found appropriate through experimentation that a pressure of approximately 100 psi imposed on the upper side of the piston **23** in each of the air cylinders **18** and **19** through their respective inlet ports **24** produces satisfactory results for most wafer sizes and thicknesses. As will hereinafter be explained, such pressure may be increased or decreased through appropriate means. It is preferable that the tension imposed on the steel band **29** by cylinders **18** and **19** be closely matched to the pressure exerted by the main power cylinder **41**. Accordingly, the effective areas of the pistons in the auxiliary cylinders **18** and **19** are proportioned to equal the effective area of the piston **46** of the main power cylinder **41**.

In the embodiment illustrated, a semiconductor wafer **62**, illustrated in plan in FIG. **9**, is provided with a first set of scribe lines **63** extending horizontally as viewed in FIG. **9** and spaced apart any requisite distance. A second set of scribe lines **64** is provided extending at right angles to the set of scribe lines **63** and therewith defining a grid pattern of scribe lines on the face **66** of the wafer. The back side **67** of the wafer is not scribed, although it is contemplated that where economically expedient, such scribing could be effected. The scribed wafer is then placed in a carrier member **68** formed from a base sheet **69** having superposed and adhesively secured thereto an apertured guide sheet **71** as shown in FIG. **10**. Preferably, the aperture **72** in the guide sheet is formed so as to be slightly larger in diameter than the unbroken wafer intended to be placed therein. The reason for the larger diameter of the guide sheet is to provide sufficient clearance to accommodate an increase in the diameter after it is broken. It will, of course, be understood that the wafer after being broken will require a somewhat larger space in which to be contained than when in unbroken form by virtue of the minute spaces created between the individual dies or chips into which the wafer has been broken. It is customary practice in this art to enclose wafers to be broken in plastic envelopes, one or more surfaces of which are adhesive in nature and stick to one or both surfaces of the wafer so as to retain the separate chips in their same positions after being broken as they were prior to being broken. It has been found that with the carrier illustrated in FIG. **10**, the use of such envelopes, and particularly the use of an adhesive sheet in conjunction with the broken wafer are unnecessary. It has been found advantageous, however, to place a very thin sheet of lens paper **73** over the scribed side of the wafer after it is deposited in the recess **72** formed by the guide sheet **71**. In FIG. **10**, a corner of such lens paper is illustrated in the lower right-hand corner of the carrier. In this view, a portion of the wafer has been broken away to reveal the recess in which it is accommodated.

To effect breaking of the wafer, the carrier thus formed, with the unbroken wafer in place, and covered with a sheet of lens paper 73, is deposited in a feed assembly designated generally by the numeral 76. The feed assembly is supported on the front wall 7 of the cabinet by an appropriate angle bracket 77 in association with a slot 78 formed in the front wall of the cabinet and through which the wafer is inserted into the apparatus. Referring to FIG. 4, the angle bracket 77 supports a guide plate 79, one end of which is appropriately supported on the support bracket, and the other end of which extends perpendicularly away from the front wall of the cabinet. The guide plate is provided with a centrally disposed dovetail groove 81 having a stop pin 82 extending from the floor of the groove, the groove being proportioned to slidably receive a complementarily shaped key 83 attached to the bottom surface of the feed slide 84. As illustrated in FIG. 5, the feed slide is provided with a pair of laterally spaced forwardly projecting arms 86 and 87, the inner edges of which are provided with rabbets 88 forming a recess within which the carrier 68 containing the wafer may be deposited. A knob 89 is provided attached to the feed slide so that the feed slide may be pushed through the aperture 78 in the front wall and against the stop blocks 59 and 59′ attached to the back wall 6. This position of the feed slide is illustrated in FIGS. 2 and 3, while the outermost position of the feed slide is illustrated in FIGS. 4 and 5.

