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(54) Title: METHOD FOR DESIGNING A CUTTING EDGE OF A CUTTING TOOL, CUTTING TOOLS COMPRISING THE SAME, AND CUTTING ELEMENTS WITH MULTIPLE SUCH CUTTING PORTIONS

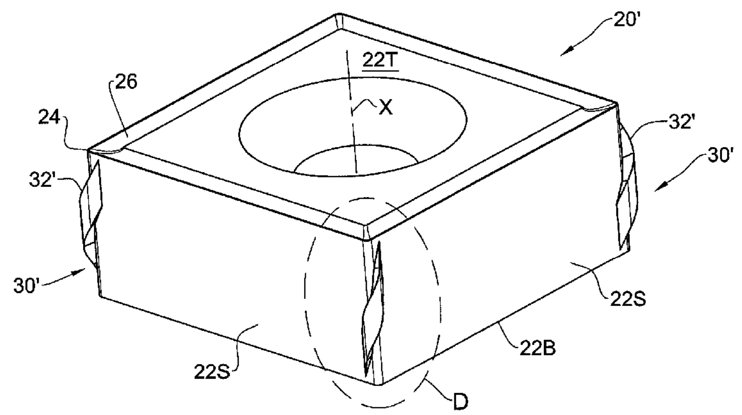

Fig. 14A

(57) Abstract: A method for designing a cutting edge of a cutting element configured for removing material from a workpiece to leave therein a desired end profile. The method comprises the steps of modeling a desired end profile of the workpiece, the profile having a longitudinal axis and being defined by a bottom surface, a side surface and an adjoining surface extending therebetween; defining a lead profile plane and an trail profile plane spaced therefrom, each of the planes being oriented perpendicular to the longitudinal axis; determining a profile contour defined by the intersection line between the end profile and the lead profile plane. The contour profile includes a bottom contour defined as the intersection line between the lead profile plane and the bottom surface, an adjoining contour defined as the intersection line between the lead profile plane and the adjoining surface, and a side contour defined as the intersection line between the lead profile plane and the side surface; designing a rake surface and a relief surface, the intersection line between which defines a cutting edge lying in the adjoining surface and spanning between the lead profile plane and the trail profile plane. The cutting edge is designed such that in any reference plane oriented perpendicular to the cutting edge, the intersection between each of the rake surface and the relief surface with the reference plane defines a respective rake line and relief line, the angle between the lines being equal to or smaller than a similar angle taken along each of a plurality of similar reference planes disposed between the reference plane and the lead profile plane.

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— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

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METHOD FOR DESIGNING A CUTTING EDGE OF A CUTTING TOOL, CUTTING TOOLS COMPRISING THE SAME, AND CUTTING ELEMENTS WITH MULTIPLE SUCH CUTTING PORTIONS

TECHNOLOGICAL FIELD

The subject matter of the present application refers to methods of designing cutting tools, in particular, methods for designing the cutting edge, rake and relief surfaces thereof, cutting tools and inserts designed by the method above and comprising additional cutting elements on a relief surface thereof, and/or a plurality of cutting edges.

PRIOR ART

References considered to be relevant as background to the presently disclosed subject matter are listed below:

- WO2011/001438

Acknowledgement of the above references herein is not to be inferred as meaning that these are in any way relevant to the patentability of the presently disclosed subject matter.

BACKGROUND

Cutting tools are used for removing material from a workpiece in order to manufacture therefrom a desired final element. There exists in common practice a great variety of operations for the removal of material, for each of which, a specific tool is designed, which may be in the form of a single body or in the form of a tool holder with one or more replaceable cutting inserts mounted thereon. Examples of such operations are drilling, milling, turning, boring etc.

A majority of cutting tools or cutting inserts are formed with a cutting edge adapted to come in contact with the workpiece, within a cutting zone, so as to remove material therefrom during a cutting operation, the removed material being in the form of a chip.

Each cutting edge of a cutting tool or cutting insert is known to have a rake surface extending from the cutting edge in the direction away from the workpiece and a relief surface extending from the cutting edge transversely to the rake surface and generally facing in the direction of the workpiece, the cutting edge being defined at the intersection between its rake and relief surfaces.

The rake surface is adapted to come in contact with the removed chip, while the relief surface is generally designed so as not to come in contact with the workpiece during cutting operation.

Cutting tools are designed so that the angle between the rake and the relief surface allows positioning the cutting tool with respect to the workpiece during a cutting operation in a way preventing the relief surface from coming in contact with the workpiece while providing a sufficient cutting angle and support to the cutting tool to obtain (a) efficient removal of chips from the workpiece and (b) sufficient mechanical integrity to the cutting edge.

Cutting tools are used for removing material from a workpiece to manufacture therefrom of desired final element. There exists in common practice a great variety of operations for the removal of material, for each of which, a specific tool is designed. Examples of such operations are drilling, milling, turning, boring etc.

The majority of cutting tools are formed with a sharp cutting edge adapted to come in contact with the workpiece, within a cutting zone, to remove material therefrom in the form of a chip, in a process referred to as chipping. During such process there is usually provided a linear displacement of the cutting tool relative to the workpiece, referred to as 'feed' and either rotation of the cutting tool with respect to the workpiece, such as e.g. in milling and drilling, or rotation of the workpiece with respect to the cutting tool, such as e.g. in turning.

Chips must be evacuated continuously during chipping and any congestion may rapidly lead to high loads, overheating and consequent break-down and failure of the cutting tool.

The cutting edge of a cutting tool is generally defined as an intersection line between a rake surface and a relief surface.

The rake surface is adapted to come in contact with the removed chip and, as such, its geometry influences the length and geometry of the removed chip, and more importantly, the manner of evacuation of the chip from the cutting zone.

The relief surface is generally designed so as not to come in contact with the portion of the workpiece from which the chip has been removed. Depending on the angle between the relief surface and the rake surface, the cutting tool is positioned such as to avoid contact between the relief surface and the workpiece.

It has been known to provide additional elements on the relief surface, for example, elements configured for deforming the workpiece prior to the cutting operation, for example, as set forth by the applicant himself in WO09053803.

Furthermore, the additional elements are also known to being used as cutting elements, as set forth by the applicant himself in WO11001438.

Cutting tools are used for removing material from a workpiece in order to manufacture therefrom a desired final element. There exists in common practice a great variety of operations for the removal of material, for each of which, a specific tool is designed, which may be in the form of a single body or in the form of a tool holder with one or more replaceable cutting inserts mounted thereon. Examples of such operations are drilling, milling, turning, boring etc.

A majority of cutting tools or cutting inserts are formed with a cutting edge adapted to come in contact with the workpiece, within a cutting zone, so as to remove material therefrom during a cutting operation, the removed material being in the form of a chip, and the process of forming chips being known as chipping.

During a cutting operation there is usually provided a linear displacement of the cutting tool relative to the workpiece, referred to as 'feed' and either rotation of the cutting tool about its central axis with the workpiece being stationary, such as e.g. in milling and drilling operations, or rotation of the workpiece about its central axis with the tool moving only linearly such as e.g. in turning, slotting, parting and the like.

Chips must be evacuated continuously during chipping and any congestion may rapidly lead to high loads, overheating, quick wear and consequent break-down, failure or malfunction of the cutting tool or cutting insert.

Each cutting edge of a cutting tool or cutting insert is known to have a rake surface extending from the cutting edge in the direction away from the workpiece and a relief surface extending from the cutting edge transversely to the rake surface and generally facing in the direction of the workpiece, the cutting edge being defined at the intersection between its rake and relief surfaces.

The rake surface is adapted to come in contact with the removed chip and may have chip deforming/splitting/breaking or the like means whose design is such as to facilitate the evacuation of the chip from the cutting zone.

The relief surface is generally designed so as not to come in contact with the workpiece during cutting operation. With a given angle between the relief and rake surfaces of each cutting edge, this is achieved by the cutting tool/cutting insert being positioned during cutting operation such as to provide a distance between the relief surface and the workpiece, said distance normally increasing in the direction away from the cutting edge.

During a cutting operation, the amount of material to be removed per time unit by a given cutting tool from a given workpiece, and particularly, the thickness of the chip removed, depends on a number of parameters including the speed of rotation $\mathbf{V_R}$ of the cutting tool relative to the workpiece and the feed **F**.

On the other hand, the above parameters have a drastic influence on loads exerted on the cutting tool during chipping. The loads exerted on the cutting tool may be so high as to cause damage thereto, rendering it useless. On top of this, friction of the cutting tool with the workpiece causes heating of the former and the latter at the cutting zone, due to which extensive cooling, usually by means of a cooling liquid, is normally required. To avoid undesirable cutting conditions, the feed **F** and rotation speed $\mathbf{V_R}$ are thus limited, and so is, as a consequence, the power used.

GENERAL DESCRIPTION

According to one aspect of the subject matter of the present application there is provided a cutting element for removing material from a workpiece and forming therein an end profile extending along a longitudinal axis, said cutting tool being formed with a cutting portion having a rake surface and a relief surface and a cutting edge defined therebetween and comprising a bottom segment and a side segment, the cutting portion being boundable by a bottom reference surface and a side reference surface transverse thereto, so that said bottom segment lies along a maximal length thereof, on said bottom surface and said side segment lies along a maximal length thereof, on said side surface, the cutting edge further comprising an adjoining segment lying outside the bottom and side reference surfaces, said adjoining segment being defined by an intersection between corresponding rake and relief portions of said rake surface and relief surfaces, wherein, for any given normal reference plane oriented perpendicular to said adjoining segment and disposed between the said leading and trailing ends thereof, the intersection between each of the rake portion and the relief portion with said normal reference plane defines a respective rake line and relief line and the angle between these lines is equal to or smaller than a corresponding angle taken along each of a plurality of other normal reference planes disposed between the given normal reference plane and the leading end.

It should be noted that the bridging segment is not limited to extending between a lead point lying on the bottom segment and a trail point lying on the side segment or vise versa. In particular, according to one example, the bridging segment can extend so as to bridge the bottom and side segments, merging therewith via its leading and trailing ends. According to another example, the bridging segment can be disposed behind the bottom and/or side segments.

In addition, the cutting element can comprise one or more bridging segments lying outside the bottom and/or side segments. The arrangement can be such that the one or more bridging segments, cover, in a proper projection, the entire profile between the bottom and the side segments.

According to another aspect of the subject matter of the present application there is provided a method for designing a cutting edge of a cutting element configured for removing material from a workpiece to leave therein a desired end profile, said method comprising:

- modeling a desired end profile of the workpiece, said profile having a longitudinal axis and being defined by a bottom surface, a side surface and an adjoining surface extending therebetween;
- defining a lead profile plane and an trail profile plane spaced therefrom, each of the planes being oriented perpendicular to said longitudinal axis;
- determining a profile contour defined by the intersection line between said end profile and said lead profile plane, including:
    - o a bottom contour defined as the intersection line between said lead profile plane and said bottom surface;
    - o an adjoining contour defined as the intersection line between said lead profile plane and said adjoining surface; and

- a side contour defined as the intersection line between said lead profile plane and said side surface;

- designing a rake surface and a relief surface, the intersection line between which defines a cutting edge lying in the adjoining surface and spanning between the lead profile plane and the trail profile plane such that in any reference plane oriented perpendicular to said cutting edge, the intersection between each of the rake surface and the relief surface with said reference plane defines a respective rake line and relief line, the angle between said lines being equal to or smaller than a similar angle taken along each of a plurality of similar reference planes disposed between the reference plane and the lead profile plane.

Hereinafter, the following terms will be adhered to:

- ***ruled surface*** – a surface in which through every point on the surface there is a straight line that lies on the surface. Typical examples are a plane, a cylinder, and, in general, any contour which is swept along a straight line. It is noted here that a cone is also considered a ruled surface which is formed by keeping one point of a straight line fixed whilst moving another point along a circle;
- ***toroid-like surface*** – in principle, a toroid surface is generated by revolving a plane geometrical figure about an axis external to that figure which is parallel to the plane of the figure and does not intersect the figure (e.g. a torus). A toroid-like surface should be understood as a surface generated by a contour (not necessarily of a regular shape) being revolved about such an axis;
- **surface** – a surface constituting the envelope of a body; and
- **plane** – a two-dimensional geometric structure used to provide a required geometric reference.

According to one design, the longitudinal axis which can be a straight line, in which case the adjoining surface obtains the shape of a portion of a ruled surface. In addition, according to a particular example of the above design, the ruled surface can be a portion of a cylinder. In addition, both the bottom surface and the side surface can be planar surfaces.

According to another design, the longitudinal axis can be an arc extending about a rotation axis, in which case the adjoining surface obtains the shape of a portion of a toroid-like surface. In addition, according to a particular example of the above design, the bottom surface can be a planar surface while the side surface can constitute a portion of a cylindrical surface.

The above design, yielding a toroid-like surface, can assume two main configurations:

concave configuration – in this case, the rotation axis is disposed facing the adjoining contour, whereby the resulting adjoining surface faces the rotation axis, i.e. constitutes an internal portion of the toroid-like surface; and

convex configuration – in this case, the rotation axis is disposed facing away from the adjoining contour, whereby the resulting adjoining surface faces away from the rotation axis, i.e. constitutes an external portion of the toroid-like surface.

In both of the above examples, since the adjoining segment of the cutting edge is designed to extend between the lead profile plane and the trail profile plane, the length $L_{ADJ-SEG}$ thereof is inevitably greater than the length $L_{ADJ-CON}$ of the adjoining contour. In particular, the ratio R_{ADJ} ($L_{ADJ-SEG}$:$L_{ADJ-CON}$) can be $R_{ADJ} \geq 1.25$, in particular $R_{ADJ} \geq 1.5$, even more particularly $R_{ADJ} \geq 1.75$, still more particularly $R_{ADJ} \geq 2$ and up to $R_{ADJ} = 10$.

The above designs of the adjoining surface are configured for the design of different cutting tools required for different cutting operations as follows:

ruled surface – configured for shaping, planing and broaching;

toroid-like surface, concave configuration – configured for drilling and milling; and

toroid-like surface, convex configuration – configured for turning and hole sawing.

Per the above, two main principles are provided for defining the trajectory/shape of the cutting curve corresponding to the adjoining segment:

<u>Mathematical method</u>

- defining a helix base axis;
- defining a pierce line extending from and oriented perpendicular to the helix base axis so that an end or the virtual extension thereof pierces the adjoining surface at a pierce point;

- defining a pitch increment **p'** and an angle increment **θ'**;
- displacing the pierce line along the helix base axis at corresponding pitch and angle increments **p'** and **θ'**;
- for each such displacement, defining a pierce point of the pierce line;
- obtaining a pierce curve extending along the adjoining surface defined by the plurality of pierce points;
- calculating the ratio $\mathbf{R_{ADJ}}$ between the length of the pierce curve and the length of the adjoining contour; and, if $\mathbf{R_{ADJ}}$ does not match a desired ratio
- re-defining the pitch increment **p'** and the angle increment **θ'** to obtain such a desired ratio $\mathbf{R_{ADJ}}$.

The pierce curve yielded by the above steps of the mathematical method constitutes the desired adjoining segment of the cutting edge. In particular, in examples in which the adjoining surface is a torus or a cylinder, the pierce curve (and consequently the adjoining segment) can constitute a portion of a helix.

With reference to the above, according to a particular example, the helix base axis can be constituted by the longitudinal axis or an axis parallel thereto.

As explained above, the overall pitch **P** of the pierce curve can be chosen based on the desired adjoining ratio $\mathbf{R_{ADJ}}$. The pitch **P** is defined by the number of pitch increments **p'** at which the sum of angle increments **θ'** equals 360°.

In this connection, it should be appreciated that the adjoining surface is never a closed contour surface, i.e. the cross-section thereof (the adjoining contour) does not produce a closed contour. As such, on the one hand, if a greater $\mathbf{R_{ADJ}}$ is desired, the pitch of the pierce curve should be increased, thereby increasing the length $\mathbf{L_{ADJ\text{-}SEG}}$ of the adjoining segment. However, on the other hand, since the dimensions of the ajoining surface are finite, it should be understood that a too greater pitch may cause the pierce curve to not fully intersect the adjoining surface. Therefore, during design of the cutting edge, an optimization of the length should be performed based on $\mathbf{L_{ADJ\text{-}SEG}}$, the dimensions of the adjoining surface and the desired $\mathbf{R_{ADJ}}$.

<u>Empiric method</u>

<u>Variation I</u>

- defining a lead point on the bottom surface or on the adjoining surface, being closer to the lead profile plane that to the trail profile plane;

- defining a trail point on the side surface or on the adjoining surface, being closer to the trail profile plane that to the lead profile plane;
- defining an intermediate point on the adjoining surface disposed between the lead profile plane and the trail profile plane;
- defining an intersecting plane by passing through the lead point, the trail point and the intermediate point;
- defining an intersecting curve which is constituted by the intersection line between the intersecting plane and the adjoining surface;
- calculating the ratio R_{ADJ} between the length of the intersecting curve and the length of the adjoining contour; and, if $\mathbf{R_{ADJ}}$ does not match a desired ratio
- re-positioning the lead point, trail point and intermediate point to obtain such a desired ratio $\mathbf{R_{ADJ}}$.

The intersecting curve yielded by the above steps of the empiric method constitutes the desired adjoining segment of the cutting edge.

According to one example, the lead point lies on the lead profile plane, at the intersection thereof with the bottom surface and the trail point lies on the trail profile plane, at the intersection thereof with the side surface. According to another example, the lead point lies on the bottom surface and the trail point lies on the side surface.

According to a particular design, it may be beneficial for the intermediate point to be located on the adjoining surface approximately between the bottom surface and the side surface, and for the distance between the intermediate point and each one of the lead profile plane and the trail profile plane to be generally similar.

Thus, during the re-positioning step, the intermediate point may remain in place and only the lead point and the trail point can be re-positioned in terms of the distance between them and the respective lead profile plane and trail profile plane.

<u>Variation II</u>

- defining an elevated reference plane disposed above the end profile and oriented to generally face at least the adjoining surface;
- defining a mimic curve extending along the elevated reference plane, the mimic curve having a start point and an end point;
- obtaining a mimic projection on the end profile in a view normal to the elevated reference plane, the mimic projection having a projection start point

and a projection end point; if the mimic projection does not completely intersects the adjoining surface

- re-orienting the elevated reference plane so that the projection start point and projection end point lie outside the adjoining surface or on the edge thereof;
- calculating the ratio R_{ADJ} between the length of the mimic projection and the length of the adjoining contour; and, if $\mathbf{R_{ADJ}}$ does not match a desired ratio
- re-orienting the elevated reference plane to obtain such a desired ratio $\mathbf{R_{ADJ}}$.

The mimic projection yielded by the above steps of the empiric method constitutes the desired adjoining segment of the cutting edge.

As explained above, the term '*completely intersects*' should be understood as defining that the projection start point and projection end point lie outside the adjoining surface or on the edge thereof.

With reference to the above, according to a particular example, the mimic curve can be constituted by a simple geometric curve, e.g. a straight line, an arc etc..

It should be understood that the above steps of the method can be extended to the design of either or both of the bottom surface and the side surface, in which case the elevated reference plane should be re-oriented so that the mimic projection fully intersects either or both of the bottom surface and the side surface respectively.

In connection with the above two variations of the empiric method, it is appreciated that each provides an approximation method for obtaining an adjoining segment which is generally similar to the adjoining segment yielded by the mathematical method.

Designing the rake and relief surfaces to acquire the features defined in the previous aspects of the subject matter of the present application can be performed as follows:

- defining a plurality of reference planes successively disposed along the cutting curve, each being pierced by said curve at a piercing point and being perpendicular to the curve at the piercing point;
- obtaining along each of said reference planes the projection of at least the adjoining contour;
- defining along each of said reference planes:
    - o a base line tangent to said projection at said piercing point; and
    - o a chip line perpendicular to said base line at said piercing point;

- defining, on each of said reference planes, a cutting contour constituted by a rake line and a relief line extending from said piercing point to define:
  - a desired cutting angle between said rake line and said chip line;
  - a desired body angle between said rake line and said relief line; and
  - a desired rear angle between said relief line and said base line;
- the body angle of the cutting contour on each reference plane being equal to or smaller than the body angle of the cutting contour of each of a plurality of reference planes disposed between the reference plane and the lead profile plane;
- designing a cutting tool constituted by a rake surface and a relief surface, each being defined by the rake and relief lines of each of the reference planes respectively.

In addition, it should be appreciated that on each of the reference planes, the rake and relief lines are designed according to the projection of the profile contour on that specific plane. In addition, the length and shape of the rake line and of the relief line are designed according to different requirements of the cutting tool, including dimensions.

Thus, in each of the reference planes the shape and angle of the rake line and of the relief line can be different and individual to that specific reference plane. In particular, the design of the rake line and of the relief line is such that they do not intersect the profile contour at any point other than the pierce point. More specifically, the design is such that the resulting cutting tool and cutting edge do not intersect the end profile at any other point along the reference plane other than the pierce point.

The rake and relief lines on each of the reference planes is not restricted to a straight line. In particular, while either of the rake and relief lines on one reference plane can be a straight line, on another reference plane the rake and/or relief line can be a curved line, a geometric curve, a portion of an arc etc.

Per the above method, a plurality of cutting tools and inserts can be devised as will be further detailed.

According to a another aspect of the disclosed subject matter, there is provided a cutting insert comprising a front surface, a rear surface and at least one side surface extending therebetween having a first portion and a second portion angled to one another to form a corner, the cutting insert being formed with a main cutting edge defined at the intersection between said front surface and the corner of the side surface, said cutting insert further comprising an additional cutting element disposed on the corner of the side surface and protruding therefrom, said additional cutting element having an auxiliary cutting edge extending along said corner between said front surface and said rear surface, between a first intersection point with said first portion of the side surface and a second intersection point with said second portion of the side surface, none of which coincides with the cutting edge of the cutting insert.

It should be noted that the terms *'front face'* and *'rear face'* designate position of the faces of the cutting insert with respect to the workpiece. Thus, in turning inserts, the front face may be equivalent to the top face while the rear face may be equivalent to the bottom face.

The auxiliary cutting element may also be referred herein as a '*cutting balcony*' or a '*cutting porch*' due to its projection beyond the main cutting edge.

The main cutting element can have a rake surface constituted by a portion of the front surface and a relief surface constituted by a portion of the side surface. Respectively, the auxiliary cutting edge can be defined at the intersection between an auxiliary rake surface of the additional cutting element outwardly projecting from the side surface and transverse thereto and an auxiliary relief surface extending transverse to the rake surface and away from the main cutting edge.

The auxiliary rake surface can form an intersection line with the side surface of the cutting element so that end points of the intersection line coincide with the first and the second intersection point of the auxiliary cutting edge. Thus, in a top view, perpendicular to the front surface (and along the side surface), both the auxiliary cutting edge and the intersection line are clearly visible, including the first and the second intersection points.

The cutting edge of the additional cutting element can be designed so that any point disposed along the auxiliary cutting edge protrudes from the side surface and is visible in a top view of the cutting insert, perpendicular to the front surface. According to a specific design, in a top view of the cutting insert, perpendicular to the front surface, all the points along the cutting edge are visible. Thus, in the top view, the auxiliary cutting edge fully envelopes the main cutting edge at the corner, from one portion of the side surface to the other.

The first intersection point can be located close to the front surface while the second intersection point can be located closer to the bottom surface. In addition, the auxiliary cutting edge can include a point, maximally distant from the side surface of the cutting insert and located between said first intersection point and said second intersection point.

The auxiliary cutting edge, in a top view perpendicular to the front surface, can have a mid-point defined as the point on the cutting edge intersecting with a bisector of the angle formed at the corner between the portions of the side surface. The auxiliary cutting edge can be divided (virtually) into a lead portion extending from the first intersection point to the mid-point and a tail portion extending from the mid-point to the second intersection point.

In addition, in a side view of the cutting insert, perpendicular to the first portion thereof, the first intersection point will be clearly visible while the second intersection point will be slightly obscured by the second portion of the side surface itself.

In operation, the cutting insert can be mounted onto a cutting tool holder to form a cutting tool. The cutting insert can be oriented on the tool slightly tilted, such that a top view of the cutting tool and a top view of the cutting insert differ from one another. In particular, the arrangement can be such that the cutting insert is tilted forward along a plane which serves as the bisector of the angle formed in the side surface, so that in a top view of the cutting tool, the main cutting edge is disposed between the intersection line and the auxiliary cutting edge.

Furthermore, in connection with the above, the cutting insert is mounted onto the cutting tool and so tilted, that the distance of the mid-point of the auxiliary cutting edge from the main cutting edge is smaller than the same distance in a top view of the cutting insert.

In general, the design of the cutting insert according to the disclosed subject matter, which includes a main cutting edge and an auxiliary cutting edge disposed in front thereof, allows removing a greater chip from the workpiece, i.e. greater penetration into the workpiece. For example, if the main cutting edge alone is configured for removing 0.3mm, the additional cutting element can even double this the penetration, i.e. removing a chip of 0.6mm.

It is also important to note that both the main cutting edge and the auxiliary cutting edge operate simultaneously during the same cutting operation to subsequently remove chips from the workpiece. This is in contrast to cutting tools which require several cutting inserts, consecutively located one behind the other in order to achieve the same effect.

Several additional advantages may arise from the design of the additional cutting element and from the location of the first and the second intersection point outside the cutting edge:

- complete separation is provided between chips removed by the main cutting edge and chips removed by the auxiliary cutting edge. If at least the first point is located on the main cutting edge, this proves to be a failure point which may cause congestion of the removed chips, consequently increasing heat generated at the interface between the workpiece and the cutting insert;
- during manufacture or thereafter, the main cutting edge and the auxiliary cutting edge can be independently sharpened; and
- additional spacing is provided between the workpiece and the cutting insert by the additional cutting element, providing more space for removed chips as well as for cooling during a cutting operation.

Several design embodiments of cutting inserts will now be described:

- a cutting insert comprising four side walls, each two adjacent side walls forming the corner. Thus, the cutting insert can be formed with four main cutting edges, maxing the cutting insert indexible. The cutting insert can be provided with four additional cutting elements, one for each of the four corners;
- the cutting insert is also be reversible, wherein each cutting element is formed with an additional auxiliary rake surface and an additional auxiliary cutting edge;
- the additional cutting element is designed such that and so mounted onto the cutting tool that in a top view of the cutting tool, the extension of the cutting edge about the corner is not symmetrical. In particular, a greater portion of the cutting edge is located in front of the first portion of the side surface, thereby allowing using the cutting insert mainly in front cutting;
- the additional cutting element is constituted by several steps, so that the auxiliary cutting edge, as well as the auxiliary rake surface are divided into

several portions. Such a design allows removing chips of smaller width but of greater number from the workpoiece;

- the auxiliary cutting edge is designed such that when the cutting insert is tilted (when mounted onto the cutting tool holder), the cutting edge extends symmetrically about the corner of the main cutting edge;
- the cutting insert can be formed with more than one additional cutting element on the same corner. For example, the cutting insert can be formed with a first additional cutting element, while that same element can be formed with an additional element of its own, allowing to further increase the penetration of the cutting tool into the workpiece;
- the corner of the cutting insert, and so the main cutting edge can be of an arbitrary shape, while the auxiliary cutting edge can be designed so as to complete the inscribing envelope of the corner. For example, the auxiliary cutting edge can form the envelope of the a right angled corner, while the main cutting edge is curved inwards from that envelope;
- the cutting insert can be formed with several additional cutting elements along the same corner, wherein each of the cutting elements comprises a cutting edge providing a different cutting radii of the angle of the same corner (along a plane parallel to the front surface of the cutting insert). For example, for a right angled corner, the first additional cutting element can have a cutting radius of R1, the second additional cutting element (protruding from the first) can have a cutting radius of $R2 < R1$, the third additional cutting element (protruding from the second) can have a cutting radius of $R3 < R2$ and so forth;
- the cutting insert can be formed with a acute angle (e.g. 60, 45, 30 deg.).

According to another aspect of the disclosed subject matter there is provided a press-mold for the manufacture of the cutting insert of the previous aspect of the present application, said mold comprising a female member with a shaped cavity and a mal member with a corresponding shape.

The arrangement can be such that the auxiliary cutting edge of the cutting insert is not located at the parting line between the male and the female member, when the former is received within the latter.

In addition, the cavity of the female member can be formed with straight surfaces and the male member can have corresponding surfaces, so that the movement of the male member is given a certain degree of freedom (along its movement axis). It is appreciated that since the mold is configured for receiving (usually) particulate material, exact measurement of the amount is not always provided.

Thus, the design of the mold allows the male member to be introduced into the female member until it reaches the particulate material, even if the amount of material is slightly greater/smaller than planned. Furthermore, the above arrangement provides, in case the amount of material is smaller than planned, for the male member to displace further into the female cavity without coming in contact there with, thereby eliminating damage to the mold members.

The cutting insert can be formed, alongside the additional cutting element, with at least one secondary cutting element disposed along the side surface of the cutting insert, at a predetermined distance from the additional cutting element. Moreover, the cutting insert can be formed with a plurality of such secondary cutting elements, disposed sequentially, one after the other, along the side surface.

Each of the secondary cutting elements can have a secondary cutting edge extending between a start point adjacent the front surface (but not located thereon) and an end point located adjacent the bottom surface.

Similar to the auxiliary cutting edge, the secondary cutting edge has a start point located on the side surface, and can also be of spiraling/curved shape, although located on the side surface and not on the corner.

The plurality of such secondary cutting edges can be configured for providing the cutting insert to perform a cutting operation during feed in a direction perpendicular to the side surface on which the secondary cutting elements are disposed, thereby removing a greater amount of material from the workpiece.

According to a particular example, the cutting insert can be provided with secondary cutting elements on both side surfaces forming the corner, thereby allowing the cutting insert to perform both front and side cutting of the workpiece.

The secondary cutting elements can be disposed along the side surfaces such that, in a top view of the cutting insert, when mounted onto a cutting tool, the secondary cutting edges overlap one another. In particular, the start point of one secondary cutting edge can overlap, in the top view, the end point of an adjacent secondary cutting edge (or an end point of the auxiliary cutting edge).

It is appreciated that in the orientation of the cutting insert when mounted onto the cutting tool holder (i.e. in a working position), the start points of the auxiliary cutting edges do not come into contact with the workpiece as they are protected by the front surface of the cutting insert.

Thus, in effect, the chips removed from the workpiece by the cutting insert always have an additional space to flow to, since the effective starting point of the cutting is spaced from the side surface of the cutting insert.

According to still another aspect of the disclosed subject matter there is provided a cutting tool holder configured for mounting thereon a cutting insert according to the previous aspects of the disclosed subject matter, said cutting tool holder having a front surface formed with an insert seat and a front surface extending transverse to the front surface, wherein said cutting tool holder comprises a dynamic chip breaker protruding from the front surface beneath the cutting insert, said dynamic chip breaker being loosely biased to protrude from the front surface and pivotally displaceable about an axis generally parallel to the front surface.

The arrangement is such that during a cutting operation, the dynamic chip breaker is configured for coming in contact with the workpiece, thereby wiping therefrom removed chips. In addition, the dynamic chip breaker can also serve as a chip breaker, causing long chips removed from the workpiece to break and split into smaller pieces.

The dynamic chip breaker is provided with a biasing element configure to provide a loose biasing force, the term 'loose' being defined herein as, on the one hand sufficient for making the breaker come into contact with the workpiece, but on the other hand, loose enough to allow the breaker to pivot about its axis under pressure exerted thereon by removed chips.

When the breaker is pivoted about the axis, it assume a position in which it protrudes to a lesser extent from the front surface of the cutting tool holder, thereby increasing the spacing between the breaker and the workpiece, allowing chips to be expelled downwardly by virtue of the rotation of the workpiece.

The cutting insert can be used in turning, milling and drilling operations. In particular, in case of milling and turning, the front and rear faces are equivalent to the front and rear faces of the cutting insert while in the case of drilling, the front and rear surfaces are angularly first and second surfaces.

In general, the cutting insert of the disclosed subject matter may provide the following, compared with a similar cutting insert formed without an additional cutting element:

- Under constant feed F, the revolution speed V_R of the workpiece can be increased by 2-3 times while maintaining the amount of heat generated during the cutting operation as well as the same life span of the cutting insert;
- Under the safe feed F and revolution speed V_R of the workpiece, the amount of heat generated during the cutting operation can be lower by about 150°, and the life span can be increased by about 5 times;
- Under the same revolution speed V_R, the feed F can be increased to about 0.8mm, while maintaining the amount of heat generated during the cutting operation as well as the same life span of the cutting insert.

According to still another aspect of the subject matter of the present application, there is provided a rotary cutting tool configured for rotation about a central axis thereof for removing material from a workpiece, said cutting tool comprising a cutting portion extending about said central axis and having a rake surface and a relief surface, defining, at the intersection thereof, a cutting edge of the cutting portion having a lead end and a trail end, said lead end being configured for coming in contact with said workpiece prior to said trail end, wherein the angle between said rake surface and said relief surface at said lead end is greater than at said trail end.