With the feed slide inserted as illustrated in FIGS. 2 and 3, the carrier borne wafer is positioned immediately above the curved surface 58 of the platen as illustrated in dash lines in FIG. 1, and as illustrated schematically in FIG. 13. In this position, the wafer is preferably oriented with respect to the lateral edges 91 and 91′ of the carrier so that one set of scribe lines, say the scribe lines 64 as illustrated in FIG. 9, lie parallel to the lateral edges 91 and 91′. When so oriented, the other set of scribe lines 63 are, of course, perpendicular to the lateral edges 91 and 91′ and parallel to lateral edges 92 and 92′. Referring to FIG. 11, it will there be seen that when the wafer is so oriented in the carrier 68, the scribe lines 64 lie parallel to a Y axis which is in turn parallel to the lateral edges 91–91′ of the carrier. In like manner, the scribe lines 63 lie parallel to the lateral edges 92 and 92′ and parallel to an X axis which is in turn parallel to the lateral edges 92 and 92′.

It will thus be seen that with the carrier 68 positioned in the rabbets 88 of the feed plate 34 so that the lateral edges 91 and 91′ extend parallel to the direction of travel of the feed slide, the scribe lines 64 of the wafer will also lie parallel to the direction of movement of the wafer, and will lie parallel to and extend transversely of the working section 36 of the taut steel band 29. If it is assumed that the curved surface 58 is curvilinear in conformation, then the scribe lines 64 will, of course, lie parallel to the curved surface 58.

Actuation of the main power cylinder 41 when the wafer is thus positioned will cause the wafer and carrier in which it is supported to be brought into tight flat abutment with the underside of the working portion 36 of the steel band 29. Since a vertical median plane including the axis of the platen and lying perpendicular to the front and back walls will also include the axis Y as illustrated in FIG. 11, it will be apparent that continued upward pressure exerted by the platen will cause the wafer to crack along the first scribe line A coincident with the Y axis as viewed in FIG. 11 and as illustrated schematically in FIGS. 13 and 14. This first crack in the wafer along the scribe line A, of course, divides the wafer into two equal halves along a median plane defined by the Y axis. The wafer is caused to crack at this scribe line by virtue of the tension imposed on the band 36 which lies in tight surface-to-surface abutment with the top surface 66 of the wafer, resulting in a concentrated bending moment being imposed against the underside of the wafer opposite the scribe line A by the upwardly moving platen 56. The two opposite halves of the wafer are caught between the underside of the taut steel band and the top surface of the platen so that a restraining force is exerted against upward movement of the wafer by the taut steel band, such restraining force being spread over the entire scribed surface of the two halves of the wafer.

It will, of course, be apparent that as the platen moves upwardly against the underside of the carrier 68, carrying the wafer into abutting surface contact with the underside of the steel band, the carrier is lifted bodily from the feed slide 84, and caused to move upwardly with the platen. Simultaneously, the upwardly moving platen imposes tension in the band in opposition to the tension therein imposed by the air cylinders 18 and 19 causing the pistons 23 in such air cylinders to move upwardly against the 100 psi pressure maintained in the cylinders above the pistons.

Continued upward movement of the platen results in greater conformation of the flexible steel band 29 with the curvature of the platen, causing each half of the wafer to be simultaneously cracked along two scribe lines B and B′ as illustrated in FIG. 15. It will thus be seen that after the first break along the scribe line A, each resulting half of the wafer is successively broken simultaneously into separate strips which remain caught between the band and the upper curved surface of the platen. Obviously, these strips retain their original orientation with respect to the carrier within which they are accommodated. As illustrated in FIG. 16, continued upward movement of the platen results in effecting the third break along the scribe lines C and C′, such breaking action of each half of the wafer continuing until the entire wafer has been broken along the scribe lines 64 parallel to the Y axis.

In the second step of the operation, the platen is retracted, the carrier and the wafer carried therein and now broken into individual strips is reoriented in the feed slide and the operation is repeated to break the wafer along the scribe lines 63 in like manner, thus effectively breaking the wafer into individual chips or dies. FIG. 11 illustrates the scribed surface of the wafer after it has been completely broken along the scribe lines 64 parallel to the Y axis. FIG. 12 illustrates the scribed surface of the wafer after it has been broken along both sets of scribe lines 63 and 64 lying parallel, respectively, to the X and Y axes. As shown, the mere act of breaking the wafer has caused the individual dies to separate somewhat to fill the recess 72 formed in the carrier 68.