The cutting tool can further comprise a standard cutting edge the contour of which extends inward of the cutting corner defined by the first and the second portion.

The at least one of the cutting edges of the first cutting portion and of the second cutting portion can have a straight segment, so that the resulting corner has a partially straight cross-sectional contour.

The cutting edge of the first cutting portion can have a first lead end and a second lead end, and of the cutting edge of the second cutting portion can have a second lead end and a second trail end, and wherein the first lead end is located in front of the lead end of the second lead end so as to come into contact with the workpiece during a cutting operation, before the second lead end. There can also exist an overlap between the cutting edge of the first cutting portion and the cutting edge of the second cutting portion so that the second lead end is disposed in front of the first trail end.

In addition, the standard cutting edge can extend so that in a view perpendicular thereto, at least one of the first lead end and the second lead end is obscured thereby. This can be particularly useful in reducing load and impact effects on the cutting edge. Specifically, it yields that the cutting edge obscured by the standard cutting edge penetrates the workpiece not at its lead end but at a point spaced from the lead end towards the trail end, thereby preventing impact of the workpiece on the lead point.

The second trail end can also comprise an extension configured for breaking off chips removed from the workpiece. In particular, in revolving tools, the extension can have a curve shaped, curving towards the center of the cutting tool (axis of rotation) at a smaller radius that that of the cutting tool, whereby removed chips are urged inwards and are broken off.

The cutting tool can be a rotary tool configured for revolution about a central axis, and wherein the first cutting portion and the second cutting portion extend about the central axis.

According to one example, the cutting edge of the first cutting portion can be configured for removing material from a surface extending parallel to the central axis and the cutting edge of the second cutting portion can be configured for removing material from a surface extending perpendicular to the central axis.

According to another example, the cutting edge of the first cutting portion can be configured for removing material from a surface extending perpendicular to the central axis and the cutting edge of the second cutting portion can be configured for removing material from a surface extending parallel to the central axis.

Regardless of the above configurations, the cutting tool can comprise several cutting segments, each segment comprising at least one of the first and the second cutting portions.

Under one design embodiment, each cutting segment includes both the first and the second cutting portion. Alternatively, the cutting segments of the cutting tool alternate so that one cutting segment is configured according to the first configuration and the other cutting segment is configured according to the other configuration.

Furthermore, according to a specific design, one cutting segment can comprise the first cutting portion and the consecutive cutting segment can comprise the second cutting portion. Thus, the segments become complementary to one another, alternating between side and bottom cutting.

The cutting tool can also be designed such that the segments also comprise a standard cutting edge disposed, in each cutting segment, in front of the first and/or second cutting portion.

Moreover, according to another design embodiment, the cutting tool can also assume the configuration under which each cutting segment comprises only one cutting portion, e.g. bottom cutting or side cutting, whereby the cutting edge of the one cutting portion cuts a slit within the workpiece and the standard cutting edges are configured thereafter for removing material from a slitted workpiece.

The cutting tool can be provided with one or more chip evacuation channels extending about an rotation axis, wherein the circumferential extension of the cutting segment about the central axis is greater than the circumferential extension of the channel about the central axis.

The arrangement can be such that the angle between the rake surface and the relief surface of at least one of the cutting portion at said lead end is greater than at said trail end. In particular, the angle between the rake and relief surfaces can be continuously reduced between the lead end and the trail end.

The first and the second cutting portions of the cutting tool can be constituted by a first cutting insert comprising the first cutting portion and a second cutting insert comprising the second cutting portion, the first and the second cutting insert being configured for mounting one on top of the other to form a combined cutting edge configured for simultaneously removing material from the same corner of the workpiece during the same cutting operation.

The arrangement can be such that the first cutting insert and the second cutting insert are configured for being mounted onto the cutting tool holder using a mutual connecting configuration.

In addition, the first cutting insert and the second cutting insert can form together a construction which cannot be manufactured in a press-mold or in a single-axis injection mold. Thus, each of the cutting inserts can be manufactured separately in a pressing process and thereafter mounted one on top of the other to form the combined arrangement.

According to a further aspect of the subject matter of the present application there is provided a cutting tool configured for removing material from a workpiece, said cutting tool comprising a cutting portion having a rake surface and a relief surface, defining, at the intersection thereof, a cutting edge having a lead end and a trail end, said lead end being configured for coming in contact with said workpiece prior to said trail end, wherein the angle between said rake surface and said relief surface at said lead end is greater than at said trail end.

According to yet another aspect of the present application, there is provided a cutting tool configured for removing material from a workpiece in order to form therein a corner of angle θ, said cutting tool comprising a first cutting portion comprising a first rake surface and a first relief surface and defining therebetween a first cutting edge, and a second cutting portion, spaced from the first cutting portion, and comprising a second rake surface and a second relief surface and defining therebetween a second cutting edge, wherein each of the first cutting edge and the second cutting edge constitute only a portion of the contour defining said angle θ.

According to still a further aspect of the subject matter of the present application there is provided a cutting tool configured for removing material from a workpiece to form a corner therein, said cutting tool comprising a first cutting element having a first cutting portion with a first cutting edge and a second cutting element having a second cutting portion with a second cutting edge, wherein, the contour of the first cutting edge and the contour of the second cutting edge are configured for forming together a combined contour corresponding to the above corner of the workpiece.

The cutting edges of the first and of the second element can be configured for simultaneously cutting respective portions of the same corner of the workpiece during the same cutting operation.

The arrangement can be such that, when combined, the cutting elements form a structure which cannot be produced in a press-mold or a single-axis injection mold.

The cutting elements can also compris an alignment arrangement configured for preventing lateral movement therebetween. The alignment arrangement can be constituted by a male-female engagement between the cutting elements.

The cutting elements are configured for simultaneously being mounted onto a cutting tool holder using a mutual securing arrangement.

In particular, the cutting elements can be configured for being mounted one on top of the other. Specifically, each of the cutting elements can be formed with a securing bore so that when the cutting elements are aligned, a single fastening bolt can be passed through the bores of the cutting elements to simultaneously secure both cutting elements to the cutting tool holder.

With respect to the above described, in all cutting operations such as milling, turning and drilling, it is appreciated that the features of the cutting tools as mentioned above may provide the cutting tools with at least one of the following advantages:

- **Feed** – under the same loads, the cutting tool may operate at greater feed and rotation speed **F** and $\mathbf{V_R}$ respectively, than an equivalent cutting tool without the above mentioned features, and, as such, remove a greater amount of material from the workpiece per time unit **t**;
- **Loads** – under the same feed and rotation speed **F** and $\mathbf{V_R}$, the cutting tool may be subjected to lower loads than an equivalent cutting tool without the above mentioned features, thereby providing an increased overall lifespan;
- **Chip** - under the same rotation speed $\mathbf{V_R}$, the cutting tool may be allowed a greater feed **F** than an equivalent cutting tool without the above features, thus allowing to remove a thicker chip per time unit **t** for one turn of the cutting tool or workpiece; and
- **Speed** - under the same feed **F**, the cutting tool or the workpiece may be allowed a greater rotation speed $\mathbf{V_R}$ than an equivalent cutting tool without the above features, removing a greater amount of chips per time unit ***t***.
- **Lifespan** – the cutting inserts/tools may be provided with a longer lifespan under the same conditions as a standard cutting insert/tool.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to better understand the subject matter that is disclosed herein and to exemplify how it may be carried out in practice, embodiments will now be described, by way of non-limiting example only, with reference to the accompanying drawings, in which:

Figs. 1A to **1F** are schematic isometric view of an end profile during consecutive stages of designing the geometry of a cutting curve according to the subject matter of the present application;

Fig. 2A is a schematic isometric view of a cutting insert designed according to the method of the present application;

Fig. 2B is a schematic enlarged view of a detail of the insert shown in Fig. 2A;

Fig. 2C is a schematic top view of the detail shown in Fig. 2B;

Fig. 3 is a schematic isometric view of the end profile shown in Figs. 1A to 1F, provided with a plurality of reference planes;

Figs. 4A to **4E** are schematic planar views of the reference planes shown in Fig. 3;

Figs. 5A and **5B** are schematic isometric views of examples of end profiles according to other examples of the present application;

Fig. 6A is a schematic isometric view of a plurality of reference planes and the geometric construction on each, used for designing the cutting edge according to the method of the present application;

Fig. 6B is a schematic isometric view of a cutting strip designed based on the reference planes shown in Fig. 6A;

Figs. 7A to **7D** are schematic cross-sectional views of the cutting strip and end profile, taken along various reference planes;

Fig. 8A is a schematic isometric view of a turning tool designed in accordance with the method of the present application;

Fig. 8B is a schematic isometric view of a cutting insert used in the cutting tool of Fig. 8A;

Fig. 8C is a schematic enlarged top view of a portion of the cutting insert shown in Fig. 8B;

Fig. 8D is a schematic isometric view of the portion shown in Fig. 8C;

Fig. 9A is a schematic isometric view of a cutting portion of a drill designed in accordance with the method of the present application;

Fig. 9B is a schematic enlarged view of a portion of the drill shown in Fig. 9A;

Fig. 10A is a schematic isometric view of a cutting portion of another example of a drill designed in accordance with the method of the present application;

Fig. 10B is a schematic enlarged view of a portion of the drill shown in Fig. 10A;

Fig. 11A is a schematic isometric view of a cutting portion of yet another example of a drill designed in accordance with the method of the present application;

Fig. 11B is a schematic enlarged view of a portion of the drill shown in Fig. 11A;

Figs. 11C and **11D** are schematic enlarged views of two sides of the drill shown in Fig. 11A;

Fig. 12A is a schematic isometric view of a cutting portion of still another example of a drill designed in accordance with the method of the present application;

Fig. 12B is a schematic enlarged view of a portion of the drill shown in Fig. 12A;

Fig. 13 is a schematic side view of a turning insert according to the present application;

Figs. 13A and **13B** are respective schematic isometric and top views of a turning insert according to the disclosed subject matter;

Fig. 13C is a schematic enlarged view of detail A shown in Fig. 13B;

Fig. 13D is a schematic enlarged view of detail B shown in Fig. 13A;

Figs. 13E and **13F** are schematic enlarged perspective views of detail B shown in Fig. 13D;

Figs. 13G and **3H** are respective schematic isometric assembled and exploded views of a mold for the manufacture of the turning insert shown in Figs. 13A to 13F;

Fig. 13I is a schematic enlarged view of a portion of the mold shown in Figs. 13G and 13H;

Fig. 13J is a schematic bottom view of a part of the mold shown in Figs. 13G and 13H;

Fig. 13K is a schematic isometric view of a turning tool comprising the insert shown in Figs. 13A to 13F;

Fig. 13L is a schematic enlarged top view of the turning tool shown in Fig. 13K;

Fig. 13M is a schematic enlarged view of detail C shown in Fig. 13L;

Fig. 13N is a schematic view of Fig. 13M including hidden lines;

Fig.14A is a schematic isometric view of a turning insert according to another example of the disclosed subject matter;

Fig. 14B is a schematic enlarged view of detail D shown in Fig. 14A;

Fig. 14C is a schematic top view of the turning insert shown in Fig. 14A;

Fig. 14D is a schematic enlarged view of detail E shown in Fig. 14C;

Fig. 14E is a schematic perspective view of detail D shown in Fig. 14B;

Figs. 14F and **14G** are respective schematic isometric assembled and exploded views of a mold for the manufacture of the turning insert shown in Figs. 14A to 14E;

Fig. 14H is a schematic isometric view of a part of the mold shown in Figs. 14F and 14G;

Fig. 14I is a schematic enlarged view of detail F shown in Fig. 14H;

Fig. 14J is a schematic isometric view of a turning tool comprising the insert shown in Figs. 14A to 14E;

Fig. 14K is a schematic enlarged top view of the turning insert of Figs. 14A to 14E when mounted onto the tool of Fig. 14J;

Fig. 14L is a schematic view of Fig. 14K including hidden lines;

Figs. 15A and **15B** are respective schematic isometric and top views of a turning tool comprising a turning insert according to still another example of the disclosed subject matter;

Fig. 15C is a schematic enlarged view of detail G shown in Fig. 15B, including hidden lines;

Fig. 15D is a schematic isometric view of the turning insert shown in Figs. 15A to 15C;

Fig. 16A is a schematic isometric view of a turning tool comprising a turning insert according to another example of the disclosed subject matter;

Fig. 16B is a schematic isometric view of the turning insert shown in Fig. 16A;

Fig. 16C is a schematic enlarged view of detail H shown in Fig. 16B;

Fig. 16D is a schematic enlarged top view of a portion of the turning insert when mounted onto the turning tool of Fig. 16A;

Fig. 16E is a schematic view of Fig. 16D including hidden lines;

Figs. 17A and **17B** are respective schematic isometric and top views of a turning tool comprising a turning insert according to still another example of the disclosed subject matter;

Fig. 17C is a schematic isometric view of the turning insert shown in Figs. 17A and 17B;

Fig. 17D is a schematic enlarged view of detail I shown in Fig. 17C;

Fig. 17E is a schematic perspective view of detail I shown in Fig. 17D;

Fig. 17F is a schematic top view of an enlarged portion of the turning insert shown in Figs. 17D and 17E;

Fig. 17G is a schematic enlarged view of detail J shown in Fig. 17B;

Fig. 17H is a schematic view of Fig. 17G including hidden lines;

Fig. 18A is a schematic isometric view of a turning insert according to still another example of the disclosed subject matter;

Fig. 18B is a schematic enlarged view of detail K shown in Fig. 18A;

Fig. 18C is a schematic perspective view of detail K shown in Fig. 18B;

Fig. 18D is a schematic top view of the turning insert shown in Figs. 18A to 18C;

Fig. 18E is a schematic top view of the turning insert shown in Fig. 18D when mounted onto a turning tool (not shown);

Fig. 18F is a schematic enlarged view of detail L shown in Fig. 18E;

Fig. 18G is a schematic view of detail L shown in Fig. 18F including hidden lines;

Fig. 19A is a schematic isometric view of a turning insert according to still another example of the disclosed subject matter;

Fig. 19B is a schematic enlarged view of detail M shown in Fig. 19A;

Fig. 19C is a schematic perspective view of detail M shown in Fig. 19B;

Fig. 19D is a schematic top view of the turning insert shown in Figs. 19A to 19C;

Fig. 19E is a schematic top view of the turning insert shown in Fig. 19D when mounted onto a turning tool (not shown);

Fig. 19F is a schematic enlarged view of detail N shown in Fig. 19E;

Fig. 19G is a schematic view of detail N shown in Fig. 19F including hidden lines;

Fig. 20A is a schematic isometric view of a turning insert according to still another example of the disclosed subject matter;

Fig. 20B is a schematic enlarged view of detail O shown in Fig. 20A;

Fig. 20C is a schematic perspective view of detail O shown in Fig. 20B;

Fig. 20D is a schematic top view of the turning insert shown in Figs. 20A to 20C;

Fig. 20E is a schematic top view of the turning insert shown in Fig. 20D when mounted onto a turning tool (not shown);

Fig. 20F is a schematic enlarged view of detail P shown in Fig. 20E;

Fig. 20G is a schematic view of detail P shown in Fig. 20F including hidden lines;

Fig. 21A is a schematic isometric view of a turning tool comprising two turning inserts according to yet another example of the disclosed subject matter, one mounted for being used as a front turning inserts and the other mounted for being used as a side turning insert;

Fig. 21B is a schematic enlarged view of detail Q shown in Fig. 21A;

Fig. 21C is a schematic isometric view of a turning insert mounted onto the turning tool for being used as a front turning insert;

Fig. 21D is a schematic isometric view of the turning insert shown in Figs. 21A to 21C;

Fig. 21E is a schematic top perspective view of a portion of the turning insert shown in Fig. 21D;

Fig. 21F is a schematic top view of the turning insert shown in Figs. 21A to 21E;

Fig. 21G is a schematic top view of the turning insert shown in Figs. 21A to 21F when mounted onto the turning tool;

Fig. 21H is a schematic enlarged view of detail R shown in Fig. 21G, including hidden lines;

Fig. 22A is a schematic isometric view of a turning tool comprising a turning insert according to yet another example of the disclosed subject matter;

Fig. 22B is a schematic isometric view of the turning insert shown in Fig. 22A;

Fig. 22C is a schematic enlarged view of a portion of the turning insert shown in Figs. 22A and 22B;

Fig. 22D is a schematic top view of the turning insert shown in Figs. 22A to 22C;

Fig. 22E is a schematic enlarged view of detail S shown in Fig. 22D;

Fig. 22F is a schematic top view of the turning insert shown in Figs. 22A to 22E when mounted onto the turning tool;

Fig. 22G is a schematic enlarged view of detail T shown in Fig. 22F;

Fig. 23A is a schematic enlarged isometric view of a portion of a turning insert according to another example of the disclosed subject matter;

Fig. 23B is a schematic enlarged top view of the portion of the turning insert shown in Fig. 23A;

Fig. 23C is a schematic bottom view of the turning insert shown in Figs. 23A and 23B;

Fig. 23D is a schematic top view of the turning insert shown in Figs. 23A to 23C, when mounted onto a turning tool (not shown);

Fig. 23E is a schematic enlarged view of detail U shown in Fig. 23D;

Fig. 23F is a schematic enlarged side view of the turning portion shown in Fig. 23B;

Fig. 24A is a schematic isometric view of a turning tool according to an example of the disclosed subject matter;

Fig. 24B is a schematic enlarged view of detail V shown in Fig. 24A;

Fig. 24C is a schematic isometric view of a biasing mechanism used in the turning tool shown in Figs. 24A and 24B;

Figs. 24D to **24G** are schematic left side, front, top and right side views of the turning tool shown in Figs. 24A and 24B;

Figs. 25A and **25B** are schematic respective right and left isometric views of a turning insert according to another example of the present application;

Figs. 25C and **25D** are schematic respective bottom and top views of the turning insert shown in Figs. 25A and 25B;

Figs. 25E and **25F** are schematic enlarged views of details W and X shown in Fig. 25D;

Fig. 25G is a schematic bottom isometric view of the turning insert shown in Figs. 25A to 25F;

Fig. 25H is a schematic enlarged view of detail Y shown in Fig. 25G;

Fig. 26A is a schematic exploded isometric view of a mold used in the manufacture of the turning insert shown in Figs. 13A to 13H;

Figs. 26B and **26C** are respective schematic isometric and top views of a male member of the mold shown in Fig. 26A;

Figs. 26D and 26E are respective schematic isometric and top views of a female member of the mold shown in Fig. 26A;

Fig. 27A is a schematic isometric view of a turning tool comprising the turning insert shown in Figs. 13A to 13H;

Fig. 27B is a schematic enlarged top view of the turning insert when mounted onto the turning tool holder shown in Fig. 27A;

Fig. 27C is a schematic enlarged view of a portion of the turning tool shown in Fig. 27B;

Fig. 27D is a schematic hidden-line view of the portion of the turning tool shown in Fig. 27C;

Fig. 27E is a schematic hidden-line view of another portion of the cutting tool shown in Fig. 27C;

Fig. 28A is a schematic isometric view of a turning insert according to still another example of the present application;

Figs. 28B and **28C** are schematic enlarged views of details of the turning insert shown in Fig. 28B;

Figs. 28D to **28H** are respective schematic bottom isometric, top, bottom, right-side and left-side views of the turning insert shown in Figs. 28A to 28C;

Fig. 29A is a schematic exploded isometric view of a mold used in the manufacture of the turning insert shown in Figs. 28A to 28H;

Figs. 29B and **29C** are respective schematic isometric and top views of a male member of the mold shown in Fig. 26A;

Figs. 29D and **29E** are respective schematic top and isometric views of a female member of the mold shown in Fig. 26A;

Fig. 30A is a schematic isometric view of a turning tool comprising the turning insert shown in Figs. 28A to 28H;

Figs. 30B to **30D** are schematic front, side and top views of the turning tool shown in Fig. 30A;

Fig. 30E is a schematic hidden-line view of a portion of the turning tool shown in Fig. 30D;

Fig. 31 is a schematic side view of a milling insert according to the present application;

Figs. 31A and **31B** are schematic isometric and exploded isometric views of a milling tool according to the present application;

Figs. 31C and **31D** are schematic isometric and top views of a milling insert used in the milling tool shown in Figs. 31A and 31B;

Fig. 31E is a schematic front view of the milling insert shown in Figs. 31C and 31D;

Fig. 31F is a schematic isometric enlarged view of a detail of the milling insert shown in Figs. 31C and 31D;

Figs. 31G to **31I** are schematic isometric views of the milling insert shown in Figs. 31C and 31D and its resulting cutting envelope when mounted onto the milling tool of Figs. 31A and 31B;

Figs. 32A to **32C** are schematic front isometric, front and bottom isometric views of a milling insert according to another example of the present application;

Fig. 32D is a schematic isometric view of a milling tool comprising a plurality of milling inserts as shown in Figs. 32A to 32C;

Fig. 32E is a schematic isometric view of the milling tool shown in Fig. 32D with one of the milling inserts removed;

Fig. 33A is a schematic isometric view of a milling tool according to another example of the present application;

Fig. 33B is a schematic isometric view of the milling tool shown in Fig. 33A with one of the milling inserts removed;

Figs. 33C and **33D** are schematic front isometric and front views of a milling insert used in the milling tool shown in Figs. 33A and 33B;

Fig. 33E is a schematic isometric enlarged view of a detail of the milling insert shown in Figs. 33C and 33D;

Fig. 34A is a schematic isometric view of a milling tool according to still a further example of the present application;

Figs. 34B to **34D** are schematic isometric, front and side views of a milling insert used in the milling tool shown in Fig. 34A;

Fig. 34E is a schematic isometric enlarged view of a detail of the milling insert shown in Figs. 34B to 34D;

Fig. 35A is a schematic isometric view of a milling tool according to yet another example of the present application;

Fig. 35B is a schematic isometric view of a milling insert used in the milling tool shown in Fig. 35A;

Fig. 35C is a schematic enlarged view of a detail of the milling insert shown in Fig. 35B;

Fig. 35D is a schematic top view of the milling insert shown in Fig. 35B;

Figs. 35E and **35F** are schematic enlarged top and isometric views of details of the milling insert shown in Fig. 35B;

Fig. 36A is a schematic isometric view of a milling tool according to still another example of the present application;

Fig. 36B is a schematic isometric view of the milling insert shown in Fig. 36A with one of the milling inserts being removed;

Fig. 36C is a schematic enlarged view of a detail of the milling tool shown in Fig. 36B;

Figs. 36D to **36F** are schematic isometric, top and side views of a milling insert used in the milling tool shown in Figs. 36A to 36C;

Fig. 36G is a schematic isometric exploded view of a mold for the manufacture of the milling insert shown in Figs. 36D to 36F;

Fig. 37A is a schematic isometric view of a milling tool according to yet another example of the present application;

Fig. 37B is a schematic isometric view of the milling insert shown in Fig. 37A with one of the milling inserts being removed;

Figs. 37C and **37D** are schematic top and isometric views of a milling insert used in the milling tool shown in Figs. 37A and 37B;

Fig. 37E is a schematic enlarged isometric view of a detail of the milling insert shown in Figs. 37C and 37D;

Fig. 37F is a schematic isometric exploded view of a mold for the manufacture of the milling insert shown in Figs. 37C to 37E;

Fig. 38A is a schematic isometric view of a milling tool according to another example of the present application;

Fig. 38B is a schematic enlarged isometric view of a milling insert mounted onto the milling tool shown in Fig. 38A;

Fig. 38C is a schematic isometric view of the milling insert shown in Fig. 38B;

Fig. 38D is a schematic enlarged isometric view of a detail of the milling insert shown in Fig. 38C;

Fig. 38E is a schematic top view of the milling insert shown in Fig. 38C;

Fig. 38F is a schematic enlarged view of a detail of the milling insert shown in Fig. 38E;

Fig. 39 is a schematic side view of a drilling insert according to the present application;

Figs. 39A is a schematic isometric view of a drilling tool according to the present application;

Fig. 39B is a schematic front isometric enlarged view of a tip of the drilling tool shown in Fig. 39A prior to its final stage of manufacture;

Fig. 39C is a schematic isometric view of the drilling tool shown in Fig. 39B;

Figs. 39Dand **39E** are schematic bottom and side views of the drilling tool shown in Fig. 39C;

Figs. 39F to **39G** are schematic enlarged left and right isometric views of the drilling tool shown in Figs. 39A to 39E;

Figs. 40A to **40I** are schematic front views of the drilling tool shown in Figs. 27A to 27G during various stages of a drilling operation within a workpiece;

Fig. 41A is a schematic left isometric view of a portion of a drilling tool according to another example of the present application;

Fig. 41B is a schematic right isometric view of the drilling tool shown in Fig. 41A after a final stage of manufacture thereof;

Fig. 41C is a schematic right isometric view of the drilling tool shown in Fig. 41B prior to its final stage of manufacture;

Figs. 41D and **41E** are schematic bottom and front views of the drilling tool shown in Figs. 41A to 41C; and

Figs. 42A to **42H** are schematic front views of the drilling tool shown in Figs. 29A to 29E during various stages of a drilling operation within a workpiece.

Fig. 43A is a schematic isometric view of a drill according to the subject matter of the present application;

Fig.43B is a schematic enlarged view of detail A shown in Fig. 43A;

Fig. 43C is a schematic enlarged view of a detail of a cutting portion of the drill shown in Fig. 43A;

Fig. 43D is a schematic front view of detail A shown in Fig. 43B;

Fig. 43E is a schematic bottom view of the drill shown in Fig. 43A;

Figs. 44A to **44H** are schematic front views of the drill shown in Fig. 1A during consecutive stages of a cutting operation;

Fig. 45A is a schematic isometric view of a cutting portion of another example of a drill of the subject matter of the present application;

Fig. 45B is a schematic enlarged view of a part of the cutting portion shown in Fig. 45A;

Fig. 45C is a schematic rotated view of the part shown in Fig. 45B;

Fig. 45D is a schematic bottom view of the drill shown in Fig. 45A;

Figs. 46A to **46F** are schematic front views of the drill shown in Fig. 3A during consecutive stages of a cutting operation;

Fig. 47 is a schematic isometric view of a cutting portion of still another example of a drill of the subject matter of the present application;

Figs. 48A to **48K** are schematic cross-sectional views of the cutting portion of the drill shown in Fig. 47 during consecutive stages of a cutting operation;

Fig. 49A is a schematic isometric view of a cutting portion of yet another example of a drill of the subject matter of the present application;

Fig. 49B is a schematic enlarged view of a part of the cutting portion shown in Fig. 49A;

Fig. 49C is a schematic rotated view of the part shown in Fig. 49B;

Fig. 49D is a schematic bottom view of the drill shown in Fig. 49A;

Figs. 49E and **49F** are schematic perspective views of a rear part of the cutting portion of the drill shown in Fig. 49A;

Fig. 50A is a schematic isometric view of a cutting portion of yet one more example of a drill of the subject matter of the present application;

Fig. 50B is a schematic enlarged view of a part of the cutting portion shown in Fig. 50A;

Fig. 50C is a schematic bottom view of the drill shown in Fig. 50A;

Fig. 51A is a schematic isometric view of a cutting portion of still one more example of a drill of the subject matter of the present application;

Fig. 51B is a schematic enlarged view of a part of the cutting portion shown in Fig. 51A;

Fig. 51C is a schematic bottom view of the drill shown in Fig. 51A;

Fig. 51D is a schematic cross-sectional view of the drill shown in Fig. 51A during a cutting operation within a workpiece;

Fig. 52A is a schematic isometric view of an endmill according to the subject matter of the present application;

Fig. 52B is a schematic enlarged view of a part of the cutting portion of the endmill shown in Fig. 52A;

Fig. 52C is a schematic front view of the enlarged part shown in Fig. 52B;

Fig. 52D is a schematic bottom view of the endmill shown in Fig. 52A;

Figs. 53A to **53E** are schematic front views of the endmill shown in Fig. 52A during consecutive stages of a cutting operation;

Fig. 54A is a schematic isometric view of an endmill according to another example of the subject matter of the present application;

Fig. 54B is a schematic enlarged front view of a cutting portion of the endmill shown in Fig. 54A;

Fig. 55A is a schematic isometric view of an endmill according to still another example of the subject matter of the present application;

Fig. 55B is a schematic enlarged view of a part of the cutting portion of the endmill shown in Fig. 55A;

Fig. 56 is a schematic isometric view of an endmill according to yet another example of the subject matter of the present application;

Fig. 57 is a schematic isometric view of an endmill according to still one more example of the subject matter of the present application;

Figs. 58A to **58D** are schematic cross-sectional comparisons between various designs of cutting portions of the subject matter of the present application;

Figs. 59A to **59D** are schematic cross-sectional views of the cutting portion of Figs. 58A to 58D during consecutive stages of a cutting operation;

Fig. 60A is a schematic isometric view of a cutting portion of yet one more example of a drill of the subject matter of the present application;

Fig. 60B is a schematic front view of a part of the cutting portion shown in Fig. 60A;

Fig. 60C is a schematic front view of a pre-formed stage of the drill shown in Fig. 60A;

Fig. 60D is a schematic front view of the formed stage of the drill shown in Fig. 60A;

Fig. 61A is a schematic isometric view of a cutting portion of still another example of a drill of the subject matter of the present application;

Fig. 61B is a schematic front view of a part of the cutting portion shown in Fig. 61A;

Figs. 61C to **61F** are schematic enlarged front views of the cutting portion of the drill shown in Fig. 61A during consecutive stages of a cutting operation;

Fig. 62A is a schematic isometric view of an endmill according to another example of the subject matter of the present application;

Fig. 62B is a schematic enlarged view of a part of the cutting portion of the endmill shown in Fig. 62A;

Fig. 63A is a schematic isometric view of an endmill according to still another example of the subject matter of the present application;

Figs. 63B and **63C** are schematic enlarged front and side views of a part of the cutting portion of the endmill shown in Fig. 63A;

Fig. 63D is a schematic bottom view of the endmill shown in Fig. 63A;

Fig. 64A is a schematic isometric view of an endmill according to yet another example of the subject matter of the present application;

Fig. 64B a schematic enlarged view of a part of the cutting portion of the endmill shown in Fig. 64A; and

Figs. 64C to **64F** are schematic side views of the endmill shown in Fig. 64A at various rotary positions about a central axis thereof.

Fig. 65A is a schematic isometric view of a milling tool according to another aspect of the subject matter of the present application;

Fig. 65B is a schematic enlarged bottom view of the milling tool shown in Fig. 65A;

Fig. 65C is a schematic isometric view of a cutting insert used in the milling tool shown in Figs. 65A and 65B;

Fig. 65D is a schematic front view of the cutting insert shown in Fig. 65C;

Fig. 66A is a schematic isometric view of a milling tool according to another aspect of the subject matter of the present application;

Fig. 66B is a schematic isometric view of a cutting insert used in the milling tool shown in Fig. 66A;

Fig. 66C is a schematic front view of the cutting insert shown in Fig. 66B;

Fig. 67A is a schematic isometric view of a milling tool according to another aspect of the subject matter of the present application;

Fig. 67B is a schematic view of a cutting insert used in the milling tool shown in Fig. 67A;

Fig. 67C is a schematic front perspective view of the cutting insert shown in Fig. 67B;

Fig. 67D is a schematic front view of the cutting insert shown in Fig. 67C;

Figs. 68A and **68B** are schematic isometric and exploded isometric views of a mold configured for the manufacture of the cutting insert shown in Figs. 3A to 3D;

Fig. 68C is a schematic enlarged isometric view of a mold piece shown in Figs. 68A and 68B;

Fig. 69A is a schematic isometric view of a milling tool according to another example of the present application;

Fig. 69B is a schematic isometric view of a cutting insert used in the milling tool shown in Fig. 69A;

Fig. 69C is a schematic isometric view of the milling tool shown in Fig. 69A with a schematic cutting envelope thereof;

Fig. 70A is a schematic isometric view of a milling tool according to another example of the present application;

Fig. 70B is a schematic isometric view of a cutting insert used in the milling tool shown in Fig. 70A;

Fig. 70C is a schematic enlarged view of a cutting portion of the cutting insert shown in Fig. 70B;

Fig. 71 is a schematic isometric view of a mold used for the manufacture of the inserts shown in Fig. 70A;

Fig. 72A is a schematic isometric view of a parting tool according to another example of the present application;

Fig. 72B is a schematic top view of the parting tool shown in Fig. 72A;

Fig. 72C is a schematic enlarged view of a detail shown in Fig. 72B;

Fig. 73A is a schematic isometric view of a parting tool according to an example of the subject matter of the present application;

Fig. 73B is a schematic isometric view of a parting insert used in the parting tool shown in Fig. 73A;

Fig. 73C is an enlarged top view of a cutting corner of the parting insert shown in Fig. 73B;

Fig. 73D is a schematic isometric view of the cutting corner shown in Fig. 73C;

Fig. 74A is a schematic isometric view of a straight saw tool according to another example of the subject matter of the present application;

Fig. 74B is an enlarged view of a saw insert used in the parting tool shown in Fig. 74A;

Fig. 75A is a schematic isometric view of a straight saw tool according to another example of the subject matter of the present application;

Fig. 75B is an enlarged view of a saw insert used in the parting tool shown in Fig. 75A;

Fig. 76A is a schematic isometric view of a turning tool according to another aspect of the subject matter of the present application;

Fig. 76B is a schematic isometric exploded view of the cutting tool shown in Fig. 76A; and

Fig. 76C is a schematic enlarged view of the cutting inserts used in the cutting tool shown in Fig. 76A.