FIGS. 17 and 18 illustrate diagrammatically the relationship between the taut steel band, the underlying platen, and the carrier-supported wafer interposed therebetween in relation to the X,Y and Z axes. Applying this system of axes to FIG. 1 of the drawing, the X and Y axes would lie horizontal, the X axis extending from left to right longitudinally of and parallel to the steel band 29, while the Y axis extends in a fore and aft direction perpendicular to the front and rear walls of the cabinet, and transversely of the steel band coincident with a vertical axis through the main drive cylinder 41. The Z axis extends vertically as viewed in FIG. 1, perpendicular to the X and Y axes and perpendicular also to the steel band.

FIG. 18 illustrates schematically the directions in which pressures are applied as between the taut steel band and the movable platen to effect the result described above. Obviously, different arrangements may be used to secure a similar effect. For instance, the platen might be stationary and the taut steel band, resiliently anchored at opposite ends, be forced downwardly by spools spaced on opposite sides of the platen. Thus, any appropriate means may be used to cause the band to drape itself over the platen.

After the wafer has been broken along the scribe lines 64 lying parallel to the Y axis, the feed slide 84 is withdrawn into the position illustrated in FIG. 4 and the carrier 68, supporting the wafer now broken along one set of scribe lines, must be reoriented with respect to the feed slide so that when it is again advanced to position the wafer above the platen, the scribe lines 63 will be oriented parallel to the Y axis. To effect such reorientation of the carrier, a turning device designated generally by the numeral 96 is provided attached to the lower side of the guide plate 79. This assembly is best shown in FIGS. 3–6. Referring to FIG. 3, the assembly includes an outer housing 97 having an internal bore 98 and a downwardly depending skirt portion 99. The skirt portion is provided with an inverted U-shaped slot 101, the downwardly depending arms of the U-shaped slot being positioned in the skirt 99 circumferentially 90° apart. Port means 102 are provided in the wall of the housing as shown, and a plug valve 103 is slidably disposed within the bore 98 of the housing. A handle 104 is provided attached to the plug valve, the handle being adapted to work in the U-shaped slot 101 so that the handle may be swung through an arc of 90° to rotate the plug valve through 90° within the housing. The plug valve 103 is provided with a transverse passageway 106 which in an elevated position of the plug valve communicates with the port 102. In the depressed position of the plug valve, as illustrated in FIG. 3, the transverse passageway 106 is blocked by the inner periphery of bore 98. A second passageway 107 is provided extending axially of the plug valve and communicating with the transverse passageway 106. The upper end of the passageway 107 communicates with an annular chamber 108 disposed below an apertured cap 109, the apertures 112 in the cap communicating the top surface of the cap with the chamber 108 thereunder. It will thus be seen that by manipulation of the handle 104 into a raised position, the transverse passageway 106 is brought into alignment with the port 102 so that suction or vacuum imposed on this port causes a reduced pressure in the chamber 108 and apertures 112, thus sucking the carrier 68 tightly down on the top surface of the cap 109. Since the action of elevating the plug valve to bring the passageway 106 into alignment with the port 102 has carried the top surface of the cap 109 upwardly, the carrier 68 has also been carried upwardly until the lateral edges 91–91′ and 92–92′ clear the rabbeted edges of the feed slide so that the carrier may be rotated through 90°. Such rotation is effected by swinging the handle 104 through an arc of 90° as illustrated in broken lines in FIGS. 5 and 6. The handle 104 is then lowered, causing the plug valve to slide downwardly, thus dropping the carrier 68 back into the receptacle formed by the rabbets in the feed slide 84. The wafer is now ready to be reinserted for breaking in the opposite direction. The port 102 is connected to a source of vacuum through an appropriate tubing (not shown) which extends into the housing at the nearest convenient point for connection to an appropriate fitting 113 carried on the back wall 6 of the housing.

The apparatus thus described in operated by a pneumatic circuit illustrated schematically in FIG. 8. As there shown, air under pressure is admitted from a convenient and appropriate source through a fitting 116 on the back wall 6 of the housing, connected by an appropriate tubing 117 to the inlet ports of a pair of miniature pressure regulators 118 and 119. The pressure regulators are adjustable and may be set to a selected output pressure by appropriate control knobs 121 (FIG. 1) the selected pressure being indicated on an appropriate gauge 122 extending through an aperture formed in the front wall 7 of the housing. The pressure regulators may conveniently be of the type manufactured by the C. A. Norgren Company, Littleton, Col., and sold under the model No. R06-200-RGK-AUI. The pressure regulator 119 is similarly provided with a gauge 123 correspondingly positioned in the front wall 7 of the housing, but adjacent the opposite edge 16 thereof.

The outlet port 126 of the pressure regulator 118 is connected by an appropriate tubing 127 to the inlet port 24 of the air cylinder 18, and by an appropriate branch line 127′ to the inlet port 24 of air cylinder 19. It will thus be seen that manipulation of the control knob 121 for pressure regulator 118 controls the pressure imposed on the pistons within air cylinders 18 and 19, and therefore controls the tension applied to the steel band 29. This pressure is constantly applied, there being no interruption necessary or desired so long as the device is connected to a source of air. The output side of the pressure regulator 119, is connected through an appropriate tubing 128 to spring pressed valves 129 and 131. Both of these valves are spring pressed in a normally closed attitude, the valve 129 having a push button 132 accessible from the front of the housing as illustrated in FIG. 1, while the valve 131 is operated automatically by movement of the platen 56 to its upper extremity, the platen carrying a short lever 133 adapted to engage the plunger 134 of valve 131. To vary the excursion of the platen, the position of the valve 131 within the housing, as illustrated best in FIGS. 1 and 3, is adjustable by a knob 136 which clamps the valve to an appropriate bracket 137 fastened to the back wall of the housing.

Mounted within the housing to the back wall thereof as illustrated in FIG. 1, is a four-way valve 141 having a main inlet port 142 connected to the outlet port of pressure regulator 119. As is conventional with four-way type air valves, the main input port 142 is flanked by appropriate exhaust ports indicated schematically in FIGS. 1 and 8 by the short arrows. Ports A and B, constituting the working ports of the valve, are connected respectively to ports 143 and 144 as shown. Opposite ends of the four-way valve are provided with pilot fittings 146 and 147, the pilot fitting 147 being connected to the output port of valve 129. The pilot fitting 146 is connected by an appropriate tubing **148** to the output port of valve **131** as shown. To actuate the apparatus, the fitting **116** is connected to an appropriate source of air under pressure, and pressure regulators **118** and **119** adjusted to the desired pressure level. It should be noted that the pressure regulator **119** is connected to the four-way valve through the inlet port **142** and therefore controls the pressure of air passing through this valve into the main drive cylinder **41**. After adjustment of the pressure, a wafer is positioned above the platen as previously described, and when in place, the push button **132** is depressed momentarily. Valve **129** is thus opened to admit air under pressure to the pilot fitting **147**, which causes the valve spool within the valve housing to shift to the left as viewed in FIG. **8**, permitting high pressure air to pass through the valve housing and port B to be admitted into the cylinder **41** through port **143** so as to cause upward movement of the piston within the cylinder. Such upward movement of the piston and platen is resisted by the tension imposed on band **29** by cylinders **18** and **19**. As previously discussed, the effective area of piston **46** in cylinder **41** is correlated to the effective area of the pistons in cylinders **18** and **19** so that the platen is carried upwardly and the pistons **23** in cylinders **18** and **19** are also carried upwardly while imposing tension on the band.

When the platen has reached its upper extremity, lever **133** (FIG. **3**) engages plunger **134** of valve **131**, causing high-pressure air to pass through this valve, through tubing **148** and into the pilot fitting **146** of the main four-way valve. The valve spool is thus shifted to the right, connecting port B thereof to one of the exhaust ports, and connecting port A to the source of high-pressure air so that air under pressure is now admitted to port **144** into the air cylinder **41** above the piston, driving the piston downwardly to shift the platen into a wafer loading position. After withdrawing the feed slide, the wafer turning mechanism **96** is actuated to rotate the wafer 90° so as to reorient it for breaking along scribe lines extending in the opposite direction to the scribe lines broken in the first operation. The feed slide is pushed in, the push button **132** is again depressed, and the apparatus is automatically recycled so as to break the wafer in the other direction.

While the foregoing constitutes manual operation of the apparatus, it will be clear that through appropriate automated feeding equipment and automated controls, the operation may proceed substantially completely without human intervention.