DETAILED DESCRIPTION OF EMBODIMENTS

Throughout the specification, several indicators are used as follows:

- in all Figs. 1 to 12B, the indicative letter B appears in front of each reference numeral in the following format – B232, B140a etc.;
- in all Figs. 13 to 42H, reference numerals appear without an indicative letter;
- in all Figs. 43A to 64F, the indicative letter Y appears in front of each reference numeral in the following format – Y232, Y140a etc.; and

- in all Figs. 65A to 76C, the indicative letter R appears in front of each reference numeral in the following format – R232, R140a etc.

Per the above, it should be understood that elements B232, 232, Y232 and R232 are not equivalents on one another.

Attention is first drawn to Figs. 2A to 12, in which a milling insert of the present application is shown, generally designated **B1.** The external surface of the milling insert **B1** has a bottom surface **B4a** and a side surface **B4c**, between which extends an adjoining surface **B4b**. In addition, the milling insert B**1** comprises a cutting corner with a cutting edge **B2** extending along a portion of the bottom surface **B4a**, adjoining surface B**4b** and side surface **B4c**.

The cutting edge **B2** is divided into a bottom segment **B2a**, an adjoining segment **B2b** and a side segment **B2c**. The bottom segment B**2a** is constituted by the intersection between the bottom surface **B4a** and a bottom rake surface **B6a**, the adjoining segment **B2b** is constituted by the intersection between the adjoining surface **B4b** and an adjoining rake surface **B6b**, and the side segment **B2c** is constituted by an intersection between the side surface **B4c** and a side rake surface B**6c**. Thus, the bottom surface **B4a**, adjoining surface **B4b** and side surface **B4c** constitute relief surfaces of the respective cutting edge segments **B2a**, **B2b** and **B2c**.

The adjoining cutting edge segment **B2b** has a start point B**3** closer to a front face of the milling insert **B1** and an end point B**5** closer to a rear surface of the milling insert **B2.** In other words, the start point **B3** and the end point **B5** lie on different reference planes, parallel and spaced from one another.

Turning now to Figs. 1A to 1F, the method of designing a cutting edge will now be described in detail. In principle, the design of the cutting tool includes two main stages:

(a) the design of the geometric outline of the cutting edge, i.e. how the cutting edge extends along the bottom surface, sides surface and adjoining surface of the cutting tool; and

(b) the design of the rake and relief surfaces about the cutting edge, i.e. the shape of each of the surfaces and the angle therebetween.

As a preliminary step to the above design stages, the desired operation for which the cutting tool is to be used should be determined, as well as the resulting shape of the workpiece after the cutting operation.

With particular reference to Fig. 1A, when a shaping/planing tool is to be designed, an end profile B**10** is first modeled, simulating a desired end profile of a workpiece after such a shaping/planing operation has taken place. As will be observed later with respect to Figs. 5A and 5B, different cutting operations yield different end profiles (**B10**, **B10'**, **B10"**).

It is observed that the end profile **B10** is formed with a bottom surface **B12**, a side surface B**16** and an adjoining surface **B14** extending therebetween. It is also noted that since, in a shaping/planing operation neither the workpiece nor the cutting tool is revolved, the end profile **B10** is modeled by an end contour **B11** extruded along a straight longitudinal axis X. As a result, the adjoining surface **B14** is a geometrically ruled surface in which through every point on the surface it is possible to pass a straight line that lies on the surface. Examples will later be described in which the adjoining surface is not ruled.

It is also observed that the contour **B11** has a bottom contour **B22** at the intersection with the bottom surface B**12**, an adjoining contour **B24** at the intersection with the adjoining surface **B14** and a side contour **B26** at the intersection with the side surface **B16**.

Turning to Fig. 1B, in order to design the geometric outline of the cutting curve, a bottom profile plane RP_B and a side profile plane RP_S are first defined, between which the cutting curve will extend. The bottom profile plane RP_B and the side profile plane RP_S each extend perpendicular to the longitudinal axis X and are spaced apart from one another.

Thereafter, a start point **B32** on the bottom surface **B12**a, lying on the bottom profile plane RP_B, an intermediate point **B34** located on the adjoining surface B**14** between the bottom profile plane RP_B and the side profile plane RP_S, and an end point **B36** on the side surface, lying on the side profile plane PR_S. In particular, the position of the intermediate point B**34** on the adjoining surface is chosen at a location approximately between the side surface B**16** and the bottom surface **B12**.

Turning to Figs. 1C to 1F, once the three points **B32**, **B34** and **B36** have been established, an intersecting plane B**39** is defined using these points, intersecting the end profile **B10** along an intersection curve **B40**.

With particular reference to Figs. 1D and 1F, the intersecting curve **B40** has intersects the adjoining surface **B14** at a lead point **B33**, at the edge with the bottom surface B**12** and at a trail point **B35** at the edge with the side surface **B16**. For each of these points **B33**, **B35**, a corresponding lead profile plane RP_L and a trail profile plane RP_T is defined, each of which is parallel to the bottom profile plane RP_B and the side profile plane RP_S, and is also perpendicular to the longitudinal axis X.

Once all four reference planes have been defined, the cutting curve B**40** can be divided into a bottom cutting curve segment **B42** extending along the bottom surface **B12**, an adjoining cutting curve segment **B44** extending along the adjoining surface B**14**, and a side cutting curve segment **B46** extending along the side surface **B16**.

Thus, a geometric outline of the cutting edge is provided. However, it should first be verified that the characteristics of the cutting curve meet the requirements of the design. Some of the requirements are:

- the adjoining ratio $\mathbf{R_{ADJ}}$ between the length of the adjoining cutting curve segment **B44** and the length of the adjoining contour **B24**; and
- the distribution ratio $\mathbf{R_{DIST}}$ between the lengths of the bottom cutting curve segment **B42**, the adjoining cutting curve segment **B44** and the side cutting curve segment B**46**; and
- the symmetry of the cutting curve.

In particular, if the desired adjoining ratio $\mathbf{R_{ADJ}}$ is $\mathbf{R_{ADJ}} = \mathbf{2.5}$**,** and the actual ratio is yielded by the given points **B32**, **B34**, **B36** is smaller, then positions of the bottom profile plane RPB and the side profile plane RPS are amended by spacing them further apart, thereby increasing the distance between the start point **B32** and the end point **B36**. In addition, the position of the intermediate point B**34** can also be amended. However, it is appreciated that the variation in the position of the intermediate point is usually more limited due to the distribution ratio $\mathbf{R_{DIST}}$ and the symmetry requirements.

Once the correct adjoining ratio $\mathbf{R_{ADJ}}$ has been established, the position of the intermediate point B**34** can be slightly amended to meet the distribution ratio $\mathbf{R_{DIST}}$ and the symmetry requirements. It is appreciated that in order to meet the above two requirements, minor tweaks in the position of the intermediate point may well be sufficient.

Upon amending the position of the points **B32**, **B34**, **B36**, the design of the geometric outline of the cutting curve **B40** is complete and can be used for the design of the rake and relief surfaces of the cutting tool thereabout, whereby it will constitute the cutting edge of the designed cutting tool.

Turning now to Figs. 3 to 4E, the second stage of designing the cutting tool will be described, in particular, the design of the rake and relief surfaces of the cutting edge.

Firstly, a plurality of reference planes PR_1 to PR_7 are defined along the cutting curve **B40**, each being pierced by the cutting curve **B40** at a pierce point P_1 to P_7 respectively. Each of the reference planes PR_1 to PR_7 is perpendicular to the cutting curve **B40** at the respective pierce points P_1 to P_7.

With reference to the above, the term 'perpendicular to the curve at a point' can be interpreted in the following two equivalent manners:

geometric – in any view in which the reference plane PR_N is seen in its edge view, the curve is perpendicular thereto; and

mathematical – given a mathematical formula f(x) of the curve, the reference plane is perpendicular to a directional vector which is the derivative f'(x) at the piercing point.

With attention being drawn to Figs. 5A and 5B, it is appreciated that for any end profile for which a cutting curve has been provided, it is possible to model appropriate reference planes perpendicular to the cutting curve. Specifically, whereas the end profile **10** models a shaping operation, the end profile **B10'** of Fig. 5A corresponds to a turning operation (a revolving workpiece) and end profile **B10"** of Fig. 5B corresponds to a milling operation.

Turning now to Figs. 6A and 6B, a projection of the end contour is provided on each of the planes PR_1 to PR_9. Thus, each reference plane PR_1 to PR_9 is provided with a bottom projection contour **B52** of the bottom end contour B**22**, an adjoining projection contour **B54** of the adjoining end contour **B24** and a side projection contour **B56** of the side end contour **B26**. Inevitably, each of the pierce points P_1 to P_9, lies on one of the projections contours **B52**, **B54**, **B56**.

With additional reference being made to Figs. 7A to 7D, once obtained, on each of the reference planes PR_1 to PR_9, a straight base line BL_1 to BL_9 is respectively defined tangent to the projection contour at the respective pierce point P_1 to P_9. In other words, if the pierce point P_N lies on the adjoining projection contour B**54**, the base line BL_N will be tangent thereto at the pierce point P_N, if the pierce point P_N lies on the side projection contour **B56**, the base line BL will be tangent thereto at the pierce point P_N, and so on. It is appreciated that since in the present example the bottom surface **B12** and the side surface **B16** are planar surfaces, the bottom projection contour **B52** and the side projection contour **B56** are straight lines and therefore, they themselves constitute the base line BL.

Thereafter, on each of the reference planes PR_1 to PR_9, a straight chip line CL_1 to CL_9 is respectively defined perpendicular to the projection contour at the respective pierce point P_1 to P_9. In other words, if the pierce point P_N lies on the adjoining projection contour **B54**, the chip line CL_N will be perpendicular thereto at the pierce point P_N, if the pierce point P_N lies on the side projection contour **B56**, the chip line CL will be tangent thereto at the pierce point P_N, and so on.

Once the base lines BL_1 to BL_7 and chip lines CL_1 to CL_9 have been defined, it is required to define, for each of the reference planes PR_1 to PR_9 a rake line RK_1 to RK_9 and a relief line RF_1 to RF_9 are defined. For each of the reference planes PR_1 to PR_9, the following angles can be defined:

- a desired cutting angle θ_C between the rake line RK_N and its respective chip line CL_N;
- a desired body angle θ_B between the rake line RK_N and the relief line RF_N; and
- a desired rear angle θ_R between the relief line RF_N and the base line BL_N.

It is observed that in the present example, both the rake line RK and the relief line RF are in the lower quadrant formed by the base line BL and the chip line CL and not in the upper quadrant. However, it is appreciated that in other examples, either or both of the rake line RK and the relief line RF can be in the upper quadrant as well.

The required above angles can be determined according to the desired cutting operation, the material of the workpiece and the material of the designed cutting tool, taken from engineering tables as known *per se*.

In addition, in the present example, the design is such that while the rear angle θ_C remains generally the same throughout the different reference planes PR_1 to PR_7, the cutting angle θ_C increases while the body angle θ_B decreases. Though this is not compulsory, in general, the body angle θ_B either decreases or remains the same throughout the cutting edge. In other words, if the body angle θ_B of a particular reference plane is designed to be equal or smaller than the body angle θ_B of any reference plane disposed between the particular reference plane and the start profile plane RP_S.

Particular attention is given to Fig. 7B, in which the relief line RF_3 is shown. When designing a relief line, care should be taken that the relief line does not intersect the projection contour, which may result in the cutting tool coming in contact with the workpiece during a cutting operation at an area other than the cutting edge thereof. Such contact can cause intense friction between the cutting tool and the workpiece which may result in excessive heat, damage to the mechanical integrity of the cutting tool and/or workpiece and, in general, in an inefficient cutting operation.

Once the rake lines RK_1 to RK_7 and relief lines RF_1 to RF_7 have been defined, a rake surface K is generated, extending through all the rake lines RK_1 to RK_9 and a corresponding relief surface F is generated, extending through all the relief lines RF_1 to RF_9. The term '*extending through all...*' is used herein to define that each of the rake lines RK_1 to RK_7 lies on the rake surface K and each of the relief lines RF_1 to RF_9 lies on the relief surface F.

It is appreciated that the rake and relief surfaces K and F respectively are usually required to be continuous surfaces (defined mathematically as a two-dimensional topological manifold). Therefore, the more reference planes are used in the constructions of the rake and relief surfaces K and F respectively, the smoother they will be. A standard computer software can be used to generate a continuous surface based on the above rake and relief lines.

As a result of the above method, the cutting tool designed thereby will be such that for a first reference plane disposed at any point along the cutting edge between a lead point and a trail point thereof and perpendicular to the cutting edge at that point, the angle between the intersection of the rake surface with reference plane and the relief surface with the reference plane will be equal or smaller that a similar angle at any one of a similar reference plane disposed along the cutting edge between the first reference plane and the lead point.

Attention is now drawn to Figs. 8A to 8D, in which on example of a cutting tool is shown, having a cutting edge designed in accordance with the above described method. The cutting tool, generally designated **B70** comprises a cutting insert **B80** having four cutting portions **B90**, one at each corner.

The cutting insert has a top surface **B82**T, bottom surface **B82**B and side surfaces **B82**S extending therebetween. The cutting insert **B80** further has a central bore **B83** configured for receiving therein a securing bolt.

With particular reference being made to Figs. 8B to 8D, the cutting inser comprises a cutting corner with a cutting edge B**85** defined at the intersection between a rake surface **B84** and a relief surface **B86**. On each side of the cutting edge B**85** there extends a cutting edge extension defined at the intersection between the top surface **B82**T and the respective side walls B**82**S. These extensions are equivalent to the bottom and side segments **B22**, **B26** of the end profile.

As observed in the above Figs, the cutting portion **B90** comprises a top cutting portion **B90**a having a cutting edge **B92**a defined between a rake surface **B94**a and a relief surface **B96**a, and a bottom cutting portion **B90**b having a cutting edge B**92**b defined between a rake surface **B94**b and a relief surface **B96**b.

Each of the cutting edges **B92**a, B**92**b extends beyond the side walls **B82**S, i.e. lying on a virtual bridging surface extending between the side walls **B82**S. Each of the cutting edges B**92**a, **B92**b, constitutes a cutting curve designed in accordance with the above describe method, wherein each cutting edge **B92**a, B**92**b, extends only partially along the bridging surface.

As particularly observed in Fig. 8C, when the cutting insert **B80** is properly positioned, the partial cutting edges B**92**a, **B92**b of the cutting portions B**90**a, **B90**b mimic a right angle, extending between the cutting extensions and beyond the cutting edge B**85** (which, in operation, may not come in contact with the workpiece at all).

Attention is now drawn to Figs. 9A and 9B, in which a drilling too, generally designated B**100** is shown, and having a cutting edge designed in accordance with the above described method. Specifically, the drilling tool **B100** comprises a regular cutting edge having a central segment B**122,** a longitudinal segment **B126** and a corner segment **B124,** bridging the segments **B122** and **B126.**

In addition, the drilling tool **B100** is formed with two bridging segments **B140a**, **B140b** extending along a virtual surface bridging a longitudinal surface (on which the longitudinal section lies) and the central surface (on which the central segment lies). More particularly, when discussing a rotary tool as in the present example, the bridging segments **B140a**, **B140b** would lie on a surface which can be mimicked by the revolution of the corner segment B**124** about the central axis of the drilling tool B**100.**

This example is a drilling variation on the previously described turning insert shown in Figs. 8A to 8D.

It is observed that the bridging segments (each on its own and when combined) are considerably longer than the corner segment B**124,** thereby allowing for a more efficient cutting operation and for the reduction of loads exerted on the cutting edge during a cutting operation.

As will be shown in other examples, such tools are not restricted to having a corner segment (e.g. **B124)** and can be formed with only the central segment (e.g. **B122)**, bridging segment (e.g. **B140)** and longitudinal segment (e.g. B**126)**.

The bridging segments B**140a**, **B140b**, though extending between the longitudinal surface and the central surface, extends entirely behind the central segment **B122** and the longitudinal segment B**126.** Nonetheless, due to the drilling tool B**100** being a rotary tool, the envelope generated by the bridging segments complete the envelope portions formed by the central segment B**122** and the longitudinal segment **B126.** As a result, during revolution and operation of the drilling tool **B100,** it is configured for completely removing all the required material from the workpiece to leave a clean corner therein.

Turning now to Figs. 10A and 10B, another example of a drilling tool is shown, generally designated as **B200.** The drilling tool **B200** is similar to the previous drilling tool B**100** (similar elements were designated with similar reference numbers, upped by **B100)**.

The difference between the drilling tool B**100** and the drilling tool **B200** lies in the design of the bridging segments. In particular, whereas the drilling tool B**100** comprised two bridging segments B**140a**, **B140b** covering (in revolution) the entire corner between the central segment **B122** and the longitudinal segment B**126,** in the present example, the bridging segment B**240** covers only half of the above mentioned corner.

Specifically, the cutting edge **B242** extends between a lead end **B232** at a location corresponding (upon revolution) to the intersection between the longitudinal segment B**126** and the corner segment **B124** and a trailing end **B236** (not shown) which does not correspond (upon revolution) to the intersection between the central segment **B122** and the corner segment **B124.**

In operation, the cutting edge **B242** is configured for cutting a slit within the bottom portion of the workpiece, only partially detaching chips of material from the workpiece. When the corner segment B**124** of the opposite half of the drilling tool B**200** passes through the partially removed chips, the resistance to complete removal thereof and the loads exerted on the corner segment are considerably lower than a corresponding drilling tool without a bridging segment B**242.**

Attention is now drawn to Figs. 11A to 11D, in which another example of a drilling tool is shown, generally designated **B300.** The drilling tool **B200** is generally similar to the previous drilling tool **B200** (similar elements were designated with similar reference numbers, upped by B**100**).

However, there are several differences between the drilling tool **B300** and previously described tools, as detailed below.

The drilling tool B**300** is asymmetric, i.e. each of the halves of the drilling tool **B300** has a different design. Each of the halves comprises a cutting edge **B320** having a central segment **B322** and a longitudinal segment **B326** but no corner segment.

The first half of the drilling tool **B300** comprises a bridging segment **B340a** of a cutting edge **B342a** extending along a bridging surface between those of the longitudinal segment **B326** and central segment **B322,** but behind them. In essence, the design of the bridging segment **B342a** is similar to that of bridging segment **B142a** described with respect to Figs. 8A to 8D.

The cutting edge **B342a** is configured for removing material from a bottom portion of the workpiece. More particularly, it is configured for partially detaching chips of material from the bottom portion.

The second half of the drilling tool **B300** comprises a bridging segment B**340b** of a cutting edge **B342b** extending along a bridging surface between those of the longitudinal segment **B326** and central segment **B322,** but behind them. In essence, the design of the bridging segment **B342b** is similar to that of bridging segment B**142b** described with respect to Figs. 8A to 8D.

The cutting edge **342b** is also configured for removing material from a side portion of the workpiece. More particularly, it is configured for partially detaching chips of material from the side portion.

Together, the cutting edges **B342a**, **B342b** mimic an operation similar to that performed by the cutting portion B**140** described with respect to Figs. 8A to 8D, and configured for leaving a sharp corner within the workpiece.

Attention is now drawn to Figs. 12A and 12B, in which a similar drilling tool is shown, generally designated as B**300'**. The main difference between the drilling tool

B300' and the previously described drilling tool **B300** is that the drilling tool **B300'** is formed with a corner segment **B324'** extending between the central segment **B322'** and the longitudinal segment **B326'**.

Turning now to Fig. 13, a schematic illustration of a turning insert is provided, demonstrating some of the main concepts of the cutting insert of the present application. In particular, it is observed that the turning insert comprises a front face FF, a rear face RF and a side face SF. The turning insert is formed with a main cutting edge MCE at the intersection between the side face SF and the front face FF.

The turning insert is provided with an auxiliary cutting element having an auxiliary cutting edge ACE having intersection points on the side face (one being visible) and extending between the front face FF and the rear face RF.

It is observed that auxiliary cutting edge ACE extends beyond the main cutting edge MCE so that the auxiliary cutting envelope AE defined by the auxiliary cutting edge ACE extends beyond the main cutting envelope AE.

The turning insert is configured for performing a cutting operation on a revolving workpiece (not shown). In accordance with the above design, the auxiliary cutting edge ACE is configured for coming in contact with the workpiece before the main cutting edge MCE.

As will be explained in detail later and based on the above described method of design of a cutting edge with respect to Figs. 1 to 12B, it is appreciated that the auxiliary cutting edge ACE is designed based on the above described method.

Several examples of turning inserts will now be described, all sharing the same features of the turning insert described above. Throughout the description, similar elements have been assigned similar reference numbers (e.g. cutting edge **324** of a turning insert **320** is equivalent to cutting edge **224** of turning insert **220** etc.).

Attention is drawn to Figs. 13A to 13F, in which a cutting insert is shown, generally being designated as **20**. The cutting insert comprises a top surface **22**T, an opposite bottom surface **22**B and four side surfaces **22**SS extending therebetween. Each two adjacent side surfaces **22**S are angled to one another to form therebetween a corner **27**. The cutting insert **20** is further formed with a central bore **25** defining a central axis X of the cutting insert **20**.

The cutting insert **20** is formed with four main cutting edges **24**, each main cutting edge **24** being defined at the intersection between the top surface **22**T and the corner **27** formed by the side surfaces **22**S. The main cutting edges **24** are provided with a rake surface **26** constituted by a portion of the top surface **22**T, extending along the intersection between the top surface **22**T and the side surfaces **22**S.

Each corner **27** is formed thereon with an additional cutting element **30**, protruding outwardly from the corner **27** so as to extend beyond the main cutting edge **24** along a plane perpendicular to the top surface **22**T and bisecting the angle of the corner **27**.

The additional cutting element **30** extends about the corner **27**, along a direction between the top surface **22**T and the bottom surface **22**B, beginning from one side surface and ending at another, so as to fully surround the corner **27**.

The additional cutting element is formed with an auxiliary cutting edge **32** defined at the intersection between a rake surface **36** and a relief surface **34** of the additional cutting element **30**.

The rake surface **36** extends generally transverse to the side surfaces **22**S and forming an intersection line **33** therewith. The intersection line has a start point $\mathbf{33}_S$ at one side surface **22**S adjacent the top surface **22**T (but not on the cutting edge **24** or on the intersection between the top surface **22**T and the side surface **22**S), and an end point $\mathbf{33}_E$ at the neighboring side surface, adjacent the bottom surface **22**B (but not on the intersection between the bottom surface **22**B and the side surface **22**S). The start point **33**S is located about **0.5m**m from the top surface **22**T along the axial direction of the cutting insert **20**.

The intersection line **33** is divided into three segments, **33**a, **33**b and **33**c, the first extending along the first side surface **22**S, the second extending along the corner **27**, and the third extending along the neighboring side surface **22**S. It is observed that in the present example, the segments **33**a and **33**c are straight, while the middle segment **33**b is curved.

Due to the curved design of the additional cutting element **30**, it is appreciated that the segment **33**a is closer to the top surface **22**T while the segment **33**c is closer to the bottom surface **22**B, with the middle segment **33**b extending therebetween.

The relief surface **34** extends along the direction between the top surface **22**T and the bottom surface **22**B, and is curved in order to fully surround the corner **27**. It is observed that, similar to the segments **33**a, **33**b, **33**c of the intersection line, the relief surface is formed with three surface portions – two planar portions at the side surfaces **22**S, and a curved portion at the corner **27**.

The auxiliary cutting edge **32** of the additional cutting element **30** extends, at its broadest sense, between a start and an end point which coincide with the start and end points $\mathbf{33}_S$, $\mathbf{33}_E$ of the intersection line **33**. However, contrary to the intersection line **33** which fully lies on the side surfaces **22**S and corner **27**, the cutting edge **32** extends beyond these surfaces and projects from the main cutting edge **24** as can be seen in the top view of Fig. 13C.

Further, as seen in the top view of Fig. 13C, the auxiliary cutting edge is formed with a max-point $\mathbf{32}_M$, which is maximally distant from the main cutting edge **24** in a top view of the cutting insert **20**. In the present example, the symmetric design of the additional cutting element **30** entails that the max-point $\mathbf{32}_M$ is located on the bisector of the angle of the corner **27**.

It is also observed that the auxiliary cutting edge **32** is formed as a single curve extending about the corner and along the direction between the top and the bottom surface **22**T, **22**B, thereby having a length which highly exceeds the length of the main cutting edge **24**.

In addition, the cutting insert **20** shown in the above example is an indexible cutting insert, wherein during each cutting operation, one of the four cutting edges **24** is configured for coming in contact with a workpiece (not shown). However, the cutting insert **20** is not reversible, i.e. the bottom portion of the cutting insert **20** is formed with not cutting edges.

Turning now to Figs. 13G to 13J, a press-mold is shown for the manufacture of the cutting insert **20** previously described, the mold comprising a female member C and a male member P configured for being received within a cavity $C_{\mathbf{14}}$ of the female member C.

First of all, it is noted that the male member P is a simple press member, having straight and planar edges and surfaces respectively, extending along the axial direction of the press-mold.

It is further observed that the cavity $C_{\mathbf{14}}$ of the female member C is shaped as the inverse image of the cutting insert **20**, and is provided, at the middle thereof with a pole member C**16** configured for forming the bore **25** of the cutting insert **20**.

In manufacture, the female member C is filled with particulate material and the male member is hard-pressed into the cavity C_{14} under predetermined heat and pressure conditions in order to solidify the particulate material and transform it into a uniform solid block constituting the cutting insert **20**.

However, it is appreciated that the amount of particulate material provided into the cavity C_{14} cannot be precisely measured (due to the nature of the particulate material), and so in the majority of case, the cavity contains either more or less material than planned.

In most molds, the male and female members are configured with a conical geometry, allowing easier extraction of the male member from the cavity. However, in the case the cavity contains less particulate material, such a configuration might prove problematic, since the male member may progress until it comes into contact, or even collision with the female member, causing damage to the mold members.

In the present example, this is elegantly prevented since the male member is free to displace along the axial direction of the mold without coming in contact with the female member. Thus, even if the female member contains less particulate material, the male member will still press the material without contacting the female member, and produce a cutting insert which is slightly shorter n height between the top and the bottom surface **22**T, **22**B.

Turning now to Figs. 13K to 13N, the cutting insert **20** is shown when mounted onto a cutting tool holder **10** and clamped with a fastening screw **40** to form a turning cutting tool **1.** It is observed that the cutting insert **20** is mounted onto the holder **10** slightly tilted forward and sideways (about **5** deg. in each of these directions).

With particular reference being made to Figs. 13M and 13N, it is observed that in the top view of the cutting tool **1** (the plane of which is perpendicular to the workpiece to be cut), the main cutting edge **24** obscured a portion of the additional cutting element **30** and of the auxiliary cutting edge **32**. However, the majority of the auxiliary cutting edge **32** is still exposed and extends beyond the main cutting edge **24**, so that, in operation, it will come into contact with the workpiece prior to the main cutting edge **24**.

It is further observed that due to the tilt of the cutting insert **20**, which is configured for allowing the cutting tool **1** to perform side cutting (progressing leftwards with respect to the top view), the max-point $\mathbf{32}_M$ is not shifted and is no longer located on the bisector of the angle of the corner **27**. In addition, it is also observed that the max-point is now closer to the main cutting edge **24**, and the entire auxiliary cutting edge **32** is now more evenly distributed about the corner **27** in comparison with the top view of the cutting insert **20** shown in Fig. 13C.

In addition, with particular reference being made to Fig. 13N, since the start and end points $\mathbf{33}_S$, $\mathbf{33}_E$ are obscured by the top surface **22**T of the cutting insert **20**, the effective start and end points of the auxiliary cutting edge **32** are points $\mathbf{32}_S$ and $\mathbf{32}_E$. These points, in the top view of Figs. 13M, 13N, lie on the intersection line between the top surface **22**T and the side surfaces **22**S.

It is also noted that since the cutting tool **1** is designated for side cutting, the additional cutting element **30** projects to a greater extent from the left side surface **22**S than from the front side surface **22**S.

Attention is now brought to Figs. 14A to 14E, in which another example of a cutting insert is shown, generally being designated as **20'**. The cutting insert **20'** is generally similar in construction to the cutting insert **20**, with the difference being in that the cutting insert **20'** is also reversible.

The cutting insert **20'** is similar to the previously described cutting insert **20** and so, similar elements have been allocated similar reference numbers with the addition of a prime ('), e.g. cutting edge **24** of cutting insert **20** is similar to cutting edge **24'** of cutting insert **20'**.

This difference is reflected in the design of the additional cutting element **30'**, which, has an additional rake surface **36'** and an additional cutting edge **32'** which are located closer to the bottom surface **22**B of the cutting insert **20**.

Thus, the cutting insert **20'** comprises eight main cutting edges **24** – four at the intersection between the top surface **22**T and the corners and four at the intersection between the bottom surface **22**B and the corners, as well as eight auxiliary cutting edges **32'**, two edges for each of the additional cutting elements **30'**.

Turning now to Figs. 14F to 14I, a press-mold is shown configured for the manufacture of the cutting insert **20'**. As opposed to the mold members P and C, the mold members P' and C' of the present example differ in their design by that the male member P' is formed with a shaped cavity portion of its own $P_{\mathbf{14}}$ configured for forming half of the cutting insert **20'**.

Reverting to Fig. 14E, it is noted that the press-mold is designed such that the parting line between the male and female members P' and C' does not pass along any of the auxiliary cutting edges **32'**, but rather along the middle of the relief surface **34** of the additional cutting element **30'**. This eliminates any unwanted tolerances or defects at the auxiliary cutting edge **32'** formed in the additional cutting element **30'**.

Attention is now drawn to Figs. 14J to 14L, in which the cutting insert **20'** is shown when mounted onto a cutting tool holder **10'** to form a turning tool **1'**, essentially similar to the turning tool **1.**

As in the previously described example, the original start and end points **33**S, **33**E are obscured in the top view, so that the effective cutting edge **32'** coming in contact with the workpiece is defined between the start and end points **32**S, **32**E.

Turning now to Figs. 15A to 15D, another example of a cutting insert is shown, being generally designated as **20''**. The cutting insert **20''** is generally similar to the previously described cutting inserts **20**, **20'**, with the difference being that the cutting insert **20''** is configured for front cutting in a turning operation, rather than for side cutting.

The cutting insert **20''** is similar to the previously described cutting inserts **20**, **20'** and so, similar elements have been allocated similar reference numbers with the addition of a double prime ("), e.g. cutting edge **24** of cutting insert **20** is similar to cutting edge **24''** of cutting insert **20''**.

First of all, it is observed that while the additional cutting elements **30**, **30'** extended, from top to bottom, in a CW direction, the additional cutting element **30''** extends in a CCW direction. In other words, the auxiliary cutting edges **32**, **32'** had a start point at the left side surface **22**S adjacent the top surface **22**T and an end point at the front side surface **22**S adjacent the bottom surface **22**B, whereas the auxiliary cutting edge **32''** has a start point at the front side surface **22**S adjacent the top surface **22**T and an end point at the left side surface **22**S adjacent the bottom surface **22**B.

As such, it is observed that the cutting insert **20''**, when similarly tilted when mounted onto the holder **10''** (**5** deg. in each direction), protrudes more from the front side surface **22**S than from the left side surface **22**S, making it more suitable for front cutting.

Attention is now drawn to Figs. 16A to 16E, yet another example of a cutting insert is shown, being generally designated as **20'''**. The cutting insert **20'''** is generally similar to that described with respect to Figs. 14A to 14L, with the difference being that the rake surface **36** of the additional cutting element is formed with several steps **36**a to **36**d, and so the auxiliary cutting edge **32**''' itself is split into several corresponding segments.

The cutting insert **20**''' is both indexible and reversible and configured for side cutting in a turning operation.

The cutting insert **20**''' is similar to the previously described cutting inserts **20**, **20**', and **20**'', and so, similar elements have been allocated similar reference numbers with the addition of a tripple prime ('''), e.g. cutting edge **24** of cutting insert **20** is similar to cutting edge **24**''' of cutting insert **20**'''.

The separation of the rake surface **36** causes the cutting insert **20**''' to remove four chips from the workpiece, each chip having a width smaller than that of the chip removed by the cutting insert **20**.

It is noted that since the cutting insert **20**''' is produced in a pressing process, the surfaces **35** bridging between the steps of the cutting portion **30**''' are of straight vertical orientation. However, since the cutting insert **20**''' is mounted onto the cutting tool holder **10** at a tilt angle (about 7° to each of the side surfaces), the surfaces **35** each obtain a different angle with respect to the workpiece.

In particular, while the top most surface **35** is angled so that the surface **36**a overlaps surface **36**b in a top view of the cutting insert shown in Fig. 16D, the neighboring surface **35** remains at the same angle (i.e. no overlapping between **36**b and **36**c) and the following neighboring surface **35** is angled such that there exist no overlap between the surface **36**c and **36**d.

Therefore, it may be required to grind the tow bottom-most surfaces **35** so as to create and overlap between the surfaces **36**b, **36**c, **36**d, such that **36**b overlaps **36**c and **36**c overlaps **36**d. It is appreciated that this cannot be performed during manufacture of the cutting insert in the pressing process.

Turning now to Figs. 17A to 17H, yet another cutting insert is shown, generally designated as **100.** The cutting insert **100** is similar to the previously described cutting inserts, with the difference being that in the working top view of the cutting insert (shown in Fig. 17G), the additional cutting element **130** extends symmetrically about the cutting corner **127** of the cutting insert **120.**

The cutting insert **120** is similar to the previously described cutting inserts **20** and so, similar elements have been allocated similar reference numbers with the addition of **100,** e.g. cutting edge **24** of cutting insert **20** is similar to cutting edge **124** of cutting insert **120.**

The cutting insert **120** is formed, similar to previous described cutting inserts, with a top surface **122T**, a bottom surface **122B** and side surfaces **122S**. In addition, it is formed with a cutting edge **124** disposed along a corner **127** and having a rake surface **126** along the top surface **122T**.

In other words, when the cutting insert **120** is mounted onto a cutting tool holder **110** and tilted both forward and sideways to the position shown in Fig. 17G, the extension of the cutting edge **132** is symmetric about the bisector of the angle of the corner **127.**

In order to achieve such symmetry in the tilted position of the cutting insert **130,** the additional cutting element as seen in Figs. 17A to 17C, is not symmetric about the corner in its normal top view.

In addition, it is observed that the cutting edge **132** of the cutting insert **120** has a first portion **132a** and a second portion **132b**, which are angled to one another, i.e. not tangent to one another.

Turning now to Figs. 18A to 18G, still another cutting insert is shown, generally designated as **220.** The cutting insert **220** is similar to the previously described cutting inserts **20**, **20'**, **20"** and **120,** and so, similar elements have been allocated similar reference numbers with the addition of **200,** e.g. cutting edge **24** of cutting insert **20** is similar to cutting edge **224** of cutting insert **220.**

The cutting insert **220** comprises two additional cutting elements **230i** and **230i**i, the cutting element **230i**i constituting the additional cutting element of the first cutting element **230i**. The cutting element **230i**i extends beyond the cutting element **230i**, allowing removing even more material from the workpiece.

Thus, each of the additional cutting elements is formed with a respective cutting edge **232i**, **232i**i, rake surfaces **236i**, **236i**i and relief surfaces **234i**, **234i**i. Consequently, each of the cutting edges has a start point $\mathbf{232}_{S\text{-}i}$, $\mathbf{232}_{S\text{-}ii}$ and an end point $\mathbf{232}_{E\text{-}i}$, $\mathbf{232}_{E\text{-}ii}$.

In the above described example, both the first additional cutting element **230i** and the second additional cutting element **230i**i extend in a CW direction about the corner **227.** However, it is appreciated that a design can be provided in which the second additional cutting element **230ii** extends in a CCW direction about the first additional cutting element **230i**.

Attention is now drawn to Figs. 19A to 19G, in which another example of a cutting insert is shown, generally being designated as **320,** which demonstrates a slightly different design of the main cutting edge **324.**

The cutting insert **320** is similar to the previously described cutting inserts **20**, **20'**, **20"**, **120** and **220,** and so, similar elements have been allocated similar reference numbers with the addition of **300,** e.g. cutting edge **24** of cutting insert **20** is similar to cutting edge **324** of cutting insert **320.**

The entire corner **327** of the cutting insert **320** is slightly clefted, so that the main cutting edge **324** comprises two portions. Respectively, the design of the additional cutting element **330** is such that covers for the clefted nature of the main cutting edge **324,** completing the cutting corner **327** to a regular, right angled corner.

The cutting insert **320** is indexible but not reversible.

Turning now to Figs. 20A to 20G, in which still another example of a cutting insert is shown, generally designated as **420.** The cutting insert **420** also comprises four main cutting edges **424** and four additional cutting elements **430,** but differs from the previous examples by the fact that the start points **432**$_S$ of the auxiliary cutting edges **432** do not coincide with the start point **433**$_S$ of the intersection line.

The cutting insert **420** is similar to the previously described cutting inserts **20**, **20'**, **20"**, **120, 220** and **320,** and so, similar elements have been allocated similar reference numbers with the addition of **400,** e.g. cutting edge **24** of cutting insert **20** is similar to cutting edge **424** of cutting insert **420.**

In particular, the cutting insert **420** comprises four side walls **422S**, each having a first portion **422S**a and **422S**b, parallel to one another, with the first portion **422S**a being more remote from the central axis X than the second portion **422S**b.

Thus, it is observed that the corner **427** is formed by curving of the second side portion **422S**b, while the curving of the first side portion **422S**a serves as the additional cutting element **430.**

With particular reference being drawn to Fig. 20E, when the cutting insert **420** is mounted onto a cutting tool, the cutting edge **432** of the additional cutting element **430** is tangent to the intersection line between the top surface **422T** and the side surface **422S**a.

Turning now to Figs. 21A to 21H, still another example of a cutting insert is shown, generally designated as **520,** and shown mounted onto a cutting tool holder **510** to form a turning tool **501.** The cutting insert **520** is used as a tangential cutting insert **520.**

The cutting insert **520** is similar to the previously described cutting inserts **20**, **20'**, **20"**, **120, 220, 320** and **420,** and so, similar elements have been allocated similar reference numbers with the addition of **500,** e.g. cutting edge **24** of cutting insert **20** is similar to cutting edge **524** of cutting insert **520.**

The cutting tool holder **510** is formed with two insert seats, each being configured for receiving the cutting insert in a different orientation.

As opposite to all previously described cutting inserts, the cutting insert **520** comprises a a first narrow side surface **522S**a and second, wide side surface **522S**b which is formed with a bore **525** (as opposed to previous cutting inserts in which the bore was formed in the top surface).

Another difference between the cutting insert of the present example and previously described cutting inserts, is that the addition elements **530** face in different directions, i.e. alternating between CW direction and CCW direction. This gives rise to a unique configuration in which, along the first side surface **522S**a, the cutting edges **532** converge towards one another.

In addition, observing Figs. 21F and 21H, when the cutting insert **530** is mounted onto the cutting tool holder **510,** the cutting edge of the additional cutting element **530** extends almost symmetrically about the corner **527** of the cutting insert **520.**

Attentions is now drawn to Figs. 22A to 22G, in which another example of a cutting insert is shown, generally designated as **620,** and having a cutting corner **627** which is not right angled, but rather of an acute angle, approx. **35**deg.

The cutting insert **620** is similar to the previously described cutting inserts **20**, **20'**, **20"**, **120, 220, 320, 420** and **520,** and so, similar elements have been allocated similar reference numbers with the addition of **600,** e.g. cutting edge **24** of cutting insert **20** is similar to cutting edge **624** of cutting insert **620.**

Thus, the cutting insert **620** has only two main cutting edges **624** at the acute corners (the other corners are not cutting corners), and two additional cutting elements **630.**

The cutting insert **620** is indexible (too cutting corners) but not reversible.

With specific attention being drawn to Fig. 22C, it is observed that a portion of the additional element can be performed by sharpening/grinding after the manufacture of the cutting insert in a press-mold.

As in previous examples, it is observed that there is a difference between the top view of the cutting insert **620** perpendicular to the top surface (Fig. 22D) and a top view of the cutting insert when mounted onto the cutting tool holder (Fig. 22F). The arrangement is such that when properly tilted (when mounted onto the cutting tool holder), the auxiliary cutting edge **632** uniformly surrounds the corner **627.**

Turning now to Figs. 23A to 23F, yet another example of a cutting insert is shown, generally being designated as **720.** The cutting insert **720,** similar to the cutting insert **220,** comprises two additional cutting elements **730i**, **730i**i, which are consecutively arranged.

The cutting insert **720** is similar to the previously described cutting inserts **20**, **20'**, **20"**, **120, 220, 320, 420, 520** and **620,** and so, similar elements have been allocated similar reference numbers with the addition of **700,** e.g. cutting edge **24** of cutting insert **20** is similar to cutting edge **724** of cutting insert **720.**

However, contrary to the cutting insert **220,** in the present example, each of the cutting elements **730i**, **730i**i is formed with a different cutting radius as seen in the top view of the cutting insert (Fig. 23E). Furthermore, it is observed that the main cutting edge **724** has a first radius R**1,** the first cutting element **730i** has a second cutting radius R**2** <R**1,** and the second cutting element **730i**i has a third cutting radius R**3** < R**2.**

Thus, the cutting insert **720** allows gradually removing material from the workpiece to create a corner therein of radius R**3,** while gradually distributing the loads on the cutting insert **720.**

Under the above design, the main cutting edge **724** can be of a very large radius more suitable for rough removal of material from the workpiece, while the additional cutting elements **730i**, **730i**i, are formed with smaller radii configured for more fine removal of material from the workpiece.

Such a design allows performing both rough and fine cutting of the workpiece using the same corner of the cutting insert at the same orientation with respect to the workpiece. In other words, there is no need to use an additional tool for fine cutting, and there is also no need for tilting/changing the orientation of the cutting insert with respect to the workpiece to distinguish between rough and fine cutting.

With respect to all previously described examples of cutting inserts, the chips removed from the workpiece by the main cutting edge are evacuated from the cutting insert via the top surface thereof, while chips removed by the auxiliary cutting edge proceed downwards to be evacuated via the bottom surface of the cutting insert. In other words, when the auxiliary cutting edge encounters the workpiece, the removed chip spirals downwards along the direction of the auxiliary cutting edge, whereas when the main cutting edge encounters the workpiece, the chips are broken off and curled upwards by virtue of the rake surface (a portion of the top surface);

Turning now to Figs. 24A to 24G, a turning tool is shown generally designated as **801,** and comprising a cutting tool holder **810** on which a cutting insert **20** is mounted, and also a chip breaking mechanism **850** disposed beneath the cutting insert **20** and biased by a biasing mechanism **860.**

The arrangement is such that the chip breaker **850** is outwardly biased by the biasing mechanism **860,** so as to protrude from a front surface **814** of the cutting tool holder **810,** beneath the cutting insert **20**.

The chip breaker **850** is in the form of an oval shaped member, having a sloped front surface **852** configured for coming in contact with the workpiece and breaking chips removed from the workpiece by the auxiliary cutting edge **32**.

The chip breaker **850** is formed with a pivot bore **857** configured for receiving therein a pivot member **862** of the biasing mechanism **860.** The biasing mechanism **860** further comprises a biasing spring **866** which is configured for urging the pivot member **862** to rotate in a CW direction, consequently urging the chip breaker **850** to protrude from the cutting tool holder **810** towards the workpiece.

With particular reference being drawn to Fig. 24G, it is noted that during the cutting operation, a front surface **852** of the chip breaker comes in contact with the workpiece to form a space defined between the breaker **850,** the workpiece and the front surface **814** of the cutting tool holder **810.**

In operation, chips removed from the workpiece by the auxiliary cutting edge **832** spiral downwards towards the chip breaker. Upon encountering the chip breaker, the chips are broken into bits.

However, it is appreciated that the broken bits of the chips are gradually accumulated within the above formed space between the chip breaker and workpiece. Thus, in order to avoid congestion of the chips, the biasing degree of the biasing spring is such that it allows, on the one hand, applying enough pressure on the chips in order to break them, but on the other hand, is loose enough to allow the chip breaker to pivot about the axis into the cutting tool holder in order to allow the accumulated chips to be removed downwardly.

Furthermore, it is appreciated that the revolving workpiece constantly urges the chip bits in a downwards direction, applying pressure thereto. Thus, when enough chips and chip bits are accumulated and enough pressure is applied on the chip breaker by the revolution of the workpiece, the biasing spring of the chip breaker can no longer withstand the pressure, allowing the chip breaker to retreat and the chips to be evacuated.

Turning now to Figs. 25A through 25H, another example of a cutting insert is shown, generally designated as **920,** and formed with a top surface **922T**, a bottom surface **922B** and a side surface **922S** extending therebetween.

The cutting insert **920** is similar to the previously described cutting inserts **20**, **20'**, **20"**, **120, 220, 320, 420, 520, 620** and **720,** and so, similar elements have been allocated similar reference numbers with the addition of **900,** e.g. cutting edge **24** of cutting insert **20** is similar to cutting edge **924** of cutting insert **920.**

The cutting insert **920** is formed with an additional cutting element **930** along the corner **927** thereof, similar to previously described cutting element **30"**, with the difference being that the cutting insert **920** is also provided with four secondary cutting elements **930'** disposed along the side surface **922S**.

Each of the secondary cutting elements **930'** has a cutting edge **932'** extending between a start point $\mathbf{933_S}$' located on the side surface **922S** (and not on the intersection between the side and top surfaces) and an end point $\mathbf{932_E}$' and the bottom surface **922B**.

The cutting edge **932'** of each of the secondary cutting elements **930'** spirals between the start and end points $\mathbf{933_S}$', $\mathbf{932_E}$' similar to the auxiliary cutting edge **932.** Specifically, it is observed that the cutting edges **932'** mimic the shape of a portion of the cutting edge **932** starting from the side surface **922S**.

The cutting insert **920** thus has only two main cutting edges **924** at the opposite corner **927,** two corresponding additional cutting elements **930** and two sets of secondary cutting element **930'**.

With particular reference to Fig. 25G, it is observed that the cutting insert **920** is designed to have no undercuts, and can therefore be produced by a press-mold, as shown in Figs. 26A to 26E.

Turning now to Figs. 26A to 26E, there is presented a press-mold configured for producing the cutting insert **920,** and comprising a male member **980** and a female member **990.**

The male member **980** comprises a body **982** having a top surface **982T**, a bottom surface **982B** and side surfaces **982S** extending therebetween, and a bore **985** axially extending between the top and bottom surface **982T**, **982B**.

Two opposite side surfaces of the male member **980** are formed with projections **983'** which mimic the shape of the bottom surface of the cutting insert **920.**

It is observed form Fig. 26C that the male member **980** has no undercuts, allowing the cutting insert **920** t be manufactured using a pressing process.

The female member **990** is formed with a central cavity **995** and a central pole **996** configured for being received within the bore **985** of the male member **980,** serving both to form the bore **925** of the cutting insert **920** as well as for alignment of the male and female members **980, 990.**

The cavity **995** has a first portion having a shape corresponding to that of the cutting insert **920** and a second portion having a shape corresponding to that of the male member **980,** the second portion being closer to a top surface **992T** of the female member **990** along the axial direction.

Turning now to Figs. 27A to 27E, the cutting insert **920** is shown when mounted onto a cutting tool holder **910,** positioned thereon at a tilt (both forward and sideways).

It is observed that in the top view shown in Fig. 27B, the auxiliary cutting edge **932** and the secondary cutting edges **932'** form a combined cutting edge extending parallel to the edge formed between the top surface **922T** and the side surface **922S**.

Thus, the cutting insert **920** is configured for a cutting operation under a side feed, progressing in the direction of arrow F, thereby removing material from the workpiece along almost the entire side surface of the cutting insert **920.**

With particular attention drawn to Figs. 27C to 27E, it is observed that, in the orientation of the cutting insert **920** when mounted onto the cutting tool holder **910,** the end point **932_E** of the auxiliary cutting edge **932** is overlapped by the secondary cutting edge **932'** of the neighboring secondary cutting element **930'**.

In addition, the end point **932_E**' of the secondary cutting edge is also overlapped by the secondary cutting edge **932'** of the neighboring secondary cutting element **930'**. This is true for all secondary cutting elements **930'** but the last (the most remote from the cutting corner **927**). Under the above design, the cutting edges **930, 930'** of the cutting insert mimic a single cutting edge extending along the majority of the side surface **922S**.

Turning now to Figs. 28A to 28H, in which yet another example of a cutting insert is shown, generally designated as **1020**. The cutting insert **1020** is generally similar to the previously described cutting insert **920,** and so, similar elements have been allocated similar reference numbers with the addition of **1000**, e.g. cutting edge **924** of cutting insert **920** is similar to cutting edge **1024** of cutting insert **1020**.

However, the cutting insert **1020** comprises a first set of secondary cutting elements on one side surface **1022**S and a second set of secondary cutting elements **1040**' on the adjacent side surface **1022**S, the side surfaces **1022**S forming the corner **1027** of the cutting edge **1024**.

It is also observed that the additional cutting element **1030** itself is formed with another cutting element **1040** thereon, with a cutting edge **1042** spiraling the opposite direction of the cutting edge **1032** of the additional cutting element **1030**.

The above cutting insert **1020**, as opposed to the previously described cutting insert **920,** is configured for performing a cutting operation in both directions, i.e. front and side, as will be shown with respect to Figs. 30A to 30E.

Turning now to Figs. 29A to 29E, a press-mold configured for producing the cutting insert **1020**, and comprising a male member **1080** and a female member **1090**.

The male member **1080** comprises a body **1082** having a top surface **1082**T, a bottom surface **1082**B and side surfaces **1082**S extending therebetween, and a bore **1085** axially extending between the top and bottom surface **1082**T, **1082**B.

Two opposite side surfaces of the male member **1080** are formed with projections **1083**' which mimic the shape of the bottom surface of the cutting insert **1020**.

It is observed form Fig. 26C that the male member **1080** has no undercuts, allowing the cutting insert **1020** t be manufactured using a pressing process.

The female member **1090** is formed with a central cavity **1095** and a central pole **1096** configured for being received within the bore **1085** of the male member **1080**, serving both to form the bore **1025** of the cutting insert **1020** as well as for alignment of the male and female members **1080**, **1090**.

The cavity **1095** has a first portion having a shape corresponding to that of the cutting insert **1020** and a second portion having a shape corresponding to that of the male member **1080**, the second portion being closer to a top surface **1092**T of the female member **1090** along the axial direction.

Turning now to Figs. 30A to 30E, the cutting insert **1020** is shown when mounted onto a cutting tool holder **1010**, positioned thereon at a tilt (both forward and sideways).

It is observed that in the top view shown in Fig. 30B, the auxiliary cutting edge **1032** and the secondary cutting edges **1032**' form a combined cutting edge extending parallel to the edge formed between the top surface **1022**T and the side surface **1022**S.

Thus, the cutting insert **1020** is configured for a cutting operation under both a side feed and a front feed, progressing in the directions of arrows F**1** and F**2** respectively, thereby removing material from the workpiece along almost the entire side surface of the cutting insert **1020**.

With particular attention drawn to Figs. 27C to 27E, it is observed that, in the orientation of the cutting insert **1020** when mounted onto the cutting tool holder **1010**, the end point $\mathbf{1032}_E$ of the auxiliary cutting edge **1032** is overlapped by the secondary cutting edge **1032**' of the neighboring secondary cutting element **1030**'.

In addition, the end point $\mathbf{1032}_E$' of the secondary cutting edge is also overlapped by the secondary cutting edge **1032**' of the neighboring secondary cutting element **1030**'. This is true for all secondary cutting elements **1030**' but the last (the most remote from the cutting corner **1027**). Under the above design, the cutting edges **1030**, **1030**' of the cutting insert mimic a single cutting edge extending along the majority of the side surface **1022**S.

With respect to all previously described cutting inserts, it is appreciated that in the orientation of the cutting insert when mounted onto the cutting tool holder (i.e. in a working position), the start points #$\mathbf{33}_S$ of the cutting auxiliary cutting edges do not come into contact with the workpiece as they are protected by the top surface #**22**T of the cutting inserts.

Thus, in effect, the chips removed from the workpiece by the cutting insert always have an additional space to flow to, since the effective starting point of the cutting is spaced from the side surface #**22**S of the cutting insert.

Turning now to Fig. 31, a schematic illustration of a milling insert is shown demonstrating some of the main concepts of the cutting insert of the present application. Similar to previously described turning inserts, the milling insert also comprises a front face FF, a rear face RF and a side face SF. The milling insert is further formed with a main cutting edge MCE at the intersection between the side face SF and the front face FF.

The cutting insert is provided with an auxiliary cutting element having an auxiliary cutting edge ACE having intersection points on the side face (one being visible) and extending between the front face FF and the rear face RF.

However, contrary to the previously described turning insert, the milling insert is configured for being mounted on a revolving tool for removing material from a static workpiece (not shown). As such, the geometry of the milling insert is slightly curved in order to correspond to the circular motion performed by the insert during its revolution together with the milling tool.

Nonetheless, as previously described with respect to the turning insert, the auxiliary cutting edge ACE still extends beyond the main cutting edge MCE so that the auxiliary cutting envelope AE defined by the auxiliary cutting edge ACE extends beyond the main cutting envelope AE.

In accordance with the above design, the auxiliary cutting edge ACE is configured for coming in contact with the workpiece before the main cutting edge MCE.

In principle, contrary to turning inserts, in a milling operation there is no requirement for providing a chip breaker on the cutting insert since the maximal length of a removed chip is equal to **50**% of the external diameter of the milling tool. Therefore, although the auxiliary cutting element is not provided with a chip breaker, it does not clog the cutting tool and/or workpiece during the milling operation.

Attention is now drawn to Figs. 31A to 31I, in which one example of a milling tool is shown, generally designated **1100** and comprising a cutting tool holder **1110** and a plurality of milling inserts **1120**.

In principle, the milling insert **1120** is similar to the previously described turning insert **20**, with the difference being in the curved geometry of the side face **1122**S.

The milling insert comprises a front surface **1122**F, an opposite rear surface **1122**R and four side surfaces **1122S** extending therebetween. Each two adjacent side surfaces **1122S** are angled to one another to form therebetween a corner **1127**. The milling insert **1120** is further formed with a central bore **1125** defining a central axis X of the milling insert **1120**.

The milling insert **1120** is formed with four main cutting edges **1124**, each main cutting edge **1124** being defined at the intersection between the front surface **1122**F and the corner **1127** formed by the side surfaces **1122S**. The main cutting edges **1124** are provided with a rake surface **11126** constituted by a portion of the front surface **1122**F, extending along the intersection between the front surface **22**F and the side surfaces **1122**S.

Each corner **1127** is formed thereon with an additional cutting element **1130**, protruding outwardly from the corner **1127** so as to extend beyond the main cutting edge **1124** along a plane perpendicular to the front surface **1122**F and bisecting the angle of the corner **1127**.

The additional cutting element **1130** extends about the corner **1127**, along a direction between the front surface **1122**F and the rear surface **1122**R, beginning from one side surface and ending at another, so as to fully surround the corner **1127**.

The additional cutting element is formed with an auxiliary cutting edge **1132** defined at the intersection between a rake surface **1136** and a relief surface **1134** of the additional cutting element **1130**.

The rake surface **1136** extends generally transverse to the side surfaces **1122S** and forming an intersection line **1133** therewith. The intersection line has a start point **1133**$_S$ at one side surface **1122S** adjacent the front surface **1122**F (but not on the cutting edge **1124** or on the intersection between the front surface **1122**F and the side surface **1122**S), and an end point **1133**$_E$ at the neighboring side surface, adjacent the rear surface **1122**R (but not on the intersection between the rear surface **1122**R and the side surface **1122**S). The start point **1133**S is located about **0.5m**m from the front surface **1122**F along the axial direction of the milling insert **1120**.

The intersection line **33** is divided into three segments, **1133**a, **1133**b and **1133**c, the first extending along the first side surface **1122**S, the second extending along the corner **1127**, and the third extending along the neighboring side surface **1122**S. It is observed that in the present example, the segments **33**a and **33**c are straight, while the middle segment **1133**b is curved.

Due to the curved design of the additional cutting element **1130**, it is appreciated that the segment **1133**a is closer to the front surface **1122**F while the segment **1133**c is closer to the rear surface **1122**R, with the middle segment **1133**b extending therebetween.

The relief surface **1134** extends along the direction between the front surface **1122**F and the rear surface **1122**R, and is curved in order to fully surround the corner **1127**. It is observed that, similar to the segments **1133**a, **1133**b, **1133**c of the intersection line, the relief surface is formed with three surface portions – two planar portions at the side surfaces **1122**S, and a curved portion at the corner **1127**.

The auxiliary cutting edge **1132** of the additional cutting element **1130** extends, at its broadest sense, between a start and an end point which coincide with the start and end points $\mathbf{1133}_S$, $\mathbf{1133}_E$ of the intersection line **1133**. However, contrary to the intersection line **1133** which fully lies on the side surfaces **1122**S and corner **1127**, the cutting edge **1132** extends beyond these surfaces and projects from the main cutting edge **1124** as can be seen in the top view of Fig. 13C.

Further, as seen in the top view of Fig. 13C, the auxiliary cutting edge is formed with a max-point $\mathbf{1132}_M$, which is maximally distant from the main cutting edge **1124** in a top view of the milling insert **1120**. In the present example, the symmetric design of the additional cutting element **1130** entails that the max-point $\mathbf{1132}_M$ is located on the bisector of the angle of the corner **1127**.

It is also observed that the auxiliary cutting edge **1132** is formed as a single curve extending about the corner and along the direction between the top and the rear surface **1122**F, **1122**R, thereby having a length which highly exceeds the length of the main cutting edge **1124**.

In addition, the milling insert **1120** shown in the above example is an indexible milling insert, wherein during each cutting operation, one of the four cutting edges **1124** is configured for coming in contact with a workpiece (not shown). However, the milling insert **1120** is not reversible, i.e. the bottom portion of the milling insert **1120** is formed with not cutting edges.

With reference to Fig. 31E, it is observed that when the milling insert **1120** is mounted into its corresponding pocket of the milling tool holder **1110**, the auxiliary cutting element **1130** protrudes beyond the envelope of the cutting edge **1124**.

It is further observed in connection with Figs. 31G to 31I, that during the milling operation, the auxiliary cutting edge **1132**, having a cutting envelope E_O first comes into contact with the workpiece. Below a predetermined feed, the arrangement is such that only the auxiliary cutting edge **1132** performs the milling operation. However, above said predetermined feed, both the main cutting edge **1124** and the auxiliary cutting edge **1132** take place in the milling operation, the auxiliary cutting edge **1132** coming in contact with the workpiece before the main cutting edge **1124**.

In operation, when a chip is removed from the workpiece by the auxiliary cutting element it is urged towards the rear face **1122**R of the milling insert **1120** and is eventually evacuated from the milling tool **1100** via a chip evacuation channel located behind the milling insert **1120**. For this purpose, the bottom surface of the seat of the milling tool **1100** can be oriented at a slight angle in order to allow more room for such removed chips to flow into the chip evacuation channel.

Turning now to Figs. 32A to 32E, another example of a milling insert is shown generally designated as **1220**. The milling insert **1220** is generally similar to the previously described milling insert **1120** with the exception of several differences as described below.

The milling insert **1220** is formed with rear projections, each being defined by a slanted surface **1229** of the insert **1220** and a rear surface **1237** of the auxiliary cutting element **1230**. The seat of the milling tool **1200** is formed with a corresponding surface **1217** configured for allowing the required space for the rear projection.

In addition, the auxiliary cutting element **1230** is designed such that, when mounted onto the milling tool holder **1210**, the projection of the auxiliary cutting edge **1232** is equally in both the radial and the axial direction, i.e. during a milling operation, the same amount of material is removed from the bottom of the workpiece as from the side thereof.

In addition, the auxiliary cutting edge **1232** is slightly longer in comparison with that of the auxiliary cutting edge **1132** of the milling insert **1120**, providing for an increased life span of the cutting insert.

Turning now to Figs. 33A to 33E, yet another example of a milling insert is shown, generally designated **1320**, and similar to previously described turning insert **20**", in which the cutting edge **1332** surrounds the corner in the opposite direction.

In this case, during a milling operation, chips removed from the workpiece by the auxiliary cutting edge **1332** are not urged downwards as in the previously described milling insert **1120**, but rather radially outwards.

Thus, chips are still being evacuated via chip evacuation channel of the milling tool **1300** located behind the milling insert **1320**, but reach that channel via the side of the milling tool **1300** and not via the bottom thereof.

Such a milling tool **1300** can be particularly useful for performing deep milling in which the sidewalls are considerably longer/taller than the milling tool, allowing the chips more room for evacuation.

Turning now to Figs. 34A to 34E, still another example of a milling tool is shown, generally designated as **1400** and comprising a plurality of milling inserts **1420**.

Contrary to the previously described milling inserts, the milling inserts **1420** are tangential milling inserts in the sense that the orientation of the milling insert **1420** on the milling tool **1400** is such that the broad side thereof faces in the radial direction. In other words, the front surface **1422**T and the rear surface **1422**B are of considerably surface area than the side surfaces **1422**S. This allows increasing the sustainability of the milling insert **1420** and its resistance to withstanding loads applied thereto during the milling operation.

Similarly to the previously described milling inserts **1120** and **1220**, chips removed during a milling operation are pushed downwards and towards the rear of the milling insert **1420** to be evacuated via a chip evacuation channel located behind the milling insert **1420**.

Turning now to Figs. 35A to 35F, in which another example of a milling tool is shown, generally designated as **1500** and comprising a plurality of milling inserts **1520**.

Each of the milling inserts **1520** is formed with an auxiliary cutting element **1530** which is essentially similar to the auxiliary cutting element **230** previously described with respect to Figs. 18A to 18G and is formed with an inner cutting edge **1532**i and an outer cutting edge **1532**o.

Each of the main cutting edge **1524**, inner cutting edge **1532**i and outer cutting edge **1532**o is configured for removing 0.3mm of material, providing the milling tool **1500** with the ability to remove 0.9mm of material from the workpiece in total, making it very suitable for surface milling.

Turning now to Figs. 36A to 36F, in which still another example of a milling tool is shown generally designated as **1600** and comprising a plurality of milling inserts **1620**.

Each of the milling inserts **1620** is formed with a plurality of auxiliary cutting elements **1530** on each of the side surfaces **1622**S forming the corner, which is essentially similar to the cutting insert **1020** previously described with respect to Figs. 28A to 28H.

It is observed that the seat of the cutting tool holder **1610** is formed with a base surface **1612** and chip evacuation flutes **1615** at its side surface configured for forming a continuation of the auxiliary cutting elements **1630**. Thus, chips removed from the workpiece during a milling operation and removed via the chip evacuation flutes formed between the auxiliary cutting elements **1630** can progress, uninterruptedly to the chip evacuation flutes **1615** to eventually be evacuated from the milling tool **1600**.

Fig. 36G illustrates a mold for the manufacture of the milling insert **1620** described above and comprises a male member **1680** and a female member **1690**. It is also observed that the cutting insert **1620** is formed with a straight portion at the rear end thereof allowing it to compensate of deficiency in material placed within the press mold. Respectively, both the male and the female members **1680**, **1690** are formed with straight portions at their ends (not conical). Thus, if not enough material placed the female member **1690** of the mold, the male member **1680** is allowed to displace deeper into the female member **1690** without getting stuck and without forming surface contact between the mold members. As a result, the milling insert **1620** may turn out to be slightly thinner than originally planned, but not to a sufficient amount so as to damage its functional characteristics.

Turning now to Figs. 37A to 37E, yet another example of a milling tool is shown, generally designated **1700** and comprising a milling tool holder **1710** and a plurality of milling inserts **1720**.

The milling insert **1720** is generally similar to previously described turning insert **920,** and, contrary to the milling insert **1620**, is formed with a plurality of auxiliary cutting elements **1730** only on one portion of the side face **1722**S of the milling insert **1720**.

Fig. 37F shows a press mold for the manufacture of the milling insert **1720** comprising a male member **1780** and a female member **1790** and is essentially similar to the press mold of the milling insert **1620**.

Turning now to Figs. 38A to 38F, still another milling tool is shown generally designated **1800** and comprising a milling tool holder **1810** and a plurality of milling inserts **1820**.

The milling insert **1820** is generally similar to previously described milling inserts **1120**, **1220** and **1320**, with the difference being in the curvature radius of the auxiliary cutting edge **1832** of the auxiliary cutting element. Specifically, the curvature radius is such that allows the milling insert **1820** to remove an almost right-angle corner within the workpiece.

Attention is now drawn to Fig. 39, in which a schematic illustration of a drilling tool is shown demonstrating some of the main concepts of the drilling tool of the present application. The drilling tool also comprises a front face FF, a rear face RF and a side face SF. The drilling tool is further formed with a main cutting edge MCE at the intersection between the side face SF and the front face FF.