Having thus described the invention, what is claimed to be novel and sought to be protected by letters patent is as follows:

1. In an apparatus for breaking a flat semiconductor wafer along predefined scribe lines, the combination comprising:

a. platen means having a curved surface adapted to initially support thereon a flat scribed wafer; and
b. non-resilient metal band means opposed to said platen initially tangentially related to the curved surface thereof and progressively conformable thereto by relative movement therebetween perpendicular to the surface of said wafer whereby a flat scribed wafer disposed between the curved surface of the platen and said means conformable thereto is broken along said scribe lines.

2. The combination according to claim **1**, in which the curved surface on said platen means is curvilinear, said means opposed to said platen constitutes a flexible band, and the linear dimension of said curved surface extends transverse of said flexible band.

3. In an apparatus for breaking a flat semiconductor wafer along predefined scribe lines cut in one surface thereof, the combination comprising:

a. means having a curved surface adapted to initially engage in line contact the side of a wafer remote from said scribe lines, said line engagement extending substantially parallel to said scribe lines; and
b. means adapted to engage in non-slipping surface contact the initially flat scribed surface of a wafer the opposite side of which is engaged in line contact by said means having a curved surface;
c. said means in surface contact with the scribed surface of the wafer comprising a non-resilient metal band progressively conformable to said curved surface by movement perpendicular thereto whereby said wafer is caused by said band to conform to said curved surface to thereby break said wafer into portions defined by said scribe lines.

4. The combination according to claim **3**, in which said means having a curved surface constitutes a platen movable from a flat wafer loading position through successive wafer breaking positions in which said wafer is made to conform to said platen and back to said flat wafer loading position.

5. The combination according to claim **3**, in which said means having a curved surface constitutes a platen having a convex curvilinear surface thereon, said means adapted to engage the flat scribed surface of the wafer in surface contact constitutes a flexible band spaced from said platen an amount sufficient to permit interposition of said wafer therebetween, and means for effecting wrapping of said band about the convex curvilinear surface of said platen.

6. The combination according to claim **3**, in which control means are provided selectively operable to effect progressive conformability of said means in surface contact with the scribed surface of the wafer to said curved surface, and means disposed between said curved surface means and said band means to retain said band means from slipping in relation to said curved surface means.

7. The combination according to claim **3**, in which said means having a curved surface constitutes a platen, said means conformable to the curved surface of said platen constitutes a flexible band, and said apparatus includes a housing divided into a wafer-breaking section and a power section, said platen and said band being enclosed within said wafer-breaking section of the housing.

8. The combination according to claim **3**, in which said means having a curved surface comprises a platen, said means adapted to conform to said curved surface comprises a flexible band, said apparatus includes a frame on which said platen and said band are supported, and means are provided on said frame connected to said platen and said band and selectively operate to effect movement thereof to conform said band to said curved surface.

9. In an apparatus for breaking a flat semiconductor wafer along predefined scribe lines, the combination comprising:

a. platen means having a curvilinear surface formed by lines parallel to the Y axis in a three dimensional XYZ system of axes and adapted to support thereon a wafer having scribe lines parallel to at least said Y axis; and

b. tensioned strap means spaced from said curvilinear surface and initially abuttable against the flat scribed surface of a wafer disposed between said curvilinear surface and said tensioned strap means, said tensioned strap means starting at said Y axis being progressively conformable to portions of said curvilinear surface lying on opposite sides of said Y axis to apply pressure progressively to the side of said wafer opposite said curved surface starting from said Y axis and progressing circumferentially thereabout whereby said wafer is progressively broken first along one of said scribe lines coincident with said Y axis and then successively along pairs of said scribe lines formed by scribe lines correspondingly spaced on opposite sides of said Y axis.

10. The method of breaking a semiconductor wafer scribed on one side to provide two sets of parallel score lines disposed at right angles to each other, comprising the steps of:

a. orienting a median scribe line of the wafer in supported relation to a curved surface formed by straight lines extending parallel to one set of said scribe lines including said median scribe line; and applying pressure progressively to the side of said wafer opposite said curved surface starting from said median scribe line and progressively therefrom and thus causing said initially flat unbroken wafer to progressively conform to said curved surface by cinching the wafer progressively starting with said median scribe line to said curved surface with a taut flexible band whereby said wafer is stressed to effect breaking thereof first along said median scribe line and thence progressively simultaneously along scribe lines correspondingly spaced on opposite sides of said median scribe line.