It is observed that the geometry of the drilling tool is circular as opposed to the straight/slightly curved geometry of the turning and milling inserts respectively. However, the drilling tool still comprises all the essential features previously described.

Specifically, the drilling tool is provided with an auxiliary cutting element having an auxiliary cutting edge ACE having intersection points on the side face (one being visible) and extending between the front face FF and the rear face RF.

In accordance with the above design, the auxiliary cutting edge ACE is configured for coming in contact with the workpiece before the main cutting edge MCE.

Turning now to Figs. 39A to 39G, an integral drilling tool is shown being generally designated **2100** and formed with a main cutting portion **2120** having a main edge **2124** and an auxiliary cutting element **2130** formed with an auxiliary cutting edge **2132**.

With particular reference to Fig. 39B, it is observed that the auxiliary cutting element **2130** is essentially similar to previously described cutting elements in connection with the turning and milling inserts, with the difference being it extending circularly around the main axis X of the drilling tool **2100**. The drilling tool **2100** shown in Fig. 39B is shown one step prior to its final manufacture.

Turning now to Fig. 39C, during a final stage of manufacture of the drilling tool **2100**, an auxiliary circular channel is carved at the side face of the drilling tool **2100** so as to form the rake surface **2136** of the auxiliary cutting element **2130**. The auxiliary channel provides for additional space for the chips removed from the workpiece to flow into the chip evacuation flute **2116** during a drilling operation.

Attentions is further drawn to Figs. 40A to 40I showing the drilling tool **2100** when received within a workpiece WP demonstrating various stages of the drilling operation. It is observed that in Fig. 40A, the main cutting edge **2124** still has not reached the corner of the workpiece. In this position, both the main and the auxiliary cutting edges **2124** and **2132** respectively are not in contact with the shown corner of the workpiece WP.

As the drilling tool rotates, the main cutting edge **2124** of radius **1.25**mm removes material from the side/bottom of the workpiece WP as shown in Fig. 40B, leaving therein a filleted corner of a considerable radius.

Thereafter, as shown in Figs. 40C to 40F, the auxiliary cutting element **2130** begins carving away the remainder of the filleted corner by the auxiliary cutting edge **2132**. Chips removed by this operation are urged downwards and backwards and are evacuated through the chip evacuation flute **2116** located behind the auxiliary element **2130**.

As seen in Figs. 40G to 40I, when the drilling tool continues revolving in the same direction, the auxiliary cutting edge **2132** removed the remainder of the chips leaving a corner of a considerably smaller radius than **1.25**mm created by the main cutting edge **2124**.

It is also observed that when the auxiliary cutting edge **2132** first comes into contact with the workpiece WP, it encounters a considerably large amount of material to be removed and therefore the angle of the rake surface **2136** at the front end of the auxiliary cutting element **2130** is of a greater angle than at the rear end of the auxiliary cutting element **2130**. Nonetheless, throughout the entire cutting element **2130**, the auxiliary cutting edge **2132** maintains a positive angle allowing it to safely remove material from the workpiece WP.

Turning now to Figs. 41A to 41E, another example of an integral drilling tool is shown being generally designated **2200** and formed with a main cutting portion **2220** having a main edge **2224** and an auxiliary cutting element **2230** formed with an auxiliary cutting edge **2232**.

With particular reference to Fig. 41C, it is observed that the auxiliary cutting element **2230** is essentially similar to previously described drilling tool **2100**, with the difference being that the auxiliary cutting element **2230** is configured for urging removed chips in an upwards direction rather than downwards.

Turning now to Fig. 41B, during a final stage of manufacture of the drilling tool **2200**, an auxiliary circular channel is carved at the side face of the drilling tool **2200** so as to form the rake surface **2236** of the auxiliary cutting element **2230**. The auxiliary channel provides for additional space for the chips removed from the workpiece to flow into the chip evacuation flute **2216** during a drilling operation.

Attentions is further drawn to Figs. 42A to 42H showing the drilling tool **2200** when received within a workpiece WP demonstrating various stages of the drilling operation.

As the drilling tool rotates, the main cutting edge **2224** removes material from the side/bottom of the workpiece WP as shown in Fig. 42A, leaving therein a filleted corner of a considerable radius.

Thereafter, as shown in Figs. 42B to 42D, the auxiliary cutting element **2230** begins carving away the remainder of the filleted corner by the auxiliary cutting edge **2232**. Chips removed by this operation are urged upwards and backwards and are evacuated through the chip evacuation flute **2216** located behind the auxiliary element **2230**.

As seen in Figs. 42E to 42H, when the drilling tool continues revolving in the same direction, the auxiliary cutting edge **2232** removed the remainder of the chips leaving a corner of a considerably smaller radius than that created by the main cutting edge **2224**.

It is also observed that when the auxiliary cutting edge **2232** first comes into contact with the workpiece WP, it encounters a considerably large amount of material to be removed and therefore the angle of the rake surface **2236** at the front end of the auxiliary cutting element **2230** is of a greater angle than at the rear end of the auxiliary cutting element **2230**. Nonetheless, throughout the entire cutting element **2230**, the auxiliary cutting edge **2232** maintains a positive angle allowing it to safely remove material from the workpiece WP.

Attention is now drawn to Figs. 43A to 64F in which several cutting tools according to one aspect of the subject matter of the present application are described. As will be explained in detail later and based on the above described method of design of a cutting edge with respect to Figs. 1 to 12B, it is appreciated that the non-standard cutting edges described hereinafter can be designed based on the above described method.

With particular reference to Figs. 43A to 43E, a rotary cutting tool is shown, generally designated as Y**1** and comprising a holder portion Y**10** having a central axis X and a cutting section P formed with a front cutting portion **Y20**, an intermediate cutting portion **Y30** and a rear cutting portion **Y40**.

The cutting tool **1** (as well as further examples) are drills or configured to perform an operation similar to that of a drill. As such, all have a radial cutting edge extending from the central axis X to the periphery of the cutting tool (not indicated). However, since the subject matter of the present application lies in the design of the peripheral cutting area, the radial cutting edge will not be discussed in detail and the tools are to be understood to comprise such a radial cutting edge unless otherwise indicated.

Each of the cutting portions Y**20**, **Y30** and **Y40** is formed with a respective cutting edge **Y22**, **Y32**, **Y42** defined between respective rake surfaces **Y24**, **Y34**, **Y44** and relief surfaces **Y26**, **Y36**, **Y46**.

The cutting tool Y**1** is configured to revolve about the central X and coming in contact with a workpiece WP (not shown) in order to remove material therefrom in order to form therein a recess having an angle θ.

It is observed that the front cutting portion **Y20**, and in particular the front cutting edge **Y22** is divided into three segments:

- **Y22**a defined between segment **Y24**a of the rake surface and segment **Y26**a of the relief surface;
- **Y22**b defined between segment Y**24**b of the rake surface and segment Y**26**b of the relief surface; and

- **Y22**c defined between segment Y**24**c of the rake surface and segment Y**26**c of the relief surface;

The cutting section **Y22**a is configured for removing material from a surface A of the workpiece WP transverse to the central axis X (also referred herein as a bottom surface), the cutting section **Y22**c is configured for removing material from a surface of the workpiece WP coextending with the central axis X (also referred herein as a side surface) and cutting section **Y22**b is an intermediate section configured for forming a fillet of radius R between the surfaces A and B of the workpiece WP.

Material removed from the workpiece by the front cutting portion **Y20** is referred herein as a 'primary chip' and is configured for being evacuated from the cutting segment P via evacuation flutes **Y16** spirally extending about the central axis X.

The intermediate cutting portion Y**30** is a side cutting portion, i.e. the cutting edge Y**32** is configured for removing additional material from surface B of the workpiece WP. As will be discussed in detail with reference to Figs. **2A** to **2H**, the operation of the cutting edge Y**32** is not configured for removing material from the workpiece WP, but rather for parting a portion of the material of the workpiece which will eventually be removed by the rear cutting portion **Y40**.

In other words, as opposed to the cutting portion **Y20**, the cutting portion **Y30** only forms a generally vertical slit within the material of the workpiece, leaving a splinter-like extension of the material still attached to the workpiece.

The cutting portion Y**40** is a bottom cutting portion, i.e. the cutting edge **Y42** is configured for removing material from surface A of the workpiece WP. In particular, the cutting edge **Y42** is configured for forming another, generally horizontal slit within the material of the workpiece, configured to detach the splinter-like extension from the workpiece, leaving a corner of angle θ as required. The removed extension is referred herein as a 'secondary chip'.

The intermediate cutting portion Y**30** and the rear cutting portion Y**40** are separated from one another via a chip channel **Y50** extending from the relief surface **Y26** of the front cutting portion to the trail end of the rear cutting edge **Y42**. The arrangement is such that the chip channel **Y50** is configured for accommodating the secondary chip during rotation of the cutting tool **Y1** (while still attached to the workpiece), i.e. providing the required space for the intermediate and rear cutting portions Y**30**, Y**40** to displace about the secondary chip.

The secondary chip is eventually evacuated from the cutting segment P via a chip evacuation flute located behind the cutting segment P, i.e. the chip evacuation flute **Y16** located subsequently after the chip evacuation flute **Y16** through which the primary chip is evacuated.

It is appreciated that the above described is valid for a situation in which the cutting tool revolves in place, i.e. without axial or lateral feed. When feed is applied, one of the intermediate portion Y**30** and the rear portion **Y40** may encounter the splinter-like extension at a location below or to the side thereof, thereby not completely detaching it from the workpiece. However, even in this position, the attachment of the splinter-like extension to the workpiece is so frail that friction forces between the cutting tool Y**1** and the splinter-like extension (secondary chip) are sufficient for detaching it from the workpiece. It is appreciated that even if the splinter-like extension is not detached from the workpiece, in the next revolution of the cutting tool it will be completely removed.

The successive stages of the cutting operation performed by the cutting tool Y**1** will now be discussed in detail with respect to Figs. 44A to 44H. The cutting tool Y**1** is shown from a front view and is shown during a CCW revolution about the central axis (i.e. progressing from left to right in the front view).

At first (Fig. 44A), the front portion **Y20** of the cutting tool Y**1** encounters the workpiece so that the segments Y**22**a, **Y22**b and **Y22**c of the cutting edge **Y22** begin to remove material from the workpiece along the filleted contour thereof. At this point, the workpiece is only in contact with the front cutting potion **Y20** while the intermediate and rear cutting potions Y**30**, **Y40** are out of contact with the workpiece, at least not with the region cut by the front cutting portion Y**20** (i.e. may be in contact with other regions of the workpiece).

As the cutting tool **Y1** continues to revolve (Fig. 44B), the primary chip PC is gradually removed from the workpiece and the intermediate cutting portion **Y30** begins approaching the workpiece, though still not in contact therewith.

As shown in Fig. 44C, the cutting edge Y**32** of the intermediate cutting portion **Y30** begins forming a slit **t** within the workpiece WP, beginning to peel off a secondary chip SC from the workpiece. It is noted that at this point, the secondary chip SC is still attached to the workpiece.

As the cutting tool **Y1** continues to revolve (Figs. 44D, 44E), the intermediate cutting portion **Y30** gradually exits the workpiece while the rear cutting portion **Y40** approaches the workpiece WP but still not in contact therewith. At this point, the secondary chip SC (not shown) is urged into the chip channel **Y50** between the cutting portions Y**30**, **Y40**. Specifically, it can also be viewed as follows: since the secondary chip SC is still attached to the workpiece, the cutting tool **Y1** simply revolves around it while it remains in place.

Turning now to Figs. 44F to 44H, further revolution of the cutting tool **Y1** about the central axis X brings the rear cutting portion **Y40** and the cutting edge **Y42** into contact with the workpiece in order to completely detach the secondary chip SC from the workpiece WP. As a result of revolution of the cutting tool **Y1,** the secondary chip SC is urged through the chip channel **Y50** and from there to the chip evacuation flute **Y16** located behind the rear portion **Y40**.

An additional reference to the stages of operation will be provided with respect to Figs. 46A to 46H and 48A to 48K.

Turning now to Figs. 45A to 45D, another example of a cutting tool is shown, generally designated **Y1'** and comprising a holder portion **Y10**' having a central axis X and a cutting section P formed with a front cutting portion Y**20**', an intermediate cutting portion Y**30**' and a rear cutting portion **Y40**'.

Similarly to cutting tool **Y1,** each of the cutting portions **Y20**', **Y30**' and **Y40**' is formed with a respective cutting edge **Y22**', **Y32**', **Y42**' defined between respective rake surfaces Y**24**', **Y34**', **Y44**' and relief surfaces **Y26**', **Y36**', **Y46**'.

Similarly to cutting tool **Y1,** the front cutting portion **Y20**', and in particular the front cutting edge **Y22**' is divided into three segments:

- **Y22**a' defined between segment Y**24**a' of the rake surface and segment **Y26**a' of the relief surface;
- **Y22**b' defined between segment Y**24**b' of the rake surface and segment Y**26**b' of the relief surface; and
- **Y22**c' defined between segment **Y24**c' of the rake surface and segment **Y26**c' of the relief surface;

The cutting section Y**22**a' is configured for removing material from a surface A of the workpiece WP transverse to the central axis X (also referred herein as a bottom surface), the cutting section Y**22**c' is configured for removing material from a surface of the workpiece WP coextending with the central axis X (also referred herein as a side surface) and cutting section **Y22**b' is an intermediate section configured for forming a fillet of radius R between the surfaces A and B of the workpiece WP.

However, contrary to the cutting tool **Y1,** in the cutting tool **Y1'**, the intermediate cutting portion **Y30**' is configured for removing material from surface A of the workpiece WP. As will be discussed in detail with reference to Figs. 45A to 45H, the operation of the cutting edge **Y32**' is not configured for removing material from the workpiece WP, but rather for parting a portion of the material of the workpiece which will eventually be removed by the rear cutting portion Y**40**'.

In other words, as opposed to the cutting portion **Y20**', the cutting portion **Y30**' only forms a generally horizontal slit within the material of the workpiece, leaving a splinter-like extension of the material still attached to the workpiece.

The cutting portion **Y40**' is a bottom cutting portion, i.e. the cutting edge Y**42**' is a side cutting portion, i.e. the cutting edge Y**42**' is configured for removing additional material from surface B of the workpiece WP.

In particular, the cutting edge Y**42**' is configured for forming another, generally vertical slit within the material of the workpiece, configured to detach the splinter-like extension from the workpiece, leaving a corner of angle θ as required.

The intermediate cutting portion Y**30**' and the rear cutting portion Y**40**' are separated from one another via a chip channel Y**50**' extending from the relief surface Y**26**' of the front cutting portion to the trail end of the rear cutting edge Y**42**'. The arrangement is such that the chip channel Y**50**' is configured for accommodating the secondary chip during rotation of the cutting tool **Y1** (while still attached to the workpiece), i.e. providing the required space for the intermediate and rear cutting portions Y**30**', Y**40**' to displace about the secondary chip.

The successive stages of the cutting operation performed by the cutting tool Y**1'** will now be discussed in detail with respect to Figs. 45A to 45H. The cutting tool Y**1'** is shown from a front view and is shown during a CCW revolution about the central axis (i.e. progressing from left to right in the front view).

In principle, the stages of operation of the cutting tool Y**1'** are similar to the stages previously shown in Figs. 44A to 44H, with the difference being that following removal of the primary chip PC by the front cutting portion Y**20'**, the secondary chip SC (not shown) is formed by the bottom cutting portion Y**30**' and then completely removed by the rear, side portion Y**40**' as explained below:

At first (Fig. 45A), the front portion Y**20**' of the cutting tool Y**1'** encounters the workpiece so that the segments Y**22**a', Y**22**b' and Y**22**c' of the cutting edge Y**22**' begin to remove material from the workpiece along the filleted contour thereof. At this point, the workpiece is only in contact with the front cutting potion Y**20**' while the intermediate and rear cutting potions Y**30**', Y**40**' are out of contact with the workpiece.

As the cutting tool Y**1'** continues to revolve (Fig. 45B), the primary chip PC is gradually removed from the workpiece and the intermediate cutting portion Y**30**' begins approaching the workpiece, though still not in contact therewith.

As shown in Fig. 45C, the cutting edge Y**32**' of the intermediate cutting portion Y**30**' begins forming a slit **t** (not shown) within the workpiece WP, beginning to peel off a secondary chip SC from the workpiece. It is noted that at this point, the secondary chip SC is still attached to the workpiece.

As the cutting tool Y**1'** continues to revolve (Figs. 45D, 45E), the intermediate cutting portion Y**30**' gradually exits the workpiece while the rear cutting portion Y**40**' approaches the workpiece WP but still not in contact therewith. At this point, the secondary chip SC (not shown) is urged into the chip channel Y**50**' between the cutting portions Y**30**', Y**40**'.

Turning now to Figs. 45F to 45H, further revolution of the cutting tool Y**1'** about the central axis X brings the rear cutting portion Y**40**' and the cutting edge Y**42**' into contact with the workpiece in order to completely detach the secondary chip SC from the workpiece WP. As a result of revolution of the cutting tool Y**1'**, the secondary chip SC is urged through the chip channel Y**50**' and from there to the chip evacuation flute Y**16** located behind the rear portion Y**40**'.

Turning now to Fig. 45, another example of a cutting tool is shown, generally designated Y**1"** and being of similar design to cutting tool Y**1'** previously described. One of the differences between the cutting tool **1"** and the cutting tool Y**1'** lies in the angles of the cutting portions Y**30**" and Y**40**".

In particular, the cutting edge Y**32**" is defined between the rake surface Y**34**" and the relief surface Y**36**" defining therebetween an angle α and the cutting edge Y**42**" is defined between the rake surface Y**44**" and the relief surface Y**46**" defining therebetween an angle β. The angles α and β are not constant throughout the cutting portions Y**30**", Y**40**" respectively, but rather gradually decrease between a lead end of the cutting edge and a trail end of the cutting edge.

With particular reference to Figs. 48A to 48K, cross-sectional views of the cutting tool Y**1"** are shown during operation thereof, denoting the change in the angles α and β at each cross-section during revolution of the cutting tool Y**1"**.

First of all, it is observed from Figs. 48A to 48E that as the cutting tool Y**1"** revolves, the angle α gradually decreases from about **75**° in Fig. Y**6A** to about Y**60**° in Fig. 48E. Similarly, as the cutting tool **1"** revolves, the angle β gradually decreases from about **75**° in Fig. 48F to about **60**° in Fig. **6K**.

It is important to note that as the cutting edges Y**32**" and Y**42**" penetrate deeper into the material of the workpiece, the removed secondary chip SC increases in volume and is pushed against surfaces A and B of the workpiece respectively. The gradual decrease in the angles α and β, increases, in opposite proportions, the free space (see shaded area) between the cutting portions Y**30**", Y**40**" and the side surfaces A and B respectively in which the secondary chip SC can be contained.

In other words, if the angles α and β are constant (as opposed to the present example), the growing chip SC would gradually fill up the space formed between the cutting portions and the surfaces A and B, causing a considerable increase in the loads exerted on the cutting tool. Specifically, the chip SC would be gradually squeezed and grinded between the cutting tool Y**1"** and the surfaces A and B leading to breakage/fracture and /or quick wear of the tool Y**1"**.

It is also appreciated that the shape of the cutting edges Y**32**", Y**42**" is such that at the towards the trail end, the cutting edges Y**32**", Y**42**" become more and more tangent to the respective side surfaces A and B of the cutting tool Y**1"**. Thus, even though the angles α and β of the cutting portions Y**30**", Y**40**" decreases, i.e. reducing their ability to withstand loads, so decreases the amount of material to be removed (due to the tangent orientation), compensating for the reduction in the angle.

Turning now to Figs. 49A to 49F, another example of a cutting tool is shown, generally designated as Y**101.** As opposed to previously disclosed cutting tools Y**1,** Y**1'** and Y**1"**, the cutting tool Y**101** does not comprise a front cutting portion but only the intermediate portion Y**130** and the rear portion Y**140.**

More particularly, in the cutting tool Y**101,** there is no cutting portion configured for removing a primary chip PC, and the intermediate portion Y**130** and rear portion **Y140** continue performing the same function as previously described, i.e. the removal of a secondary chip. It should be noted that although the secondary chip SC is now the first chip to be removed, it is still referred herein as a secondary chip due to the similar method of its removal (i.e. in two stages).

It is also for that reason that the intermediate cutting portion **Y130** and rear cutting portion **Y140** are still referred herein as 'intermediate' and 'rear' although, in essence, the intermediate cutting portion **Y130** is the first to encounter the workpiece.

The cutting tool **Y101** further comprises a chip splitter **Y160** disposed at the lead end of the intermediate cutting edge **Y132** and a chip breaker disposed at the trail end of the rear cutting portion **Y140.**

The cutting tool **Y101** is configured for axial progression (along the central axis X) when moving into the workpiece. Therefore, and due to the fact that cutting tool **Y101** does not comprise a front cutting portion, there is a risk that the chip removed from the workpiece by the radial cutting edge (not indicated) will be urged into the chip evacuation channel **Y150** and clog it.

As an elegant solution, the chip splitter **Y160** disposed at the lead end of the cutting edge **Y132** is configured for splitting the chip removed by the radial cutting edge from the chip removed by the cutting edge **Y132.** As a result, the split chip (removed by the radial cutting edge and split by the splitter **Y160)** will be urged into the chip evacuation flute **Y116,** while the secondary chip SC removed by the cutting edges **Y132** and **Y142** will be urged into the chip channel **Y150** as described with reference to previous examples.

The splitter is formed as a pocket formed in the lead end of the cutting edge **Y132,** thereby, when the chip removed by the radial cutting edge reaches the pocket it is interrupted and a new chip (the secondary chip) begins at the cutting edge **Y132.** It is appreciated that the size of the pocket of the splitter **Y160** is configured for a certain feed, beyond which, the chip removed by the radial cutting edge may remain loosely attached to the workpiece.

In addition, since the cutting tool **Y101** only comprises the intermediate and rear cutting portion **Y130, Y140,** there is a chance that the removed secondary chip SC will become an endless string remaining within the channels **Y150** and clogging them up and/or progressing to the next cutting portion.

For this purpose, a chip breaker **Y170** is added at the trail end of the rear cutting edge **Y142** formed with a rake surface **Y174** and a relief surface **Y176,** defining at the intersection thereof a curved cutting edge **172** configured for curving the secondary chip SC removed by the portions **Y130, Y140.** During operation of the cutting tool **Y101,** this curvature serves to break the secondary chip SC into bits and urging these bits to be evacuated from the cutting tool **Y101** via the flues **Y116.**

The curved portion of the cutting edge **Y172** also serves for curling of the removed secondary chip SC, throwing it towards the center and reducing its likelihood of entering the chip evacuation channel **Y150** of the subsequent cutting portion.

Turning now to Figs. 50A to 50D, another example of a cutting tool is shown, generally designated as **Y201.** The cutting tool **Y201** is generally similar to the cutting tool **Y101** previously described, with the difference being in the dimensions (specifically the width) of the chip channel **Y250.**

In particular, in the previously described cutting tools **Y1, Y1'**, **Y1"** and **Y101,** the intermediate cutting portion and the rear cutting portion each constituted a part of the corner being cut from the workpiece. In other words, the two portions were complementary so that revolution of the cutting tool about its axis without axial displacement would result in the removal of a corner of angle θ from the workpiece.

To the contrary, in the cutting tool **Y201,** the rear cutting portion **Y240** is located axially above the intermediate cutting portion **Y230,** so that revolution of the cutting tool about its axis without axial displacement would result in a continuous partial secondary chip attached to the bottom surface of the workpiece.

The cutting tool **Y201** is configured for revolving about its axis X and displacing axially so that the intermediate cutting portion **Y230** forms a spiral slot within the workpiece WP, resulting in a spiral secondary chip SC still being attached to the workpiece. Thereafter, upon further axial displacement, the rear cutting edge **Y242** displaces downwards and removes the thread completely.

It is appreciated that the cutting tool **Y201** has two intermediate cutting portions **Y230** and two rear cutting portions **Y240,** so that under different feeds, the following configurations are possible:

- Under very high feed, the cutting edge **Y242** is configured for remove that spiral secondary chip formed directly by the cutting edge **Y232** in front of it;

- under moderate feed, the cutting edge Y**242** is configured for remove that spiral secondary chip formed directly by the other cutting edge Y**232;** and
- under low feed, the cutting edge Y**242** can be configured for remove that spiral secondary chip previously formed by the other cutting edge Y**232** (a revolution before, two revolutions before and even more).

It is appreciated that the cutting tool Y**201** has at least the following advantages:

- the chip channel Y**250** is considerably wider, allowing the secondary chips SC to flow more freely therein, thereby reducing the loads exerted on the cutting tool Y**201;** and
- the loads exerted on the rear cutting portion Y**240** in its downward displacement are smaller since the secondary chip portion SC removed thereby is not supported by full material of the workpiece but rather by additional portions of the secondary chips SC.

Turning now to Figs. 51A to 51D, another example of a cutting tool is shown, generally designated as Y**201'**, which is of similar design to that of cutting tool Y**201** previously described.

One of the differences between the cutting tool Y**201'** and the cutting tool Y**201** lies in that the cutting tool Y**201'** comprises a front cutting portion Y**220'** and an intermediate cutting portion Y**230'** without a rear cutting portion. In particular, the front cutting portion Y**220'** is located axially higher than the intermediate cutting portion Y**230'**.

Whereas in the previous example the threaded portion of the partial secondary chip SC was removed by the rear portion Y**240,** in the present example, the same is removed by the front cutting portion Y**220'** lagging behind the intermediate cutting portion Y**230.**

As shown in Fig. 51D, in cross-section, the secondary chip SC forms splinter-like extensions spirally extending from the side surface of the workpiece which are gradually removed therefrom by the cutting portion Y**220'**.

It is important to note that in both cases of cutting tools Y**201** and Y**201'**, if the hole is a through going hole, the side surface of the workpiece will be generally smooth (without residual material), while, if the hole is not through going (blind bore), a small amount of residual material will remain at the bottom of the bore.

It is appreciated that in this case as well, there remains the advantage of reducing the loads on the front cutting edge Y**222'**, since it is required to remove only spikes (threaded portion of the workpiece) and not whole material. This may considerably reduce wear and heat damage and increase the lifespan of the cutting tool Y**201'**.

Turning now to Figs. 52A to 52D, a milling tool is shown generally designated Y**301** and comprising, similarly to previously described cutting tools, an intermediate cutting portion Y**330** and a rear cutting portion Y**340** with a chip channel Y**350** formed therebetween. In the present example, as well as in following examples, the cutting tools are formed without a front cutting portion, i.e. without a portion configured for removing a primary chip and forming a filleted, partial corner within the workpiece.

In the present example, the intermediate cutting portion Y**330** is configured for side cutting while the rear cutting portion Y**340** is configured for bottom cutting. In particular, the cutting portions Y**330,** Y**340** are configured for producing a chamfered corner within the workpiece, i.e. to create a phase of about **45**° and having a width of 0.6mm.

It is appreciated that the angle of the cutting edges Y**332,** Y**342** of the cutting portions Y**330,** Y**340** varies from their respective lead end to their respective trail end. Thus, the intermediate cutting edge Y**332** begins removing material in a direction generally parallel to the central axis of the cutting tool Y**301** and gradually angles to provide its half of the **45**° phase while the rear cutting edge Y**342** begins removing material in a direction generally perpendicular to the central axis of the cutting tool Y**301** and gradually angles to provide its half of the **45**° phase.

With reference to Figs. 53A to 53E, various stages of the cutting operation are shown. At first (Figs. 53A, 53B), the intermediate cutting edge Y**332** begins removing the secondary chip (not shown), starting from a position nearly parallel to the side surface (i.e. vertical) and slowly developing into a **45**° angle towards the bottom surface.

Thereafter (Figs. 53C to 53E), the rear cutting edge Y**342** begins removing material from the bottom surface of the workpiece WP, starting from a position generally parallel to the bottom surface (horizontal) and gradually developing into a full **45**° angle towards the side surface.

Turning now to Figs. 54A and 54B, another example of a milling tool is shown, generally designated as Y**301"**, and is of similar design to the previously described milling tool Y**301.** The main difference between the milling tool Y**301** and the milling tool Y**301'** lies in the different arrangement of the intermediate and rear portions Y**330'**, Y**340'**.

In particular, as opposed to the cutting tool Y**301,** the intermediate cutting portion Y**330** is configured for bottom cutting (i.e. removing material from a bottom surface of the workpiece) and the rear cutting portion Y**340** is configured for side cutting (i.e. removing material from a side surface of the workpiece).

Attention is now drawn to Figs. 55A and 55B in which another example of a milling tool is shown, generally designated Y**301"** and having a design similar to that of milling tool Y**301'** in the sense that is comprises an intermediate cutting portion Y**330"** and a rear cutting portion Y**340"** configured for cutting the side and bottom surfaces of the workpiece WP respectively.

However, the milling tool Y**301"** also includes a main chip splitter Y**360"** located at the lead end of the intermediate cutting edge Y**332"** and a chip breaker Y**370"** located at the trail end of the rear cutting edge Y**342"**.

In operation, the intermediate cutting edge Y**332"** begins cutting the side surface of the workpiece, removing material therefrom first leaving a radial contour and gradually straightening to provide a chamfered contour of about **45**°. At this point, the secondary chip SC is still attached to the workpiece.

Thereafter, the cutting edge Y**342"** of the rear cutting portion Y**340"** begins completing the removal of the secondary chip SC by cutting the bottom surface of the workpiece WP, first leaving a radial contour and gradually straightening to provide a chamfered contour of about **45**° meeting the contour left by the intermediate cutting edge Y**332"** to form a chamfered corner.

The cutting tool Y**301"** also comprises a safety cutting edge Y**392"** located just before the chip breaker Y**370"** configured for making sure that the secondary chip is indeed removed from the workpiece. In particular, in cases of sufficient feed, the secondary chip may not be fully detached from the workpiece and the cutting edge Y**392"** facilitates its removal.

In addition, in case of wear of the intermediate cutting portion Y**330"**, the rear cutting portion Y**340"** can serve as an intermediate cutting portion and the safety cutting portion Y**390"** can serve as a rear cutting portion, thereby changing configuration to one previously described.

In the present example, as previously described with respect to cutting tool Y**101** shown in Figs. 59A to 59E, the chip splitter Y**360"** is configured to split the chips removed from the workpiece by a radial cutting edge (or at least a portion thereof) from those removed by the intermediate cutting edge Y**332"** so that the formers will not progress into the chip channel Y**350"** and clog it.

In addition, also as previously described with respect to cutting tool Y**101** shown in Figs. 59A to 59E, the milling tool Y**301"** includes a chip breaker Y**370"** configured for breaking the secondary chip progressing through the chip channel Y**350"** so that it does not form an endless chip string and/or accidently be urged towards the subsequent cutting portion.

Turning now to Fig. 56, another example of a milling tool is shown, generally designated Y**401,** also comprising an intermediate cutting portion Y**430** with an intermediate cutting edge Y**432** and a rear cutting portion Y**440** comprising a rear cutting edge Y**442.**

As opposed to the pervious example, the cutting portions Y**430,** Y**440** of the milling tool Y**401** are arranged such that the rear cutting edge Y**442** is configured for removing material from both the bottom and the side surfaces of the workpiece, leaving thereafter a chamfered contour while the intermediate cutting edge Y**432** is simply configured for vertical cutting. In other words, the rear cutting portion Y**440** is formed with the entire chamfered corner remaining within the workpiece after the cutting operation.

One advantage of the above design over the previous examples is that the chip channel Y**450** is slightly wider, providing a more convenient progression of the secondary chips SC therethrough, reducing the loads on the milling tool.

Attention is now drawn to Fig. 58, in which yet another example of a milling tool is shown, generally designated as Y**501** configured primarily for cutting under lateral feed. As opposed to all previously described examples, the milling tool Y**501** comprises a front cutting portion Y**520** and an intermediate cutting portion Y**530** which is the single cutting portion of the milling tool Y**501.**

In particular, the intermediate cutting portion Y**530** is configured for removing material from the side surface of the workpiece WP to leave therein a chamfered corner and therefore includes the entire chamfer contour required therefor.

However, contrary to previously described examples, the front cutting portion was located on the envelope, in the present example, the cutting portion **Y520** is located radially inwards, and is configured to remove material (splinter-like extensions) left one the bottom surface of the workpiece under predetermined feed in a lateral direction.

As in previously described examples, the milling tool **Y501** also comprises a chip splitter **Y570** configured to split the chips removed from the workpiece by the radial cutting edge from the chips removed by the intermediate cutting portion **Y530.**

Attentions is now turned to the diagrams shown in Figs. 58A to 58D and 59A to 59D, in which advantages of the chamfered design of the cutting portion is illustrated. In all illustrations, the following indications are adhered to:

- WP – workpiece;
- C.T. – cutting tool;
- C.E. – cutting edge;
- SC – secondary chip; and
- C**50** – secondary chip channel.