11. The method according to claim **10**, in which tension is applied to said flexible band to effect cinching thereof around said curved surface.

12. The method according to claim **10**, in which said curved surface is curvilinear, the straight lines forming said curved surface extending parallel to the Y axis of a system of XYZ axes, causing said curved surface to move in the direction of said Z axis, and tensioning said flexible band in the direction of said X axis while retaining the band against slippage in relation to said wafer.

13. The method of breaking a semiconductor wafer scribed on one side to provide two sets of parallel score lines disposed at right angles to each other, comprising the steps of:

a. orienting the wafer in relation to an XYZ system of axes so that one set of said scribe lines extends parallel to the X axis and the other set of said scribe lines extends parallel to said Y axis;

b. applying pressure progressively to both sides of said wafer along lines coincident with said scribe lines parallel to said Y axis whereby said wafer is first broken along a median scribe line parallel to said Y axis and thence progressively simultaneously broken along scribe lines correspondingly spaced on opposite sides of said Y axis;

c. removing the pressure from said wafer whereby the broken strips of wafer reorient themselves in a flat attitude;

d. reorienting the wafer so that the other set of scribe lines lies parallel to said Y axis; and

e. again imposing pressure progressively on both sides of said wafer in the direction of said Z axis along lines coincident with said scribe lines parallel to said Y axis to effect breaking of said wafer strips along a median scribe line parallel to said Y axis and thence progressively simultaneously along scribe lines correspondingly spaced on opposite sides of said Y axis.

14. In an apparatus for breaking a flat semiconductor wafer along predefined scribe lines, the combination comprising:

a. platen means having a curved surface adapted to initially support thereon a flat scribed wafer; and

b. means opposed to said platen initially tangentially related to the curved surface thereof and progressively conformable thereto by relative movement therebetween perpendicular to the surface of said wafer whereby a flat scribed wafer disposed between the curved surface of the platen and said means conformable thereto is broken along said scribe lines;

c. said means opposed to said platen means comprising a taut band resiliently anchored at each end, said platen means being movable against said band in opposition to said resilient anchoring means.

15. In an apparatus for breaking a flat semiconductor wafer along predefined scribe lines, the combination comprising:

a. platen means having a curved surface adapted to initially support thereon a flat scribed wafer; and

b. means opposed to said platen initially tangentially related to the curved surface thereof and progressively conformable thereto by relative movement therebetween perpendicular to the surface of said wafer whereby a flat scribed wafer disposed between the curved surface of the platen and said means conformable thereto is broken along said scribe lines;

c. said means opposed to said platen means constituting a flexible band, means provided to tension said band, and means provided to move said platen in opposition to said band to effect cinching of said band about the curved surface of said platen means.

16. In an apparatus for breaking a flat semiconductor wafer along predefined scribe lines, the combination comprising:

a. platen means having a curved surface adapted to initially support thereon a flat scribed wafer; and

b. means opposed to said platen initially tangentially related to the curved surface thereof and progressively conformable thereto by relative movement therebetween perpendicular to the surface of said wafer whereby a flat scribed wafer disposed between the curved surface of the platen and said means conformable thereto is broken along said scribe lines;

c. said means opposed to said platen means constituting a band, said platen means being movable relative to said band, and pneumatic circuit means including a pair of air cylinders provided to impose tension on said band in opposition to movement of said platen means thereagainst.

17. In an apparatus for breaking a flat semiconductor wafer along predefined scribe lines, the combination comprising:

a. platen means having a curved surface adapted to initially support thereon a flat scribed wafer; and

b. means opposed to said platen initially tangentially related to the curved surface thereof and progressively conformable thereto by relative movement therebetween perpendicular to the surface of said wafer whereby a flat scribed wafer disposed between the curved surface of the platen and said means conformable thereto is broken along said scribe lines;

c. said means opposed to said platen means comprising a flexible band, and control means provided to effect progressive conformability of said band to the curved surface of said platen means so as to cinch a wafer interposed therebetween into conformity with the curvature of said platen means, said control means including an air cylinder operable to effect movement of said platen means, a pair of air cylinders attached to opposite ends of said flexible band to impose tension thereon, pressure regulator means for controlling the pressure in said air cylinders, valve means for controlling release of air under pressure to the air cylinder controlling movement of said platen means, and valve means actuated by said platen means upon completion of a predetermined excursion and effective to reverse the cycle to return the platen means to a wafer loading position and release tension on said flexible band.

18. In an apparatus for breaking a flat semiconductor wafer along predefined scribe lines cut in one surface thereof, the combination comprising:

a. means having a curved surface adapted to engage in line contact the side of a wafer remote from said scribe lines, said line engagement extending substantially parallel to said scribe lines; and

b. means adapted to engage in surface contact the flat scribed surface of a wafer the opposite side of which is engaged in line contact by said curved surface;

c. said means in surface contact with the scribed surface of the wafer being progressively conformable to said curved surface by movement perpendicular thereto whereby said wafer is caused to conform to said curved surface to thereby break said wafer into portions defined by said scribe lines;

d. said means having a curved surface adapted to engage said wafer in line contact comprising a platen having a curvilinear surface thereon, said means adapted to engage the flat scribed surface of a wafer in surface contact comprising a taut flexible band disposed adjacent said curved surface of the platen whereby wrapping of said band about said platen effects breaking of said wafer first along a median scribe line and thence progressively simultaneously along scribe lines correspondingly spaced on opposite sides of said median scribe line.

19. In an apparatus for breaking a flat semiconductor wafer along predefined scribe lines cut in one surface thereof, the combination comprising:

a. means having a curved surface adapted to engage in line contact the side of a wafer remote from said scribe lines, said line engagement extending substantially parallel to said scribe lines;

b. means adapted to engage in surface contact the flat scribed surface of a wafer the opposite side of which is engaged in line contact by said curved surface;

c. said means in surface contact with the scribed surface of the wafer being progressively conformable to said curved surface by movement perpendicular thereto whereby said wafer is caused to conform to said curved surface to thereby break said wafer into portions defined by said scribe lines; and

d. a pneumatic circuit including a plurality of selectively operable air cylinders, a pair of said air cylinders being connected to said flexible band and another of said cylinders being connected to said platen, and valve means for actuating said cylinder connected to said platen to effect movement of said platen in opposition to said band.

20. In an apparatus for breaking a flat semiconductor wafer along predefined scribe lines cut in one surface thereof, the combination comprising:

a. means having a curved surface adapted to engage in line contact the side of a wafer remote from said scribe lines, said line engagement extending substantially parallel to said scribe lines; and

b. means adapted to engage in surface contact the flat scribed surface of a wafer the opposite side of which is engaged in line contact by said curved surface;

c. said means in surface contact with the scribed surface of the wafer being progressively conformable to said curved surface by movement perpendicular thereto whereby said wafer is caused to conform to said curved surface to thereby break said wafer into portions defined by said scribe lines;

d. said apparatus including a housing having a wafer-breaking section and a power section, and wafer support means are provided associated with said wafer-breaking section of the housing operable to support said wafer in said wafer-breaking section between said means having a curved surface and said means conformable thereto.

21. In an apparatus for breaking a flat semiconductor wafer along predefined scribe lines, the combination comprising:

a. platen means having a curvilinear surface formed by lines parallel to the Y axis in a three dimensional XYZ system of axes and adapted to support thereon a wafer having scribe lines parallel to at least said Y axis;

b. strap means spaced from said curvilinear surface and initially abuttable against the flat scribed surface of a wafer disposed between said curvilinear surface and said strap means, said strap means being progressively conformable to portions of said curvilinear surface lying on opposite sides of said Y axis whereby said wafer is progressively broken first along one of said scribe lines coincident with said Y axis and then successively along pairs of said scribe lines formed by scribe lines correspondingly spaced on opposite sides of said Y axis; and

c. means to impose tension on said strap means and for effecting movement of said strap means to effect progressive conformability of said strap means to said curvilinear surface.