With particular reference to Fig. 58A, a cutting portion is shown having a filleted (circular) contour shape. It is observed that, in this example, the load exerted on the cutting portion is provided from above by the to-be removed material (see arrow), so the volume of the cutting portion which is configured to withstand that load is A_1. It is also noted that the space available for the secondary chip to progress into is denoted by B_1.

To the contrary, as shown in Fig. 58B, the cutting portion is formed with a chamfered contour so that when the cutting portion penetrates into the material of the workpiece WP, the load exerted thereon is angled to the cutting portion (see arrow) and so the volume configured to withstand that load is $A_2 > A_1$, adding to the robustness and mechanical integrity of the cutting portion.

It is also noted that whereas in both examples the angle of the cutting portion (i.e. angle between rake and relief surface) is set to **70**°, due to the chamfered design of the cutting tool of Fig. 58B, the rake surface is angled to the axis of the cutting tool and not perpendicular thereto, thereby providing for the mechanical integrity (against fracture/breakage) without giving up the required **70**° angle.

More particularly, the amount of material in the direction in which the load is applied is considerably greater in the example of Fig. 58b than the example of Fig. 58A, contributing to the mechanical integrity.

It is also appreciated that the example shown in Fig. 58B transforms smoothely from as filleted contour to a chamfered contour (the filleted contour is tangent to the chamfer contour), thereby avoiding any sharp corners on order to prevent focus of stresses thereon.

Figs. 58C and 58D are schematic diagrams of superposition of the diagrams 58A and 58B, demonstrating the difference between the examples shown therein.

With particular reference to Figs. 59A to 59D, the chamfered example is shown during various stages of operation thereof.

In particular, it is observed that as the cutting portion of the cutting tool C.T. progresses within the material, the secondary chip SC is gradually pressed against the surface of the workpiece WP. However, since the orientation of the rake and relief surfaces of the cutting portion varies constantly (gradually rotating CCW), there is always sufficient space for the secondary chip SC to be urged into.

In particular, it is observed that in the position shown in Fig. 59A, the angle of the rake surface with the horizontal reference plane is γ while the angle of the relief surface with that plane is δ.

As the cutting operation progresses, the orientation of the cutting portion changes (rotating CCW) so that the angle of the rake surface with the horizontal reference plane is $\gamma' > \gamma$ while the angle of the relief surface with that plane is $\delta' < \delta$. It is important to note that the angle between the rake surface and the relief surface is still **70**° at this point.

Turning to Fig. 59C, upon further progression, the cutting portions penetrates the workpiece with the chamfered portion thereof while the orientation keeps changing. In the position shown in Fig. 59C, the angle of the rake surface with the horizontal reference plane is $\gamma'' > \gamma' > \gamma$ while the angle of the relief surface with that plane is $\delta'' < \delta' < \delta$. It is important to note that even in this position, the angle between the rake surface and the relief surface is still **70**° as required in view of mechanical integrity of the cutting portion.

Attention is now drawn to Figs. 60A to 60D, in which another example of a drilling tool is shown, generally designated Y**600,** and comprising a body portion Y**610** and a cutting portion **Y620.** As in previously described drills, the body portion **Y610** comprises spirally extending sections **Y614** defining therebetween corresponding spirally extending chip evacuation flutes **Y616.**

In the present example, the cutting portion **Y620** comprises a main cutting edge **Y622** having three segments: **Y622c** extending from the central axis of the drill **Y600, Y622c** defining the corner of the drill and **Y622b** extending between **Y622a** and **Y622c**. Each of the cutting edges **Y622a**, **Y622b** and **Y622c** is provided with a rake surface **Y624a**, **Y624b**, **Y624c** respectively and a relief surface **Y626a**, **Y626b**, **Y626c** respectively.

The drill **Y600** further comprises an auxiliary cutting edge **Y632** having a lead end located along the circumference of the drill **Y600** located behind the cutting edge **Y622.** The cutting edge **Y632** has a rake surface **Y634** and a relief surface **Y636.**

The arrangement is such that, during operation, the cutting edges **Y622** remove material from a workpiece WP (not shown) leaving therein a rounded corner corresponding in shape and size to that of the cutting edge **Y622a**. Thereafter, the cutting edge **Y632** penetrates into the workpiece, forming therein a horizontal slit partially detaching an additional chip of material therefrom.

Following the above, the consecutive cutting edge **Y622a** comes into contact with the workpiece WP and completely removes the partially removed chip and again, leaving a rounded corner. During revolution of the drill **Y600,** each cutting edge **Y622a** removes the partially attached chip formed by the preceding cutting edge **Y632** as well as removing additional material to form the rounded corner.

One advantage of the above design as opposed to the design of the previously described drill **Y200'** is that, due to the minimal axial distance between the cutting edge **Y622** and the cutting edge **Y632,** when the operation of the drill **Y600** is halted, a minimal amount of excess material from the workpiece remains between the cutting edge **Y632** and the workpiece, thereby minimizing the amount of force required to remove the drill **Y600** from the bore.

With particular reference to Fig. 60C and 60D, the rear end of the cutting element **Y630** is pre-formed to have a positive angle α configured for allowing the cutting element **Y630** to remove material from the workpiece when the drill **Y600** is revolved in the opposite direction (for example, when removing the drill from the bore).

In particular, a cutting edge Y**682** is formed, having a rake surface Y**684** and a relief surface Y**686.**

A similar example of a drill is shown in Figs. 61A and 61B, in which the drill, generally designated Y**600'** also comprises a cutting edge Y**622a**' and an auxiliary cutting edge Y**632'**.

However, the difference between the drill Y**600** and the drill Y**600'** lies in the orientation of the auxiliary cutting edge Y**632'**. In particular, whereas the cutting edge Y**632** penetrates the workpiece to generate a horizontal slit, the cutting edge Y**632'** penetrates the workpiece vertically to form a vertical slit partially detaching a chip from the workpiece.

In other aspects, operation of the drill Y**600'** is similar, i.e. each cutting edge Y**632'** is configured for partially removing a chip from the workpiece and each cutting edge Y**622a**' is configured for removing the partially attached chip removed by the preceding auxiliary cutting edge Y**632'**.

One advantage of the above described drill lies in the

Turning now to Figs. 62A and 62B, another example of an endmill is shown generally designated Y**700** and comprising a body portion Y**710** and three cutting portions Y**720.** Each cutting portion is provided with a main cutting edge Y**722** and an auxiliary cutting element Y**730.**

In the present example, the cutting portion Y**720** comprises a cutting edge Y**722** defining the corner formed in the workpiece, and has a rake surface Y**724** and a relief surface Y**726.**

The auxiliary cutting element Y**730** has an auxiliary cutting edge Y**732** having a lead end located along the circumference of the endmill Y**700** located behind the cutting edge Y**722.** The cutting edge Y**732** has a rake surface Y**734** and a relief surface Y**736.**

The arrangement is such that, during operation, the cutting edges Y**722** remove material from a workpiece WP (not shown) leaving therein a rounded corner corresponding in shape and size to that of the cutting edge Y**722.** Thereafter, the cutting edge Y**732** penetrates into the workpiece, forming therein a vertical slit partially detaching an additional chip of material therefrom.

Following the above, the consecutive cutting edge Y**722** comes into contact with the workpiece WP and completely removes the partially removed chip and again, leaving a rounded corner. During revolution, each cutting edge Y**722** removes the partially attached chip formed by the preceding cutting edge **Y732** as well as removing additional material to form the rounded corner.

Turning now to Figs. 63A to 63D, another example of an endmill is shown, generally designated **Y700'** and comprising a body portion **Y710'** and three cutting portions **Y720'**.

The endmill **Y700'** is similar to the previously described endmill **Y700,** with the difference being in the design of the auxiliary cutting element **730'**. In particular, the cutting edge **Y732'** of the cutting element **Y730** extends along the entire corner of the endmill **Y700'**, beginning from a horizontal orientation at the bottom surface of the endmill **Y700'** and ending in a vertical orientation at a side surface of the endmill **Y700'**.

Thus, in operation, the cutting edge **Y732'** removes material from the workpiece leaving therein a corner of radius r, whereafter, extremities of the cutting edge **Y722'** operate for removing remaining material from the workpiece. Specifically, the greater the feed of the tool **Y700'**, the greater the portion of the extremities of the cutting edge **Y722'** which operate to remove material from the workpiece.

Under the above, in the event of higher feed, the loads are distributed between the cutting edge **Y722'** and the auxiliary cutting edge **Y732'**. Alternatively, during low feed, the endmill **Y700'** can achieve a higher revolution speed since a smaller portion of the cutting edge **Y722'** comes in contact with the workpiece WP.

Turning now to Figs. 64A to 64F, another example of an endmill is shown, generally designated **Y700''**. As previously described, the endmill **Y700''** also comprises a body portion **Y710''** and four cutting portions **Y720''**.

However, as opposed to previously described endmills, the cutting portions **Y720''** are not identical. Specifically, while the cutting edges **Y722''** are identical for all the four cutting portions **Y720''**, the auxiliary cutting elements are not. In particular, two cutting portions **Y720''** comprise a first auxiliary cutting element **Y730''** while the other two cutting portions **Y720''** comprise a second auxiliary cutting element **Y740''**.

The first auxiliary cutting element **Y730''** is formed with a cutting edge **Y732''** having a rake surface **Y734''** and a relief surface **Y736''** and a generally horizontal configuration, configured for forming a horizontal slit in the workpiece to partially detach a chip therefrom.

The second auxiliary cutting element **Y740"** is formed with a cutting edge **Y742"** having a rake surface **Y744"** and a relief surface **Y746"** and a Yenerally vertical configuration, configured for forming a vertical slit in the workpiece to partially detach a chip therefrom.

The cutting portions **Y720"** are arranged alternately so that a cutting portion **Y720"** having a first auxiliary cutting element **Y730"** is followed by a cutting portion **Y720"** having a second auxiliary cutting element **Y740"** and vise versa.

Under the above arrangement, due to the alternating arrangement, the cutting edge **Y722"** of a portion with a first auxiliary cutting element **Y730"** is configured for removing the partially attached chip formed by the preceding cutting edge **Y742"** of a second auxiliary cutting element **Y740"** and vise versa.

Consequently, when the endmill **Y700"** is operated without providing feed thereto (i.e. only revolution without displacement), it is configured for eventually leaving the workpiece with a sharp corner (without a radius). Specifically, when revolved in place, the cutting edges **Y732"** and **Y742"** form the horizontal and vertical slits respectively, leaving forming the sharp corner, with the cutting edges **Y722"** not coming into contact with the workpiece. Thus, this tool can be particularly useful for finishing purposes.

It is appreciated that one of the advantages of the endmill **Y700"** of the present example is its convenient manufacturing. In particular, each of the cutting edges **Y722"**, **Y732"** and **Y742"** can easily be manufactured by grinding and/or honing due to the convenient access to each of the cutting edges.

Attention is now drawn to Figs. 65A to 76C in which several cutting tools according to one aspect of the subject matter of the present application are described. As will be explained in detail later and based on the above described method of design of a cutting edge with respect to Figs. 1 to 12B, it is appreciated that the non-standard cutting edges described hereinafter can be designed based on the above described method.

With reference to Figs. 65A to 65D, a milling tool is shown generally designated **R1** and comprising a milling tool holder **R10** having six milling inserts R**20** mounted thereof along the circumference thereof.

As observed from Figs. 65C and 65D, the milling insert **R20** is formed with a first cutting portion R**30** having a first cutting edge R**32** and a second cutting portion

R40 having a second cutting edge **R42**. Each of the cutting edges **R32**, **R42**, is defined at the intersection between corresponding rake and relief surface **R34**, **R36** and R**44**, **R46** respectively.

It is also noted that the intermediate portion **R50** constituted by the surface **R52** between the cutting portions **R30**, **R40** is produced by grinding as such a surface cannot be produced by simple pressing/mold process.

Each of the cutting edges **R32**, **R42** of the portions **R30**, **R40** is configured for cutting a different part of the removed chip. In particular, during operation of the milling tool **R1,** the cutting edge **R32** first comes into contact with the workpiece creating a vertically incision/slit therein, only partially separating a chip from the workpiece. Thereafter, upon rotation of the milling tool R**1,** once the cutting edge **R32** disengages from the workpiece (not shown), the cutting edge R**42** comes into contact with the workpiece and completely separates the chip from the workpiece by making a lateral incision/slit.

It is also noted that the tow cutting portions are designed such that each of the cutting edges R**32**, **R42** is configured for leaving a radial incision within the workpiece, so that together, the cutting insert **R20** forms a filleted recess within the workpiece.

It is also observed that an upper portion **R38** of the cutting edge **R32** located above the radial portion turns inward (having a smaller diameter), thereby allowing to reduce the sheer forces acting on the cutting edge during operation of the milling tool **R1** as well as prevent continuous impact on the cutting portion **R30**.

Attention is now drawn to Figs. 66A to 66C, in which another example of a milling tool is shown generally designated as **R1'** which is similar to the milling tool **R1** previously described. However, the milling tool **R1'** differs in that each of the cutting portions R**30**, **R40** also comprises a chip splitter **R37**, **R47** located along the cutting edges **R32**, **R42** respectively.

Specifically, the chip splitter R**37** is configured for splitting the chip at the beginning of the cutting edge **R32** so that the chip removed by the cutting edges R**32**, **R42** and forming the corner of the workpiece is disconnected from the chip removed from the side wall of the workpiece.

Furthermore, the chip splitter **R47** located at the end of the cutting edge **R42** serves for splitting the chip after it has been completely separated from the workpiece at the corner, thereby disconnecting if from any further chips formed.

The above design allows preventing chips removed from the side wall from flowing into the corner cutting zone.

Attention is now drawn to Figs. 67A to 68C, in which still another example of a milling tool is shown, generally designated **R1"** and a mold for the manufacture of inserts **R20**" thereof. The milling tool R1" comprises a milling tool holder **R10**" and a plurality of cutting insert **R20**" circumferentially mounted thereon.

The cutting insert **R20**" differs from the previously described cutting inserts **R20**, **R20**' by the fact that the first cutting portion **R30**" is a regular cutting portion and not an elongated cutting portion as previously described. In other words, the cutting portion **R30**" comprises a standard cutting edge **R32**" which is generally radial and covers about half the span of the corner.

The cutting insert R**20**" further comprises a second cutting portion **R40**" having an elongated cutting edge **R42**" which has an angled (not radial) configuration, providing additional robustness to the cutting portion **R40**.

In operation, the standard cutting edge **R32**" cuts off a portion of a portion of the chip from the workpiece leaving therein a radial recess extending a part of the corner formed in the workpiece. Thereafter, the cutting edge **R42**" comes into contact with the workpiece, removing therefrom a straight chip leaving a phased portion of the corner. Thus, the recess formed in the corner of the workpiece has a radial half and a straight, inclined half.

Attention is now drawn to Figs. 68A to 68C, in which a mold **R2** for the manufacture of the cutting insert R**20**" is shown, comprising a cavity part **R60** and a pressing part **R70**, as well as two lateral pieces **R80** and **R90** configured for forming the central bore of the cutting insert **R20**".

It is noted that the cutting insert **R20**" can be manufactured by a mold pressing process (unlike the previously described inserts **R20**, **R20**'), making it more economically viable.

It is also noted that the central bore of the cutting insert **R20**" is noted formed by an integral portion of the cavity part **R60** but rather by the two lateral pieces **R80** and **R90**, which is highly irregular.

Turning now to Figs. 69A to 69C, another example of a milling tool **R1'''** is shown, comprising a milling tool holder **R10'''** and milling inserts **R20'''** mounted circumferentially thereon.

In the present example, the cutting insert **R20'''** also comprises a regular cutting portion **R30'''** and an elongated balcony portion **R40'''**, each having a corresponding cutting edge **R32'''**, **R42'''** respectively.

It is noted that at part of the cutting edge **R42'''** of the cutting portion **R40'''** extends beyond a cutting envelope created by the cutting edge **R32'''** of the cutting portion **R30'''** during revolution of the milling tool R1'''. The milling tool **R1'''** is configured for side cutting, i.e. advancing sidewards and not downwards.

In addition, it is observed that the cutting portion **R40'''** extends beyond a rear surface of the cutting insert **R20'''**, thereby allowing extending the cutting edge **R42** thereof compared to a similar cutting insert which terminates at the rear surface (the surface mated against the seat of the milling tool holder **R10'''**).

Attention is now drawn to Figs. 70A to 71 in which another milling tool is shown, generally designated **R101** and comprising a milling tool holder R**110** and a plurality of milling inserts R**120** mounted circumferentially thereon.

In contrast to previously described cutting inserts **R20**, R20', **R20''** and R20''', the presently described cutting insert **R120** comprises four cutting corners as opposed to two. Each of the corners comprises a main, regular cutting portion **R130** and an elongated cutting portion **R140,** each having a corresponding cutting edge **R132, R142** respectively.

The milling tool **R101** is configured for side cutting, i.e. advancing sidewards and not downwards.

With particular reference to Fig. 71, the mold for the manufacture of the milling insert **R120** comprises a cavity part **R160** and a pressing part **R170,** the cavity part **R160** comprising a central pole **R162** configured for producing the central bore **125** of the cutting insert.

Turning now to Figs. 72A to 72C, a parting tool generally designated **R201** is shown comprising a tool holder **R210** and a parting insert **R220.** The parting insert comprising two corners, each having a main cutting portion **R230** with a main cutting edge **R232,** and a secondary cutting portion **R240** having a cutting edge **R242.**

The arrangement is such that the cutting edge **R242** of the cutting edge **R240** does not extend all along the parting tool **R201** but rather only partially extends towards the middle of the parting insert **R220.**

Thus, in operation, when the parting tool is brought into contact with the workpiece, the secondary cutting portions R**240** performing a cutting operations on the flanks of the workpiece, forming a slit therein, while the main cutting edge **R232** follows and completely separates the chip from the workpiece. In other words, the arrangement is such that the secondary cutting edges **R242** do not cut in the center of the workpiece but only at the sides thereof.

It is also noted that the surface **R227** of the parting insert **R220** are performed by grinding after the insert R**220** has been pressed as these surfaces cannot be formed by pressing (owing to undercut conditions).

It should be noted that during a parting operation (on a revolving workpiece), the diameter of the workpiece WP is gradually reduced. Thus, while at the beginning of the turning operation both cutting edges **R232,** R**242** come into contact with the workpiece, as the parting process progresses, the cutting edge **R242** gradually comes out of contact with the workpiece (being now located below it owing to diminishing diameter) and the majority of the parting operation is performed, at that stage, by the main cutting edge **R232.**

Turning now to Figs. 73A to 73D, another parting tool is shown generally designated as **R300** and comprising a tool holder **R310** and a parting insert **R320.**

The parting insert **R320** comprises two main cutting portions R**330,** extending on two sides of the insert R**320.** Each of the main cutting portions **R330** comprises a first cutting portion **R340** with a first cutting edge **R342** and a second cutting portion **R350** with a second cutting edge **R352.** Each of the cutting edges **R342, R352** is defined between corresponding rake and relief surfaces R**344-R346,** R**354-R356** respectively.

Contrary to the previously described parting tool R**200,** the parting tool **R300** comprises three cutting edges for each cutting side: a standard edge **R332,** a first parting edge **R342** (of the first, top cutting portion) and a second cutting edge **R352** (of the second, bottom cutting portion).

As in the parting tool **R200,** after the parting insert is manufactured within the press-mold, grinding may be required to provide for undercut surfaces which cannot be easily formed in a pressing process of the insert.

In addition, with particular reference being made to Fig. 73C, it is observed that the cutting edged **R342,** R**352** are configured for removing a right-angled corner from the workpiece, each cutting portion **R340, R350** contributing its **45**° half of removing material from the workpiece WP.

Turning now to Figs. 74A and 74B, a straight saw tool is shown, generally designated R**201'** comprising a saw holder **R210'** and a plurality of saw inserts **R220'** linearly disposed along the saw holder **210'**. The saw inserts **R220'** are essentially similar to the parting inserts R**220** previously described with respect to the parting tool **R201,** and have similar features, and therefore will not be described here in detail.

With reference to Figs. 75A and 75B, a circular saw tool is shown, generally designated **R201"** comprising a saw holder **R210"** and a plurality of saw inserts **R220"** linearly disposed along the saw holder **R210"**. The saw inserts **R220"** are essentially similar to the parting inserts **R220** previously described with respect to the parting tool **R201,** and have similar features, and therefore will not be described here in detail and have similar features.

Turning now to Figs. 76A to 76C, another turning tool is shown generally designated **R401** and comprising a tool holder **R410** and two turning inserts **R420A** and **R420B**, each having a cutting portion **R430A**, **R430B** respectively.

In essence, the cutting tool R**401** is similar to the previously described cutting tool **70** previously described in Figs. 8A to 8D. However, the main concept of the above turning tool **R401** lies in the separation of the two complementary cutting portions **R430A**, **R430B** between two separate cutting inserts **R420A**, **R420B**. In other words, instead of manufacturing a single cutting insert having two cutting portions, each cutting insert **R420A**, **R420B** is separately manufactured and can be mounted together to provide the required design of the combined cutting edge.

In particular, it is noted that the cutting inserts **R420A**, **R420B** are configured for being mounted onto the same seat **R416** of the cutting tool holder **R410,** one on top of the other. The bottom cutting insert **R420B** is first mounted onto the seat **R416** and thereafter, the top cutting insert **R420A** is mounted over the cutting insert **R420B**.

In order to prevent lateral displacement between the cutting inserts R**420A**, **R420B**, the bottom insert **R420B** is formed with positioning protrusions R**440** and the top insert **420A** is formed with corresponding recesses (not seen) configured for receiving therein the protrusions **R440** when mounted as shown in Fig. 76A.

Furthermore, it is noted that both cutting inserts **R420A**, **R420B** are configured for being secured onto the cutting tool holder **R410** using a single fastening screw

R450, passing through the central bores **R325A**, R**325B** of the cutting inserts **R420A**, **R420B** respectively.

Reverting now to Fig. 76A, it should be understood that manufacturing the combined cutting edge **R432A+R432B** in a pressing process is highly impractical at best, and impossible at most owing to the undercuts and spaces formed between the cutting portions **R430A**, **R430B**.

Therefore, the above concepts provides for a unique way of achieving the desired resulting design of the cutting edge **R432A+R432B** by manufacturing each of the cutting inserts **R420A**, **R420B** separately, in a simple pressing process and only thereafter combining the cutting insert by mutual mounting.

With respect to all of the above described cutting tools – milling, turning and drilling, it is appreciated that the features of these cutting tools as mentioned above may provide the cutting tools with at least one of the following advantages:

- **Feed** – under the same loads, the cutting tool may operate at greater feed and rotation speed **F** and $\mathbf{V_R}$ respectively, than an equivalent cutting tool without the above mentioned features, and, as such, remove a greater amount of material from the workpiece per time unit **t**;
- **Loads** – under the same feed and rotation speed **F** and $\mathbf{V_R}$, the cutting tool may be subjected to lower loads than an equivalent cutting tool without the above mentioned features, thereby providing an increased overall lifespan;
- **Chip** - under the same rotation speed $\mathbf{V_R}$, the cutting tool may be allowed a greater feed **F** than an equivalent cutting tool without the above features, thus allowing to remove a thicker chip per time unit **t** for one turn of the cutting tool or workpiece; and
- **Speed** - under the same feed **F**, the cutting tool or the workpiece may be allowed a greater rotation speed $\mathbf{V_R}$ than an equivalent cutting tool without the above features, removing a greater amount of chips per time unit ***t***.
- **Lifespan** – the cutting inserts/tools may be provided with a longer lifespan under the same conditions as a standard cutting insert/tool.

It should further be clear that most principles and features described above with respect to cutting tools and inserts **B1, B70, B100, B200, B300, B300', 1, 1', 1'', 1''', 120, 220, 320, 420, 510, 601, 701, 720, 801, 901, 1001, 1100, 1200, 1300, 1400, 1500, 1600, 1700, 180,, 2100, 2200, Y1, Y10, Y1', Y10', Y110, Y201, Y201', Y301, Y301', Y300'', Y401, Y501, Y600, Y600', Y600'', Y700, Y700', Y700'', R1, R1', R1'', R1''', R101, R201, R201', R201'', R301** and/or **R401** shown in Figs. 1A to 76C, are not restricted to those cutting tools in connection with which they are described/shown, and may independently be applied, *mutatis mutandis*, to each other or to any other tools, in any combination considered to be appropriate by a person skilled in the art.

Those skilled in the art to which this invention pertains will readily appreciate that numerous changes, variations, and modification can be made without departing from the scope of the invention, *mutatis mutandis*.

CLAIMS:

1. A method for designing a cutting edge of a cutting element configured for removing material from a workpiece to leave therein a desired end profile, said method comprising:

- modeling a desired end profile of the workpiece, said profile having a longitudinal axis and being defined by a bottom surface, a side surface and an adjoining surface extending therebetween;
- defining a lead profile plane and an trail profile plane spaced therefrom, each of the planes being oriented perpendicular to said longitudinal axis;
- determining a profile contour defined by the intersection line between said end profile and said lead profile plane, including:
  - o a bottom contour defined as the intersection line between said lead profile plane and said bottom surface;
  - o an adjoining contour $L_{ADJ-CON}$ defined as the intersection line between said lead profile plane and said adjoining surface; and
  - o a side contour defined as the intersection line between said lead profile plane and said side surface;
- designing a rake surface and a relief surface, the intersection line between which defines a cutting curve lying in the adjoining surface and spanning between the lead profile plane and the trail profile plane such that in any reference plane oriented perpendicular to said cutting edge, the intersection between each of the rake surface and the relief surface with said reference plane defines a respective rake line and relief line, the angle between said lines being equal to or smaller than a similar angle taken along each of a plurality of similar reference planes disposed between the reference plane and the lead profile plane.

2. A method according to Claim 1, wherein the longitudinal axis is a straight line and the adjoining surface obtains the shape of a portion of a ruled surface.

3. A method according to Claim 2, wherein the ruled surface is a portion of a cylinder.

4. A method according to Claim 1 or 2, wherein both the bottom surface and the side surface are planar surfaces.

5. A method according to Claim 2, wherein the longitudinal axis is an arc extending about a rotation axis and the adjoining surface obtains the shape of a portion of a toroid-like surface.

6. A method according to Claim 5, wherein the bottom surface is a planar surface while the side surface constitutes a portion of a cylindrical surface.

7. A method according to Claim 5 or 6, wherein the adjoining surface is concave such that the rotation axis is disposed facing the adjoining contour $L_{ADJ\text{-}CON}$, whereby the resulting adjoining surface constitutes an internal portion of the toroid-like surface.

8. A method according to Claim 7, wherein the adjoining surface is convex such that the rotation axis is disposed facing away from the adjoining contour, whereby the resulting adjoining surface constitutes an external portion of the toroid-like surface.

9. A method according to any one of Claims 5 to 8, wherein the length of the adjoining segment $L_{ADJ\text{-}SEG}$ is greater than the length of the adjoining contour $L_{ADJ\text{-}CON}$.

10. A method according to Claim 9, wherein the ratio R_{ADJ} ($L_{ADJ\text{-}SEG}$:$L_{ADJ\text{-}CON}$) is $R_{ADJ} \geq 1.25$, in particular $R_{ADJ} \geq 1.5$, even more particularly $R_{ADJ} \geq 1.75$, still more particularly $R_{ADJ} \geq 2$ and up to $R_{ADJ} = 10$.

11. A method according to any one of Claims 1 to 10, wherein the adjoining surface are configured for the design of different cutting tools required for different cutting operations.

12. A method according to any one of Claims 1 to 11, wherein defining the trajectory of the cutting curve includes the steps of:

- defining a helix base axis;
- defining a pierce line extending from and oriented perpendicular to the helix base axis so that an end or the virtual extension thereof pierces the adjoining surface at a pierce point;
- defining a pitch increment **p'** and an angle increment **θ'**;
- displacing the pierce line along the helix base axis at corresponding pitch and angle increments **p'** and **θ'**;
- for each such displacement, defining a pierce point of the pierce line;
- obtaining a pierce curve extending along the adjoining surface defined by the plurality of pierce points;
- calculating the ratio $\mathbf{R_{ADJ}}$ between the length of the pierce curve and the length of the adjoining contour; and, if $\mathbf{R_{ADJ}}$ does not match a desired ratio

- re-defining the pitch increment **p'** and the angle increment **θ'** to obtain such a desired ratio $\mathbf{R_{ADJ}}$.

13. A method according to Claim 12, wherein the pierce curve yielded by the above steps constitutes the desired adjoining segment of the cutting edge.

14. A method according to Claim 13, wherein, when the adjoining surface is a torus or a cylinder, the pierce curve constitutes a portion of a helix.

15. A method according to Claim 14, wherein the helix base axis is constituted by the longitudinal axis or an axis parallel thereto.

16. A method according to Claim 15, wherein the overall pitch **P** of the pierce curve is chosen based on the desired adjoining ratio $\mathbf{R_{ADJ}}$.

17. A method according to Claim 16, wherein the pitch **P** is defined by the number of pitch increments **p'** at which the sum of angle increments **θ'** equals 360°.

18. A method according to any one of Claims 10 to 17, wherein the adjoining surface is an open contour.

19. A method according to any one of Claims 10 to 18, wherein defining the trajectory of the cutting curve includes the steps of:

- defining a lead point on the bottom surface or on the adjoining surface, being closer to the lead profile plane that to the trail profile plane;
- defining a trail point on the side surface or on the adjoining surface, being closer to the trail profile plane that to the lead profile plane;
- defining an intermediate point on the adjoining surface disposed between the lead profile plane and the trail profile plane;
- defining an intersecting plane by passing through the lead point, the trail point and the intermediate point;
- defining an intersecting curve which is constituted by the intersection line between the intersecting plane and the adjoining surface;
- calculating the ratio R_{ADJ} between the length of the intersecting curve and the length of the adjoining contour; and, if $\mathbf{R_{ADJ}}$ does not match a desired ratio
- re-positioning the lead point, trail point and intermediate point to obtain such a desired ratio $\mathbf{R_{ADJ}}$.

20. A method according to Claim 19, wherein the intersecting curve yielded by the above steps of the empiric method constitutes the desired adjoining segment of the cutting edge.

21. A method according to Claim 19 or 20, wherein the lead point lies on the lead profile plane, at the intersection thereof with the bottom surface and the trail point lies on the trail profile plane, at the intersection thereof with the side surface.

22. A method according to Claim 19 or 20, wherein the lead point lies on the bottom surface and the trail point lies on the side surface.

23. A method according to any one of Claims 19 to 22, wherein the intermediate point is located on the adjoining surface approximately between the bottom surface and the side surface, so that the distance between the intermediate point and each one of the lead profile plane and the trail profile plane is generally similar.

24. A method according to any one of Claims 1 to 18, wherein defining the trajectory of the cutting curve includes the steps of:

- defining an elevated reference plane disposed above the end profile and oriented to generally face at least the adjoining surface;
- defining a mimic curve extending along the elevated reference plane, the mimic curve having a start point and an end point;
- obtaining a mimic projection on the end profile in a view normal to the elevated reference plane, the mimic projection having a projection start point and a projection end point; if the mimic projection does not completely intersects the adjoining surface
- re-orienting the elevated reference plane so that the projection start point and projection end point lie outside the adjoining surface or on the edge thereof;
- calculating the ratio R_{ADJ} between the length of the mimic projection and the length of the adjoining contour; and, if $\mathbf{R_{ADJ}}$ does not match a desired ratio
- re-orienting the elevated reference plane to obtain such a desired ratio $\mathbf{R_{ADJ}}$.

25. A method according to Claim 24, wherein the mimic projection yielded by the above steps of the empiric method constitutes the desired adjoining segment of the cutting edge.

26. A method according to Claim 25, wherein the mimic curve is constituted by a simple geometric curve.

27. A method according to Claim 26, wherein the simple geometric curve is a straight line.

28. A method according to any one of Claims 24 to 27, wherein the method is implemented for the design of either or both of the bottom surface and the side surface.

29. A method according to any one of Claims 1 to 28, wherein design of the rake and relief surfaces includes the following steps:

- defining a plurality of reference planes successively disposed along the cutting curve, each being pierced by said curve at a piercing point and being perpendicular to the curve at the piercing point;
- obtaining along each of said reference planes the projection of at least the adjoining contour;
- defining along each of said reference planes:
  - a base line tangent to said projection at said piercing point; and
  - a chip line perpendicular to said base line at said piercing point;
- defining, on each of said reference planes, a cutting contour constituted by a rake line and a relief line extending from said piercing point to define:
  - a desired cutting angle between said rake line and said chip line;
  - a desired body angle between said rake line and said relief line; and
  - a desired rear angle between said relief line and said base line;
- the body angle of the cutting contour on each reference plane being equal to or smaller than the body angle of the cutting contour of each of a plurality of reference planes disposed between the reference plane and the lead profile plane;
- designing a cutting tool constituted by a rake surface and a relief surface, each being defined by the rake and relief lines of each of the reference planes respectively.

30. A method according to Claim 29, wherein on each of the reference planes, the rake and relief lines are designed according to the projection of the profile contour on that specific plane.

31. A method according to Claim 30, wherein the length and shape of the rake line and of the relief line are designed so as not to intersect the profile contour at any point other than the pierce point.

32. A cutting element for removing material from a workpiece and forming therein an end profile extending along a longitudinal axis, said cutting tool being formed with a cutting portion having a rake surface and a relief surface and a cutting edge defined at the intersection therebetween and comprising a bottom segment and a side segment, the cutting portion being boundable by a bottom reference surface and a side reference surface transverse thereto, so that said bottom segment lies along a maximal length thereof, on said bottom surface and said side segment lies along a maximal length thereof, on said side surface, the cutting edge further comprising an adjoining segment lying outside the bottom and side reference surfaces, said adjoining segment being defined by an intersection between corresponding rake and relief portions of said rake surface and relief surfaces, wherein, for any given normal reference plane oriented perpendicular to said adjoining segment and disposed between a lead end and trail end of the adjoining segment, the intersection between each of the rake portion and the relief portion with said normal reference plane defines a respective rake line and relief line and the angle between these lines is equal to or smaller than a corresponding angle taken along each of a plurality of other normal reference planes disposed between the given normal reference plane and the lead end.

33. A cutting element according to Claim 32, wherein the adjoining segment extends so as to bridge the bottom and side segments, merging therewith via its leading and trailing ends.

34. A cutting element according to Claim 32, wherein the adjoining segment is disposed behind the bottom and/or side segments.

35. A cutting element according to Claim 32, wherein the cutting element comprises one or more bridging segments lying outside the bottom and/or side segments.

36. A cutting element according to Claim 35, wherein the one or more bridging segments, cover, in a proper projection, the entire profile between the bottom and the side segments.

37. A cutting piece comprising a front surface, a rear surface and at least one side surface extending therebetween having a first portion and a second portion angled to one another to form a corner, the cutting insert being formed with a main cutting edge defined at the intersection between said front surface and the corner of the side surface, said cutting insert further comprising an additional cutting element disposed on the corner of the side surface and protruding therefrom, said additional cutting element having an auxiliary cutting edge extending along said corner between said front surface and said rear surface, between a first intersection point with said first portion of the side surface and a second intersection point with said second portion of the side surface, none of which coincides with the cutting edge of the cutting insert.

38. A cutting piece according to Claim 37, wherein the main cutting element has a rake surface constituted by a portion of the front surface and a relief surface constituted by a portion of the side surface.

39. A cutting piece according to Claim 38, wherein the auxiliary cutting edge is defined at the intersection between an auxiliary rake surface of the additional cutting element outwardly projecting from the side surface and transverse thereto and an auxiliary relief surface extending transverse to the rake surface and away from the main cutting edge.

40. A cutting piece according to Claim 39, wherein the auxiliary rake surface is defined as an intersection line with the side surface of the cutting element so that end points of the intersection line coincide with the first and the second intersection point of the auxiliary cutting edge.

41. A cutting piece according to Claim 40, wherein, in a top view, perpendicular to the front surface and along the side surface, both the auxiliary cutting edge and the intersection line are clearly visible, including the first and the second intersection points.

42. A cutting piece according to Claim 41, wherein the cutting edge of the additional cutting element is designed so that any point disposed along the auxiliary cutting edge protrudes from the side surface and is visible in the above top view.

43. A cutting piece according to Claim 42, wherein the auxiliary cutting edge fully envelopes the main cutting edge at the corner, from one portion of the side surface to the other.

44. A cutting piece according to Claim 43, wherein the first intersection point is located close to the front surface while the second intersection point is located closer to the bottom surface.

45. A cutting piece according to Claim 44, wherein the auxiliary cutting edge includes a point, maximally distant from the side surface of the cutting insert and located between said first intersection point and said second intersection point.

46. A cutting piece according to Claim 45, wherein the auxiliary cutting edge has a mid-point defined as the point on the cutting edge intersecting with a bisector of the angle formed at the corner between the portions of the side surface, so that the auxiliary cutting edge has a lead portion extending from the first intersection point to the mid-point and a tail portion extending from the mid-point to the second intersection point.

47. A cutting piece according to Claim 46, wherein, in a side view of the cutting insert, perpendicular to the first portion thereof, the first intersection point is clearly visible while the second intersection point is obscured by the second portion of the side surface itself.

48. A cutting piece according to any one of Claims 37 to 47, wherein the cutting piece is a cutting insert configured for being mounted onto a cutting tool holder to form a cutting tool.

49. A cutting piece according to Claim 48, wherein the cutting insert is oriented on the tool at an angle such that, in operation, the main cutting edge is disposed between an intersection line of the auxiliary cutting element with the side surface and the auxiliary cutting edge, with respect to the workpiece.

50. A cutting piece according to any one of Claims 37 to 49, wherein the additional cutting element is configured for removing more material from the workpiece that the main cutting edge.

51. A cutting piece according to Claim 50, wherein the additional cutting element is configured for removing double the amount of material removed by the main cutting edge.

52. A cutting piece according to any one of Claims 37 to 51, wherein both the main cutting edge and the auxiliary cutting edge are configured to operate simultaneously during the same cutting operation to subsequently remove chips from the workpiece.

53. A cutting piece according to any one of Claims 37 to 52, wherein complete separation is provided between chips removed by the main cutting edge and chips removed by the auxiliary cutting edge.

54. A cutting piece according to any one of Claims 37 to 53, wherein the main cutting edge and the auxiliary cutting edge are configured for being independently sharpened.

55. A cutting piece according to any one of Claims 37 to 54, wherein additional spacing is provided between the workpiece and the cutting insert by the additional cutting element, providing more space for removed chips as well as for cooling during a cutting operation.

56. A cutting piece according to any one of Claims 37 to 55, wherein the cutting piece is a cutting insert comprising four side walls, each two adjacent side walls forming the corner.

57. A cutting piece according to Claim 56, wherein the cutting insert is formed with four main cutting edges and four additional cutting elements, one for each of the four corners.

58. A cutting piece according to Claim 56 or 57, wherein the cutting insert is reversible, wherein each cutting element is formed with an additional auxiliary rake surface and an additional auxiliary cutting edge.

59. A cutting piece according to Claim 56, 57 or 58, wherein the additional cutting element is constituted by several steps, so that the auxiliary cutting edge, as well as an auxiliary rake surface thereof, are divided into several portions.

60. A cutting piece according to any one of Claims 56 to 59, wherein there is at least one view of the cutting insert in which the cutting edge extends symmetrically about the corner of the main cutting edge.

61. A cutting piece according to any one of Claims 56 to 60, wherein the cutting insert is formed with more than one additional cutting element on the same corner.

62. A cutting piece according to Claim 61, wherein the cutting insert is formed with a first additional cutting element, and the additional cutting element is formed with an additional sub-element allowing to further increase the penetration of the cutting tool into the workpiece.

63. A cutting piece according to Claim 62, wherein the cutting insert is formed with several additional cutting elements along the same corner, wherein each of the cutting elements comprises a cutting edge providing a different cutting radii of the angle of the same corner.

64. A cutting piece according to Claim 63, wherein the first additional cutting element has a cutting radius of R1, the second additional cutting element has a cutting radius of $R2 \leq R1$, the third additional cutting element has a cutting radius of $R3 \leq R2$ and so forth.

65. A press-mold for the manufacture of the cutting piece of any one of Claims 37 to 64, said mold comprising a female member with a shaped cavity and a male member with a corresponding shape.

66. A press-mold according to Claim 65, wherein the auxiliary cutting edge of the cutting insert is not located at the parting line between the male and the female member, when the former is received within the latter.

67. A press-mold according to Claim 66, wherein the cavity of the female member is formed with straight surfaces and the male member has corresponding surfaces, so that the movement of the male member is given a certain degree of freedom.

68. A press-mold according to Claim 67, wherein the press-mold is configured for receiving therein particulate material, the mold being such that allows the male member to be introduced into the female member until it reaches the particulate material, even if the amount of material is slightly greater/smaller than planned.

69. A press-mold according to Claim 68, wherein, when the amount of material is smaller than planned, the male member is configured to displace further into the female cavity until movement thereof is restricted by the amount of material, without coming in contact with an inner surface there, thereby eliminating damage to the mold members.

70. A cutting tool holder configured for mounting thereon a cutting piece according to any one of Claims 37 to 64, said cutting tool holder having a front surface formed with an insert seat and a front surface extending transverse to the front surface, wherein said cutting tool holder comprises a dynamic chip breaker protruding from the front surface beneath the cutting insert, said dynamic chip breaker being loosely biased to protrude from the front surface and pivotally displaceable about an axis generally parallel to the front surface.

71. A cutting tool holder according to Claim 70, wherein, during a cutting operation, the dynamic chip breaker is configured for coming in contact with the workpiece, thereby wiping therefrom removed chips.

72. A cutting tool according to Claim 71, wherein the dynamic chip breaker is provided with a biasing element configure to provide a loose biasing force which, on the one hand is sufficient for making the breaker come into contact with the workpiece, and on the other hand, is loose enough to allow the breaker to pivot about its axis under pressure exerted thereon by removed chips.

73. A cutting tool according to Claim 72, wherein the breaker is configured to pivot in order to assume a position in which it protrudes to a lesser extent from the front surface of the cutting tool holder, thereby increasing the spacing between the breaker and the workpiece, to allow chips to be expelled downwardly by virtue of the rotation of the workpiece.

74. A cutting tool configured for removing material from a workpiece in order to form therein a corner of angle θ, said cutting tool comprising a first cutting portion comprising a first rake surface and a first relief surface and defining therebetween a first cutting edge, and a second cutting portion, spaced from the first cutting portion, and comprising a second rake surface and a second relief surface and defining therebetween a second cutting edge, wherein each of the first cutting edge and the second cutting edge constitute only a portion of the contour defining said angle θ.

75. A cutting tool according to Claim 74, wherein the cutting tool further comprises a standard cutting edge the contour of which extends inward of the cutting corner defined by the first and the second portion.

76. A cutting tool according to Claim 74 and 75, wherein at least one of the cutting edges of the first cutting portion and of the second cutting portion has a straight segment.

77. A cutting tool according to Claim 76, wherein the resulting corner has a partially straight cross-sectional contour.

78. A cutting tool according to any one of Claims 74 to 77, wherein the cutting edge of the first cutting portion has a first lead end and a first trail end, and of the cutting edge of the second cutting portion has a second lead end and a second trail end, and wherein the first lead end is located in front of the lead end of the second lead end so as to come into contact with the workpiece during a cutting operation, before the second lead end.

79. A cutting tool according to Claim 78, wherein there exists and overlap between the cutting edge of the first cutting portion and the cutting edge of the second cutting portion so that the second lead end is disposed in front of the first trail end.

80. A cutting tool according to Claim 78 or 79, wherein the standard cutting edge extends so that in a view perpendicular thereto, at least one of the first lead end and the second lead end is obscured thereby.

81. A cutting tool according to any one of Claims 78 to 80, wherein the second trail end comprise an extension configured for breaking off chips removed from the workpiece.

82. A cutting tool according to any one of Claims 74 to 81, wherein the cutting tool is a rotary tool configured for revolution about a central axis, and wherein the first cutting portion and the second cutting portion extend about the central axis.

83. A cutting tool according to Claim 82, wherein the cutting edge of the first cutting portion is configured for removing material from a surface extending parallel to the central axis and the cutting edge of the second cutting portion is configured for removing material from a surface extending perpendicular to the central axis.

84. A cutting tool according to Claim 83, wherein the cutting edge of the first cutting portion is configured for removing material from a surface extending perpendicular to the central axis and the cutting edge of the second cutting portion is configured for removing material from a surface extending parallel to the central axis.

85. A cutting tool according to Claim 83 or 84, wherein the cutting tool comprises several cutting segments, each segment comprising at least one of the first and the second cutting portions.

86. A cutting tool according to Claim 85, wherein each cutting segment includes both the first and the second cutting portion.

87. A cutting tool according to Claim 86, wherein the cutting segments of the cutting tool alternate so that one cutting segment is configured according to Claim 83 and the other cutting segment is configured according to Claim 84.

88. A cutting tool according to Claim 87, wherein one cutting segment comprises the first cutting portion and the consecutive cutting segment comprises the second cutting portion.

89. A cutting tool according to Claim 88, wherein each of the cutting segments also comprises a standard cutting edge disposed, in each cutting segment, in front of the first and/or second cutting portion.

90. A cutting tool according to any one of Claims 78 tor 89, wherein the cutting tool is provided with one or more chip evacuation channels extending about an rotation axis, wherein the circumferential extension of the cutting segment about the central axis is greater than the circumferential extension of the channel about the central axis.

91. A cutting tool according to any one of Claims 74 to 90, wherein the angle between a rake surface and a relief surface of at least one of the cutting portions at said lead end is greater than at said trail end.

92. A cutting tool according to Claim 91, wherein the angle between the rake and relief surfaces is continuously reduced between the lead end and the trail end.

93. A cutting tool according to any one of Claims 74 to 92, wherein the cutting tool comprises a first cutting insert comprising the first cutting portion and a second cutting insert comprising the second cutting portion, the first and the second cutting insert being configured for mounting one on top of the other to cut the same corner.

94. A cutting tool according to Claim 93, wherein the first cutting insert and the second cutting insert are configured for being mounted onto a cutting tool holder using a mutual connecting configuration.

95. A cutting too according to Claim 93 or 94, wherein the first cutting insert and the second cutting insert form together a construction which cannot be manufactured in a press-mold.

96. A cutting too according to Claim 93 or 94, wherein the first cutting insert and the second cutting insert form together a construction which cannot be manufactured in a single-axis injection mold.

97. A cutting tool configured for removing material from a workpiece, said cutting tool comprising a cutting portion having a rake surface and a relief surface, defining, at the intersection thereof, a cutting edge having a lead end and a trail end, said lead end being configured for coming in contact with said workpiece prior to said trail end, wherein the angle between said rake surface and said relief surface at said lead end is greater than at said trail end.

98. A cutting tool configured for removing material from a workpiece to form a corner therein, said cutting tool comprising a first cutting element having a first cutting portion with a first cutting edge and a second cutting element having a second cutting portion with a second cutting edge, wherein, the contour of the first cutting edge and the contour of the second cutting edge are configured for forming together a combined contour corresponding to the above corner of the workpiece.

99. A cutting tool according to Claim 98, wherein the cutting elements are configured for being mounted one on top of the other.

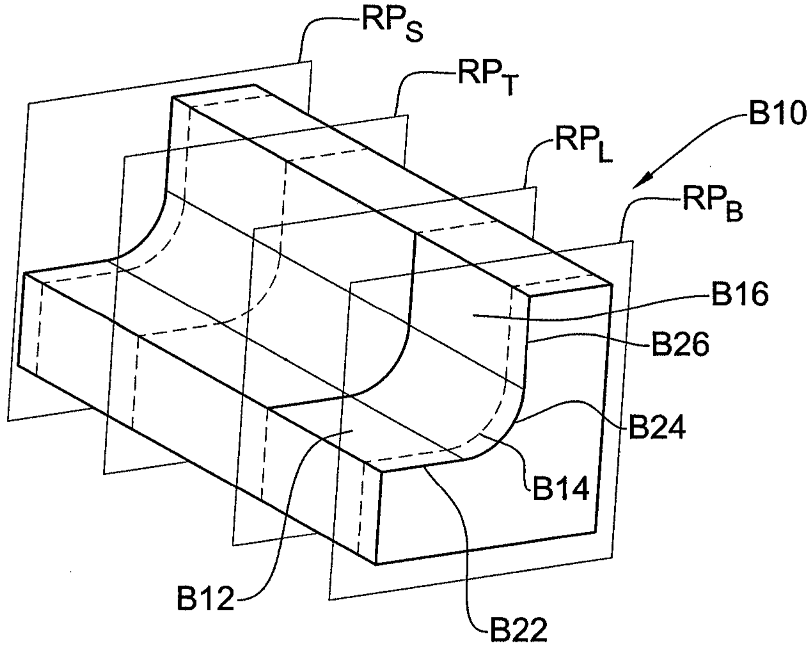
100. A cutting tool according to Claim 98 or 99, wherein, when combined, the cutting elements form a structure which cannot be produced in a press-mold or a single-axis injection mold.

101. A cutting tool according to Claim 98, 99 or 100, wherein the cutting edges of the first and of the second element are configured for simultaneously cutting respective portions of the same corner of the workpiece during the same cutting operation.

102. A cutting tool according to any one of Claims 98 to 101, wherein the cutting elements comprise an alignment arrangement configured for preventing lateral movement therebetween.

103. A cutting tool according to Claim 102, wherein the alignment arrangement is constituted by a male-female engagement between the cutting elements.

104. A cutting tool according to any one of Claims 98 to 103, wherein the cutting elements are configured for simultaneously being mounted onto a cutting tool holder using a mutual securing arrangement.


RPS
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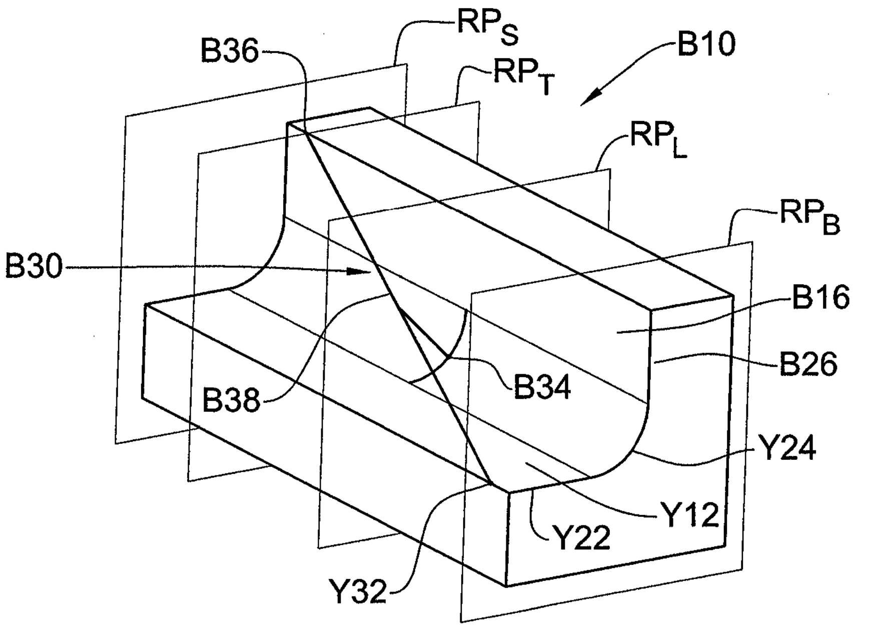
B10
RPL
RPB
B16
B26
B24
B14
B12
B22

Fig.1A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Y24
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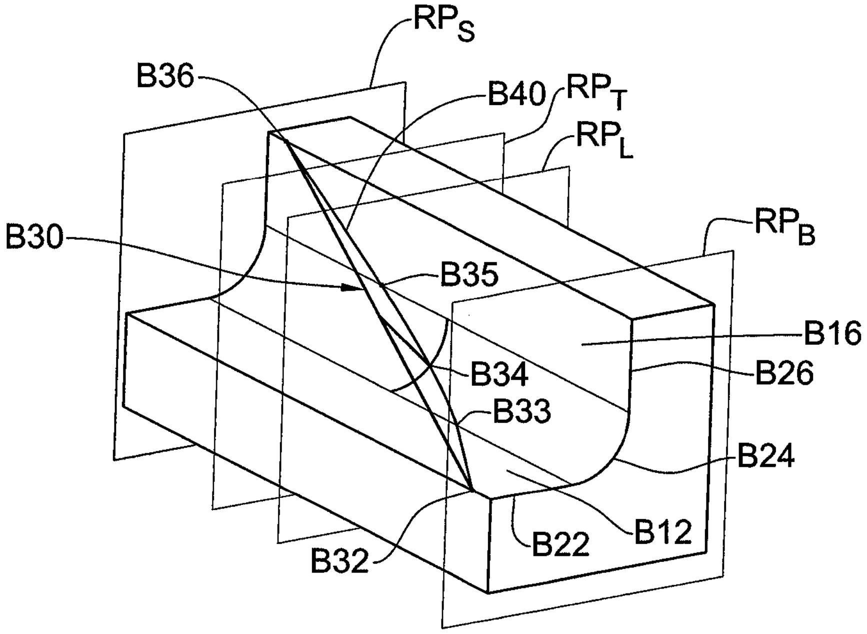
Y22
Y32

Fig.1B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RP$_T$
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B35
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B34
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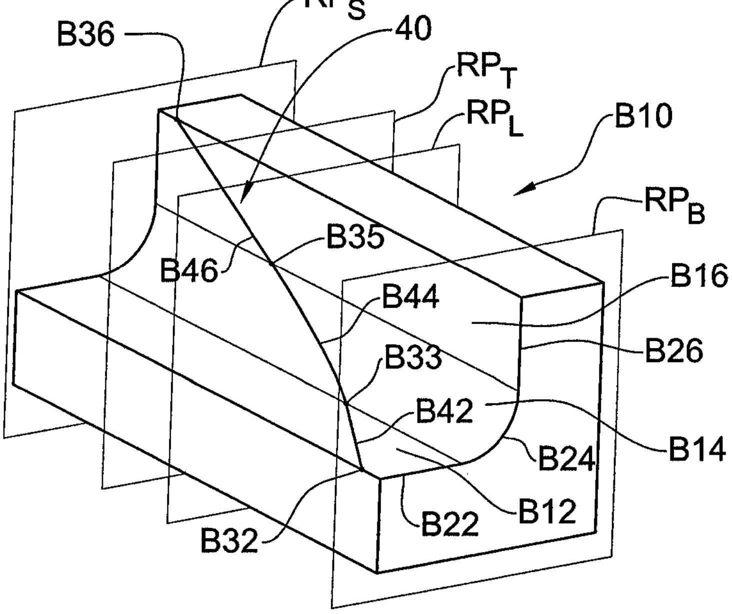
B22
B32

Fig.1C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B10
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B33
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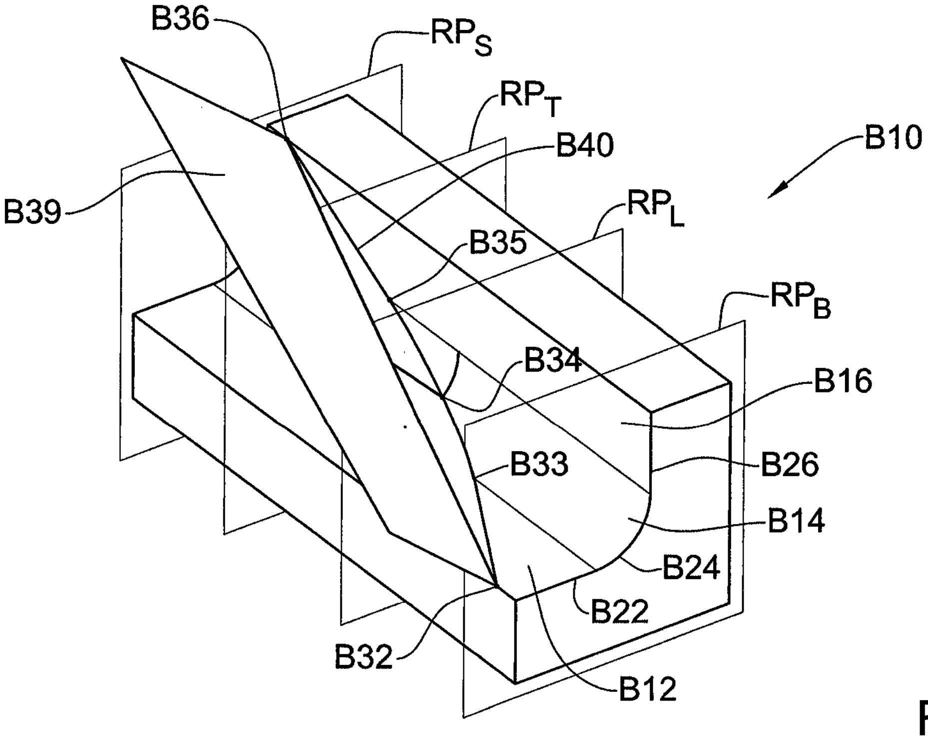
B24
B12
B22
B32

Fig. 1D


B36
RP$_S$
RP$_T$
B10
B40
B39
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RP$_B$
B34
B16
B33
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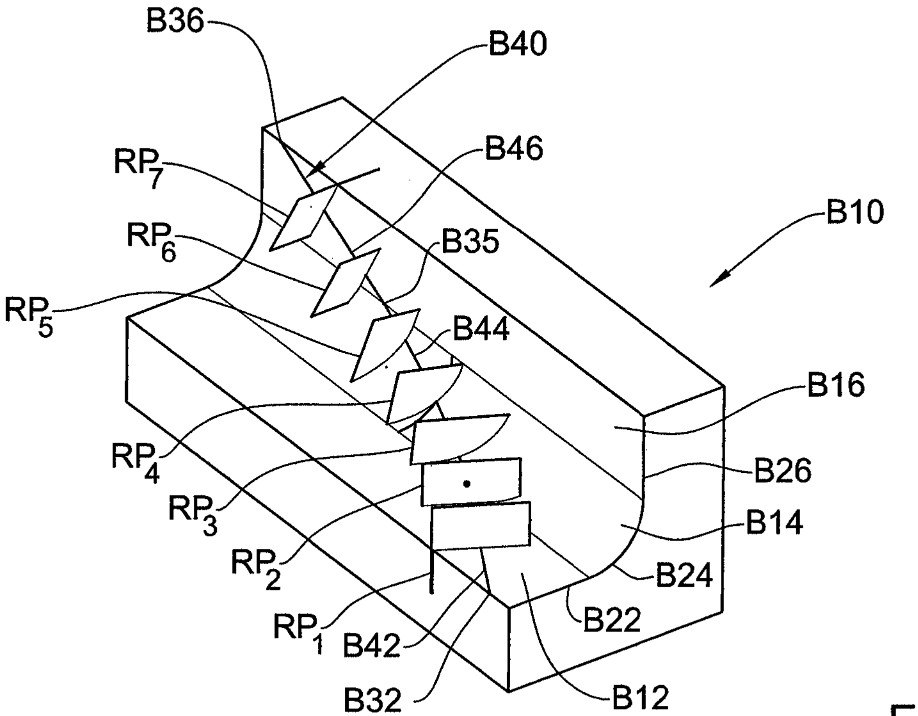
B32
B12

Fig. 1E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B40
B46
RP$_7$
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B35
RP$_5$
B44
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RP$_2$
B24
B22
RP$_1$
B42
B32
B12

Fig. 1F

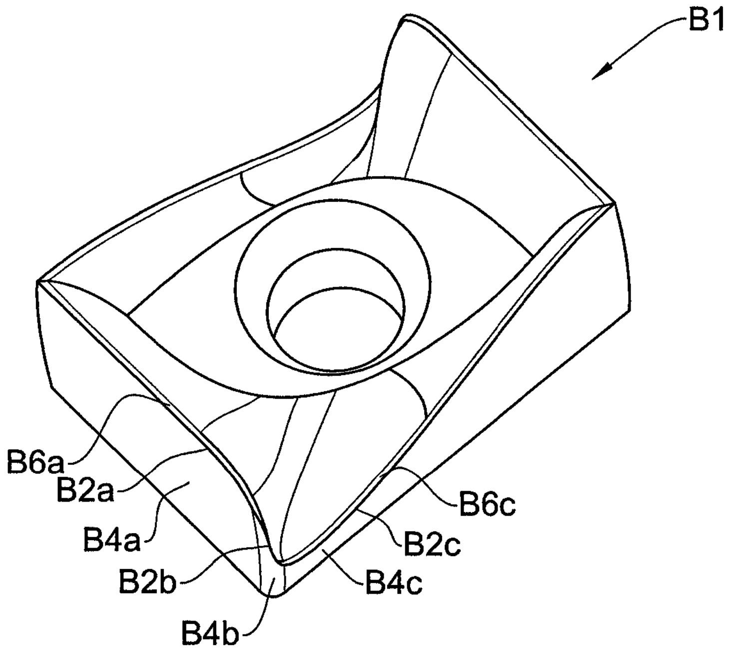


Fig. 2A

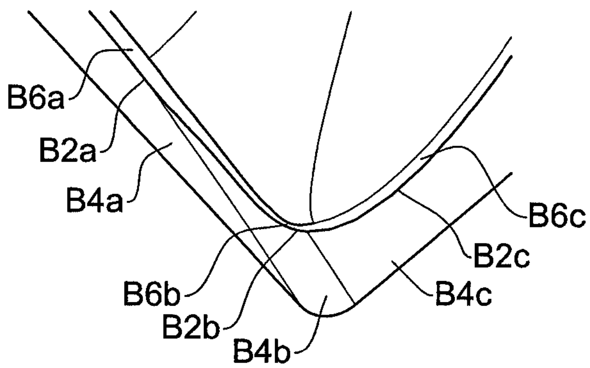


Fig. 2B

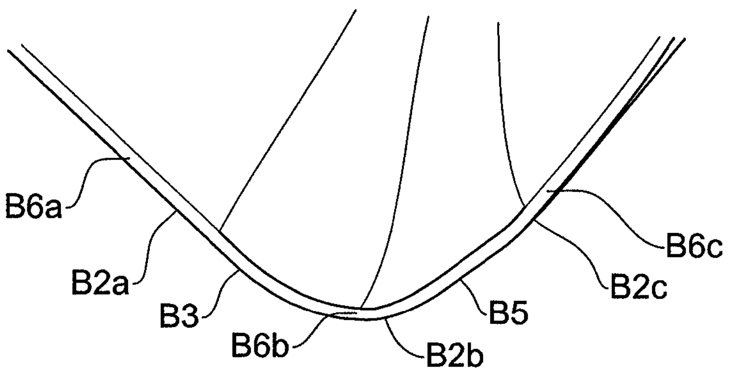
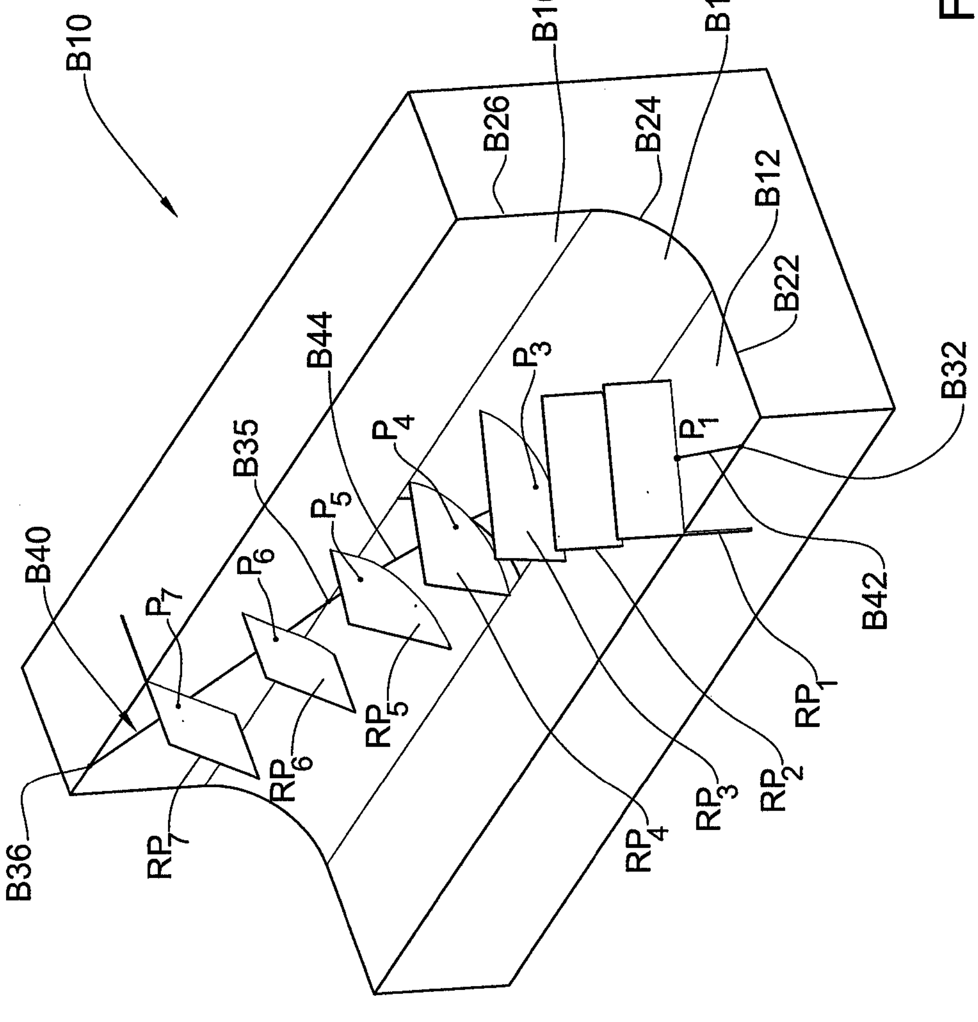