22. In an apparatus for breaking a flat semiconductor wafer along predefined scribe lines, the combination comprising:

a. platen means having a curvilinear surface formed by lines parallel to the Y axis in a three dimensional XYZ system of axes and adapted to support thereon a wafer having scribe lines parallel to at least said Y axis; and

b. strap means spaced from said curvilinear surface and initially abuttable against the flat scribed surface of a wafer disposed between said curvilinear surface and said strap means, said strap means being progressively conformable to portions of said curvilinear surface lying on opposite sides of said Y axis whereby said wafer is progressively broken first along one of said scribe lines coincident with said Y axis and then successively along pairs of said scribe lines formed by scribe lines correspondingly spaced on opposite sides of said Y axis;

c. said apparatus including a housing including an intermediate support wall dividing said housing into a wafer-breaking section and the power section, said platen means and said strap means being enclosed within said wafer-breaking section, and power means provided within said power section and connected to said platen means and strap means to tension said strap and effect movement thereof to progressively conform the strap means to said platen means.

23. In an apparatus for breaking a flat semiconductor wafer along predefined scribe lines, the combination comprising:

a. platen means having a curvilinear surface formed by lines parallel to the Y axis in a three dimensional XYZ system of axes and adapted to support thereon a wafer having scribe lines parallel to at least said Y axis;

b. strap means spaced from said curvilinear surface and initially abuttable against the flat scribed surface of a wafer disposed between said curvilinear surface and said strap means, said strap means being progressively conformable to portions of said curvilinear surface lying on opposite sides of said Y axis whereby said wafer is progressively broken first along one of said scribe lines coincident with said Y axis and then successively along pairs of said scribe lines formed by scribe lines correspondingly spaced on opposite sides of said Y axis; and

c. control means for controlling movement of said strap means and platen means, said control means including a pneumatic circuit having a plurality of air-actuated cylinders therein, one of said cylinders being operatively connected to said platen means, and a pair of said cylinders connected to opposite ends of said strap means whereby each cylinder acts in opposition to the other cylinders.

24. In an apparatus for breaking a flat semiconductor wafer along predefined scribe lines, the combination comprising:

a. platen means having a curvilinear surface formed by lines parallel to the Y axis in a three dimensional XYZ system of axes and adapted to support thereon a wafer having scribe lines parallel to at least said Y axis;

b. strap means spaced from said curvilinear surface and initially abuttable against the flat scribed surface of a wafer disposed between said curvilinear surface and said strap means, said strap means being progressively conformable to portions of said curvilinear surface lying on opposite sides of said Y axis whereby said wafer is progressively broken first along one of said scribe lines coincident with said Y axis and then successively along pairs of said scribe lines formed by scribe lines correspondingly spaced on opposite sides of said Y axis; and

c. a frame, said platen means and strap means being supported on said frame, and wafer support means mounted on said frame and selectively operable to insert an unbroken wafer between said platen means and said strap means and to withdraw said wafer therefrom after it has been broken.

25. In an apparatus for breaking a flat semiconductor wafer along predefined scribe lines, the combination comprising:

a. platen means having a curvilinear surface formed by lines parallel to the Y axis in a three dimensional XYZ system of axes and adapted to support thereon a wafer having scribe lines parallel to at least said Y axis; and

b. strap means spaced from said curvilinear surface and initially abuttable against the flat scribed surface of a wafer disposed between said curvilinear surface and said strap means, said strap means being progressively conformable to portions of said curvilinear surface lying on opposite sides of said Y axis whereby said wafer is progressively broken first along one of said scribe lines coincident with said Y axis and then successively along pairs of said scribe lines formed by scribe lines correspondingly spaced on opposite sides of said Y axis;

c. said apparatus including a frame, said platen means and strap means being supported on said frame, a wafer support assembly mounted on said frame for supporting a wafer oriented so that a selected set of scribe lines thereon lie parallel to said Y axis, said wafer support means including a feed slide movable to carry a properly oriented wafer between said platen means and said strap means, said strap means extending in the direction of said X axis, means associated with said strap means for imposing tension on said strap means in the direction of said X axis, means associated with said platen means for effecting movement of said platen in the direction of said Z axis whereby said strap means is caused to be wrapped around the curvilinear surface of said platen means to effect progressive breaking of said wafer along a first set of scribe lines, and means associated with said feed slide to effect rotation of said wafer by approximately 90° so as to reorient the wafer with the unbroken set of scribe lines parallel to said Y axis.

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