Fig. 2C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B12
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B32
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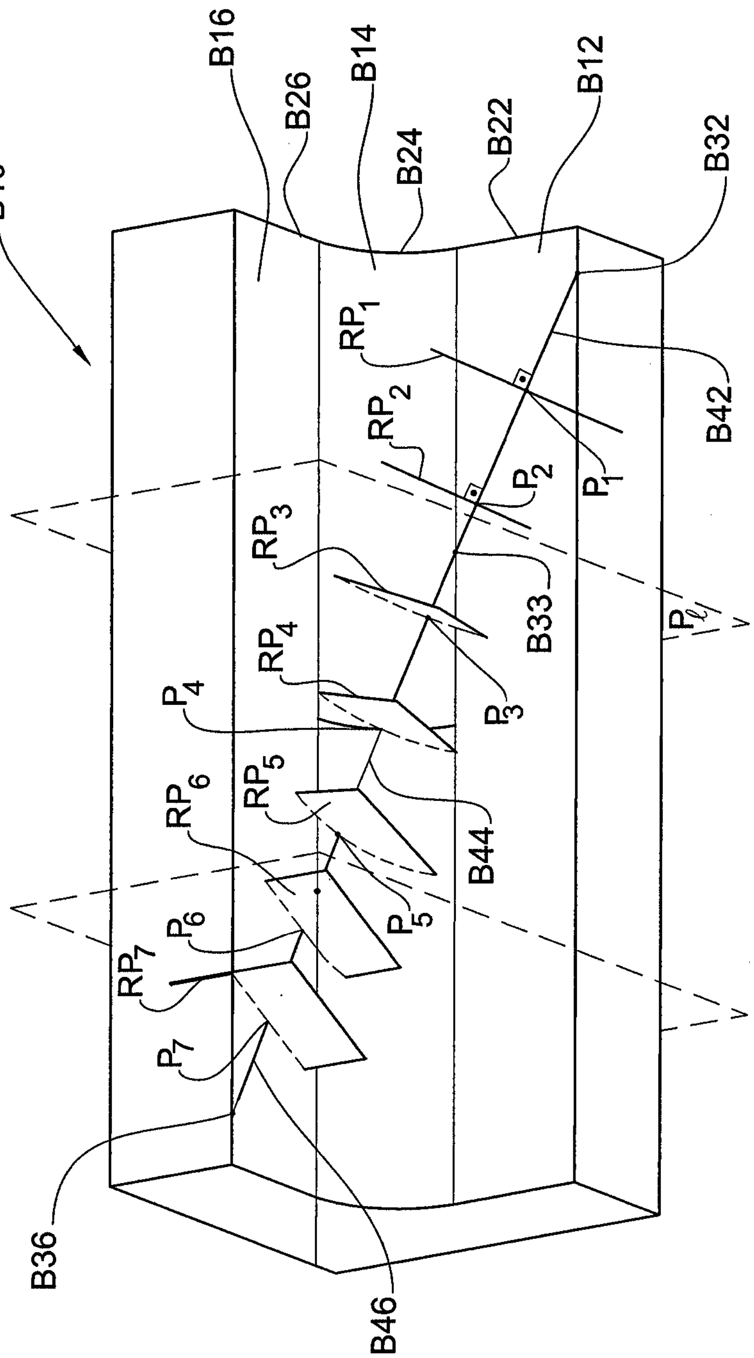
P3
P4
B35
P5
P1
P6
B40
P7
B42
RP1
RP5
RP6
B36
RP7
RP4
RP3
RP2

Fig. 3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B12
B32
RP1
RP2
RP3
RP4
RP5
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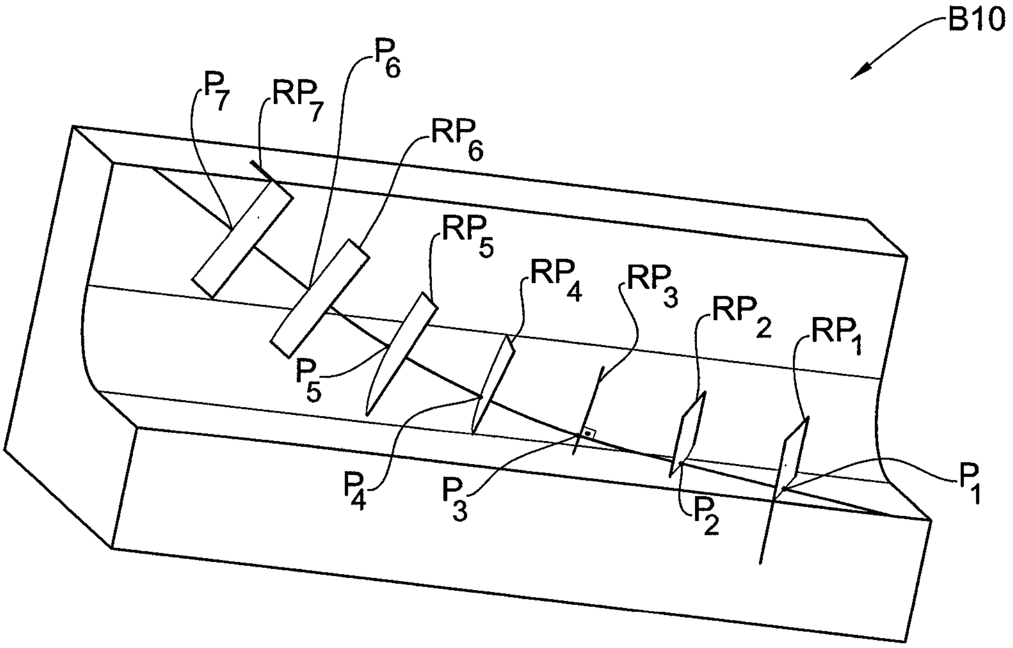
RP7
P1
P2
P3
P4
P5
P6
P7
B42
B33
B44
B36
B46

Fig. 4A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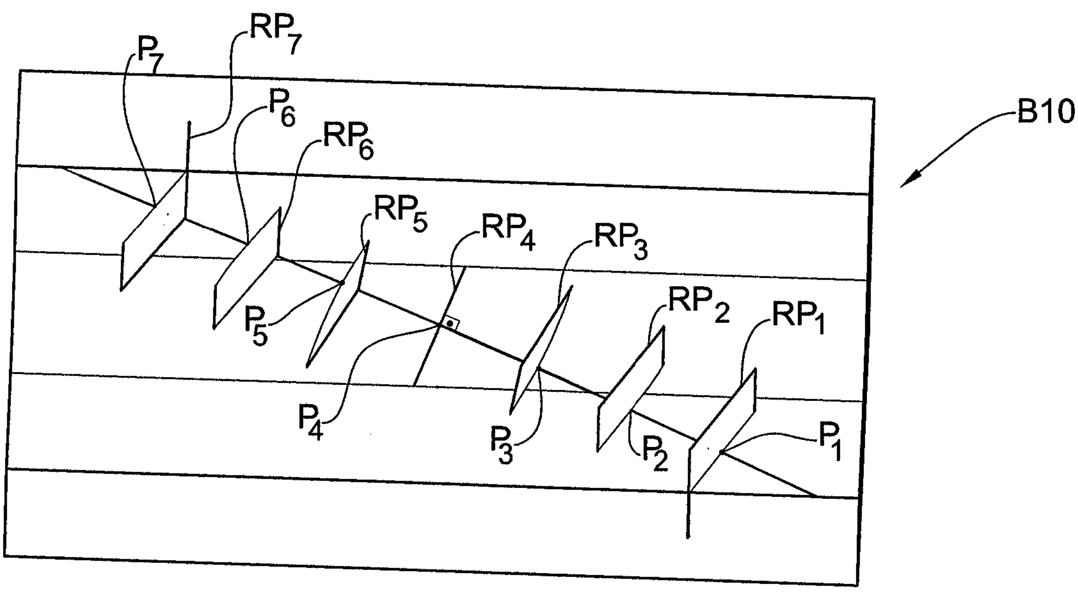
RP1
P5
P4
P3
P2
P1

Fig. 4B


RP7
P7
P6
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RP4
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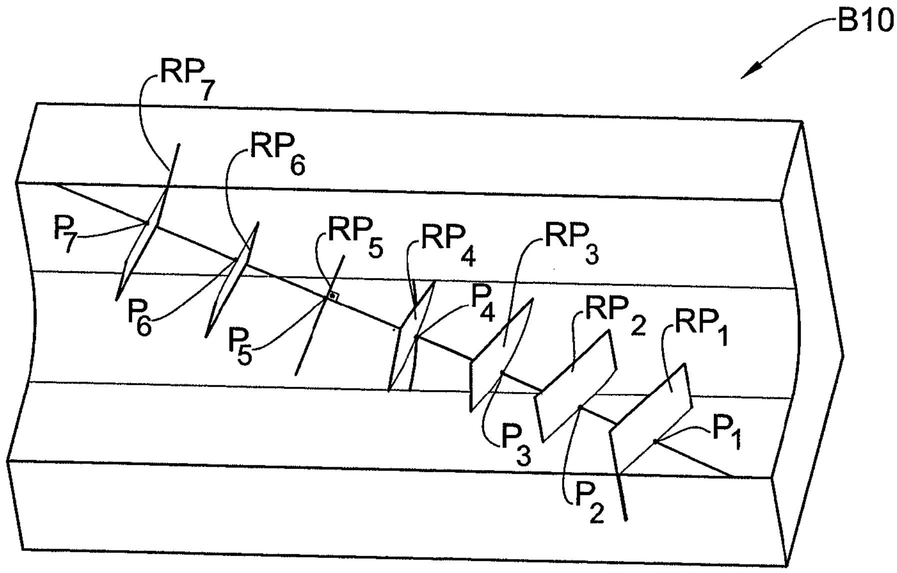
RP2
RP1
B10
P5
P4
P3
P2
P1

Fig. 4C


B10
RP7
RP6
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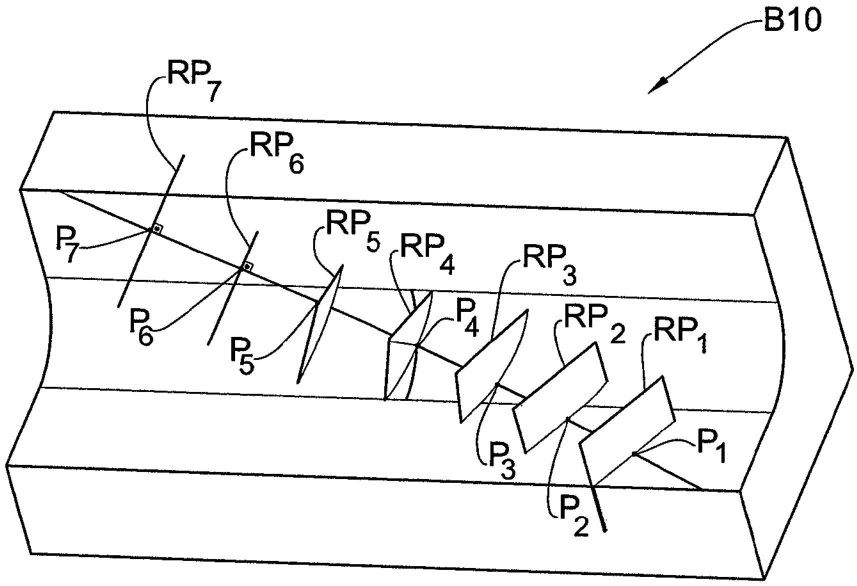
RP3
RP2
RP1
P7
P6
P5
P4
P3
P2
P1

Fig. 4D


B10
RP7
RP6
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RP4
RP3
RP2
RP1
P7
P6
P5
P4
P3
P2
P1

Fig. 4E

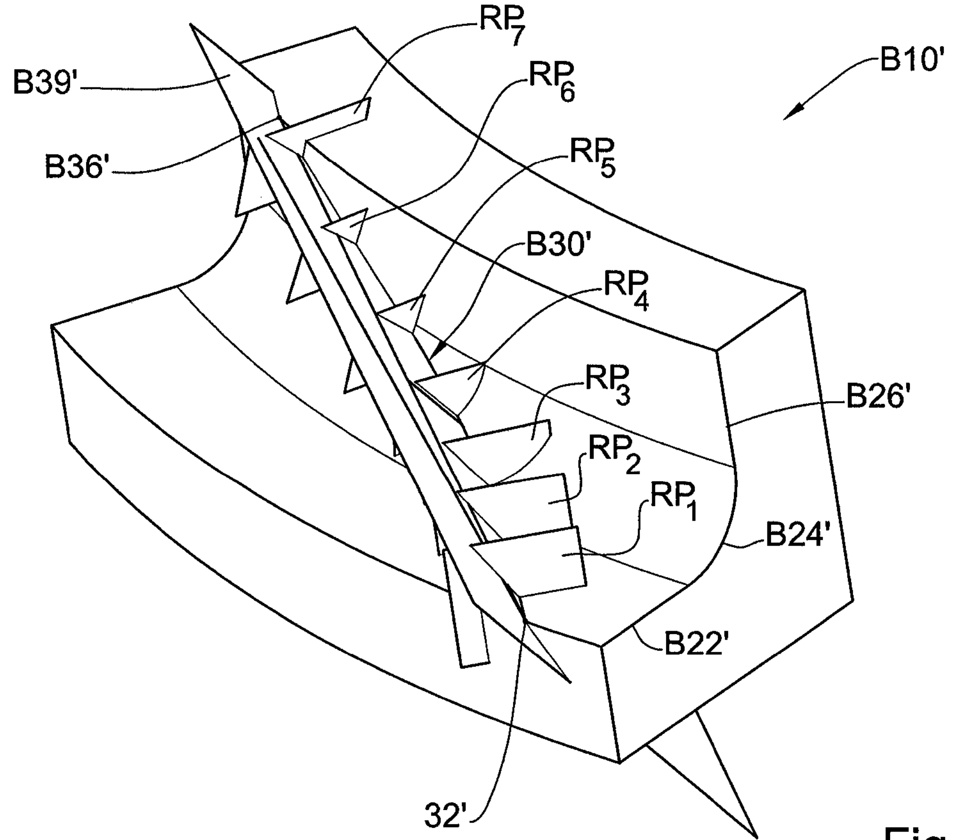
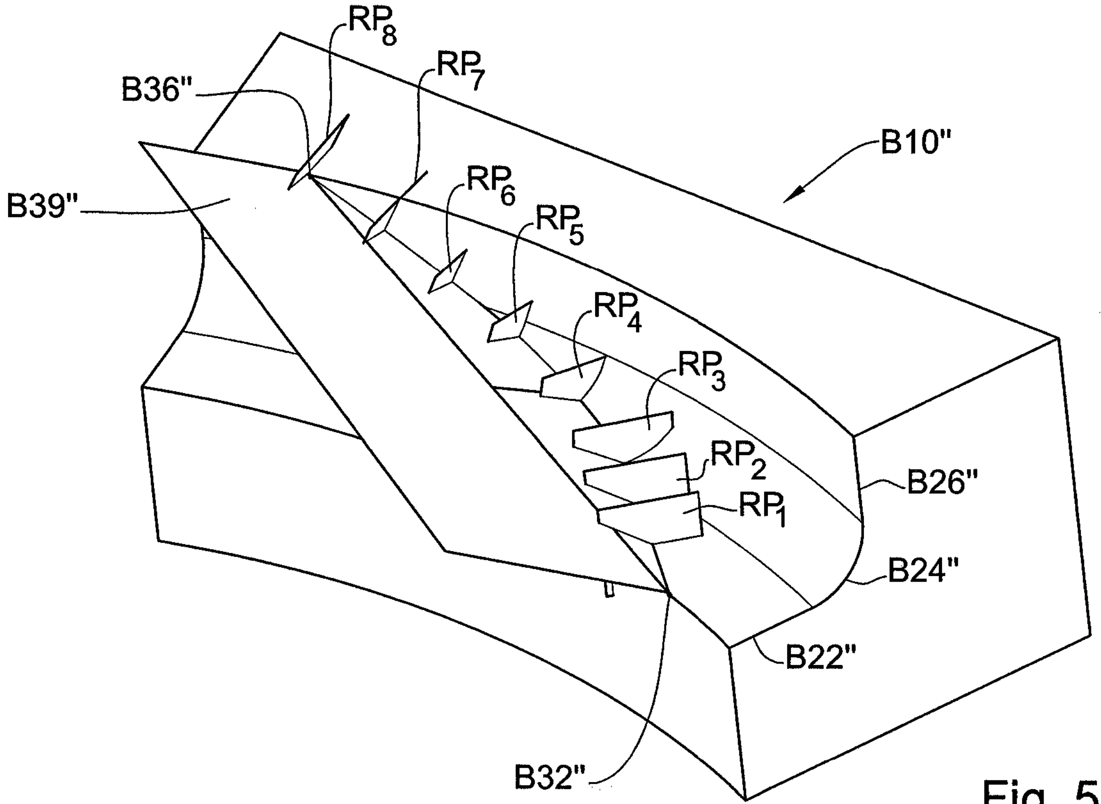

B10'
B39'
B36'
RP7
RP6
RP5
B30'
RP4
RP3
RP2
RP1
B26'
B24'
B22'
32'

Fig. 5A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B36"
B10"
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RP6
RP5
RP4
RP3
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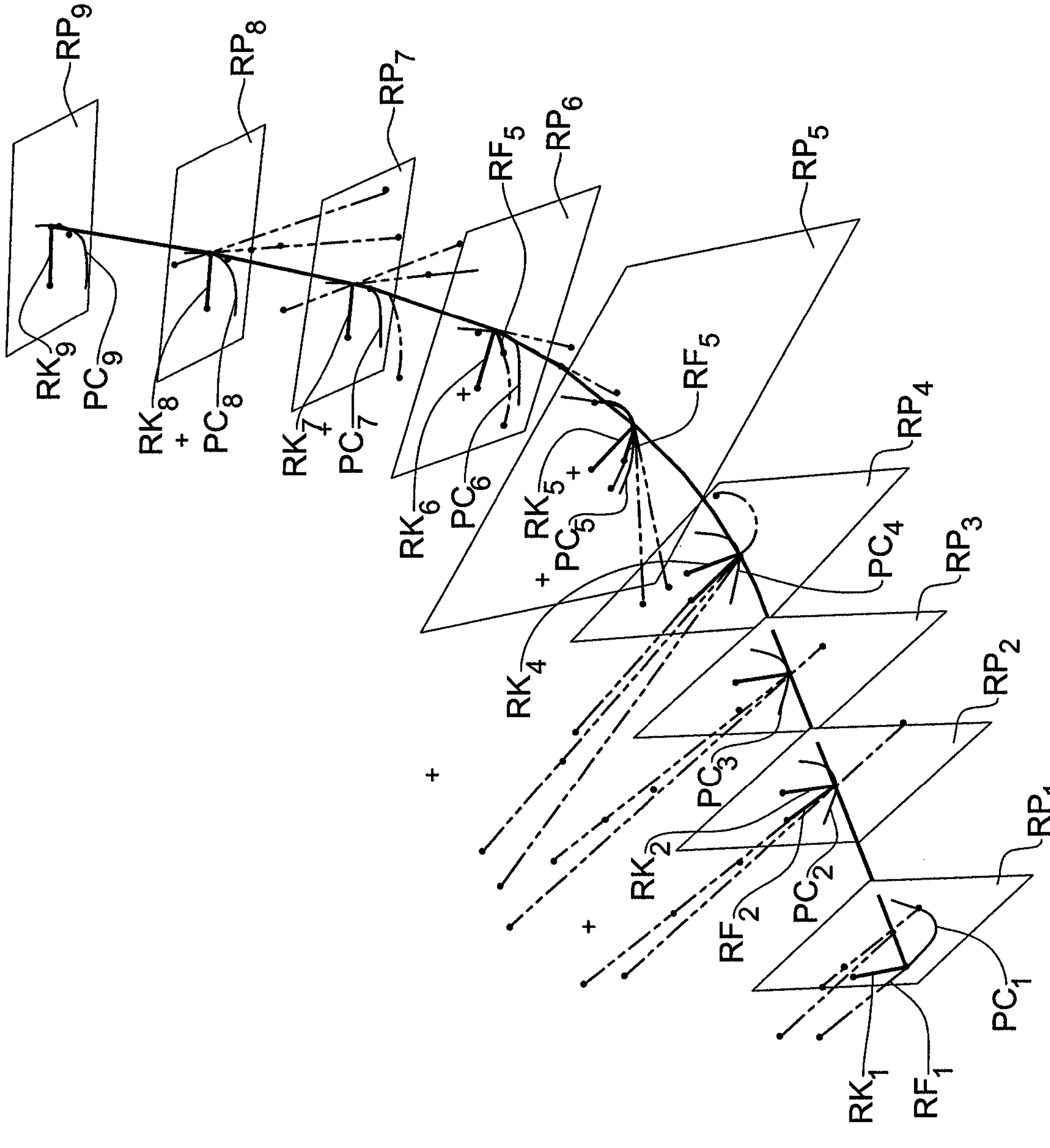
B26"
B24"
B22"
B32"

Fig. 5B

Fig. 6A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RF1

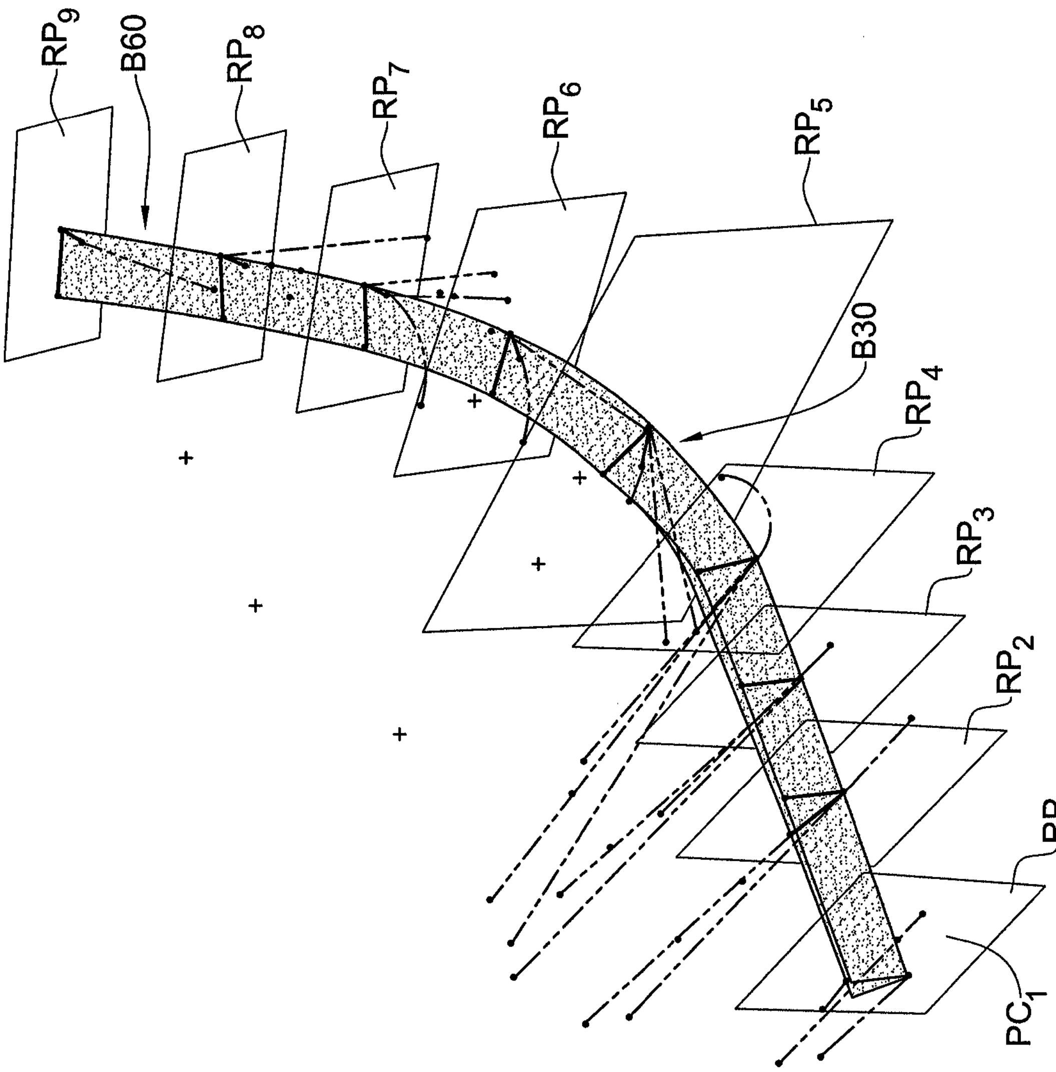


Fig. 6B

Fig. 7B

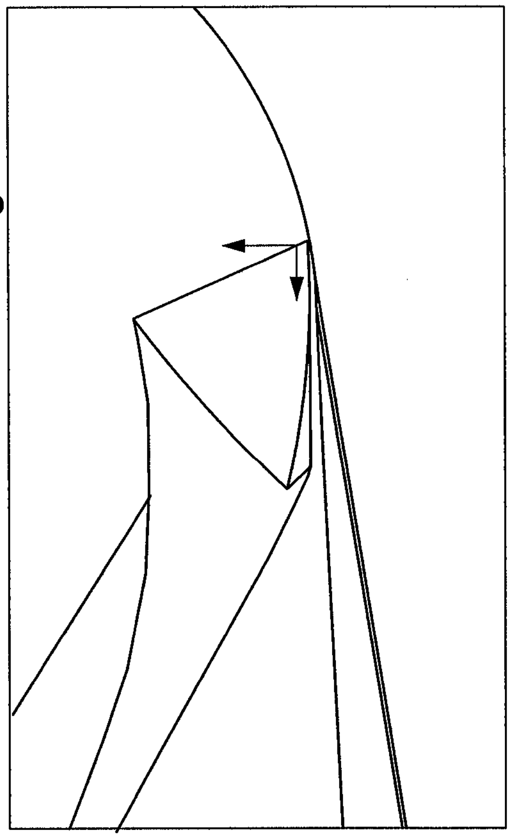


Fig. 7A

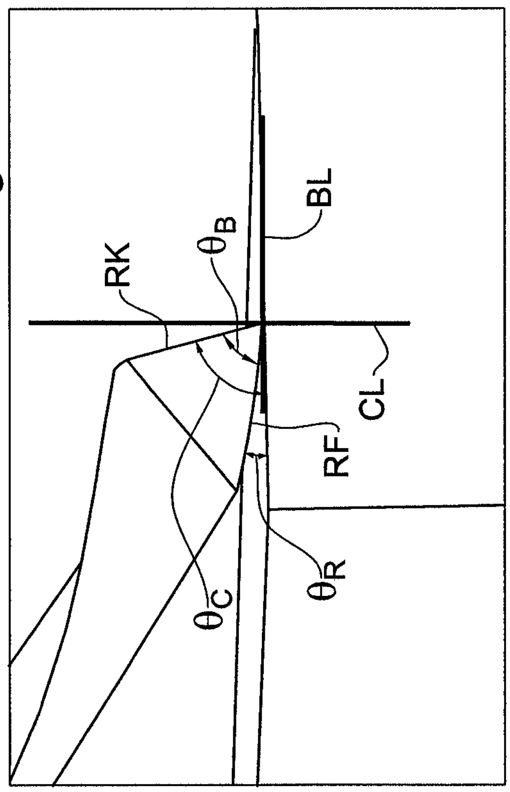


Fig. 7D

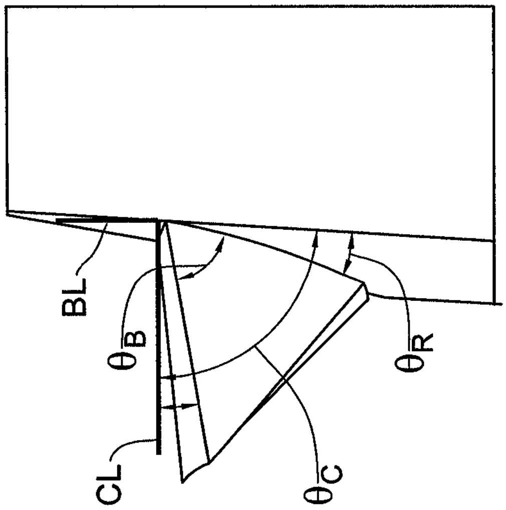
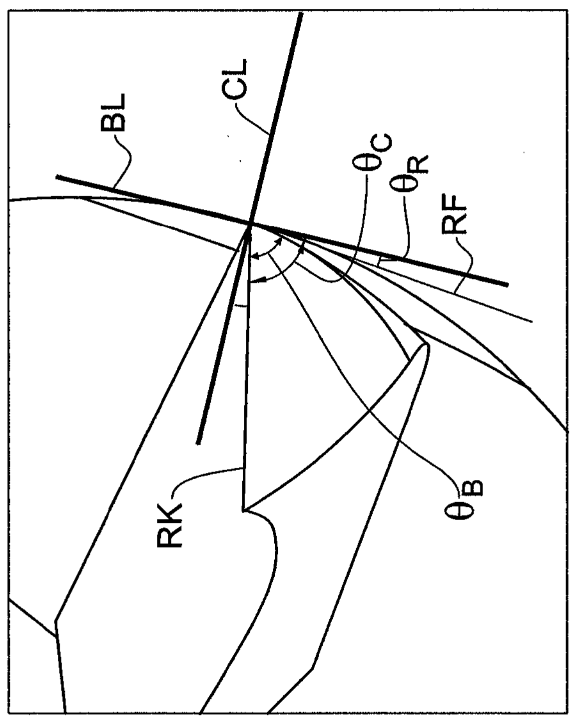


Fig. 7C



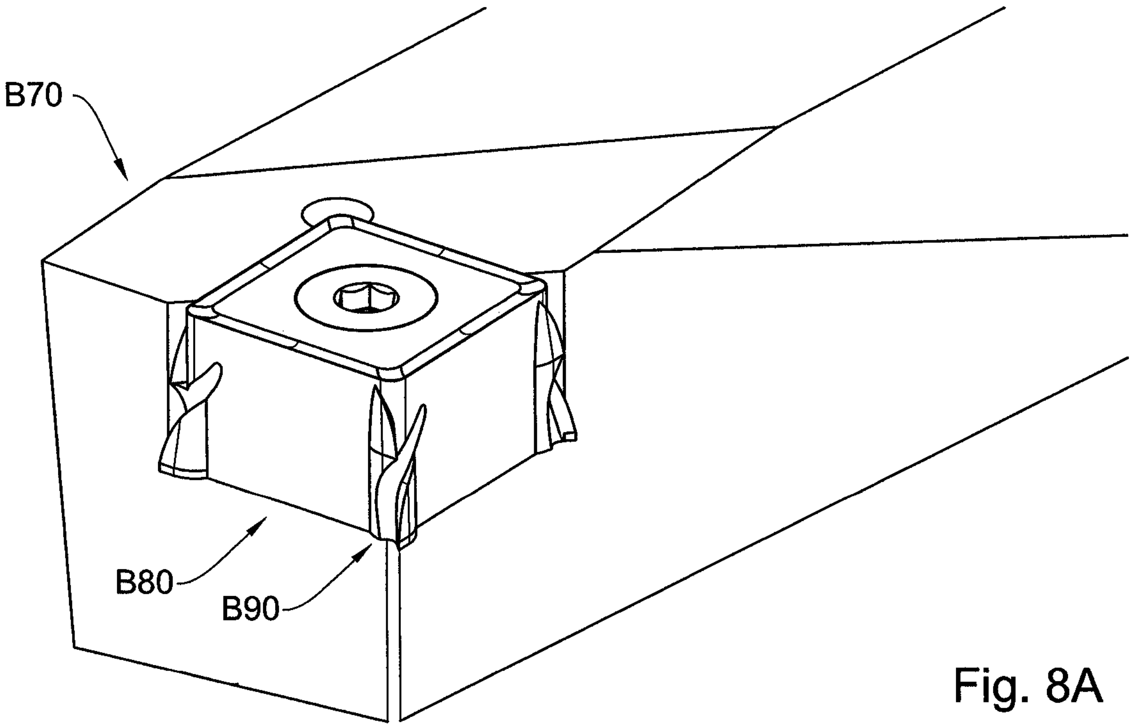
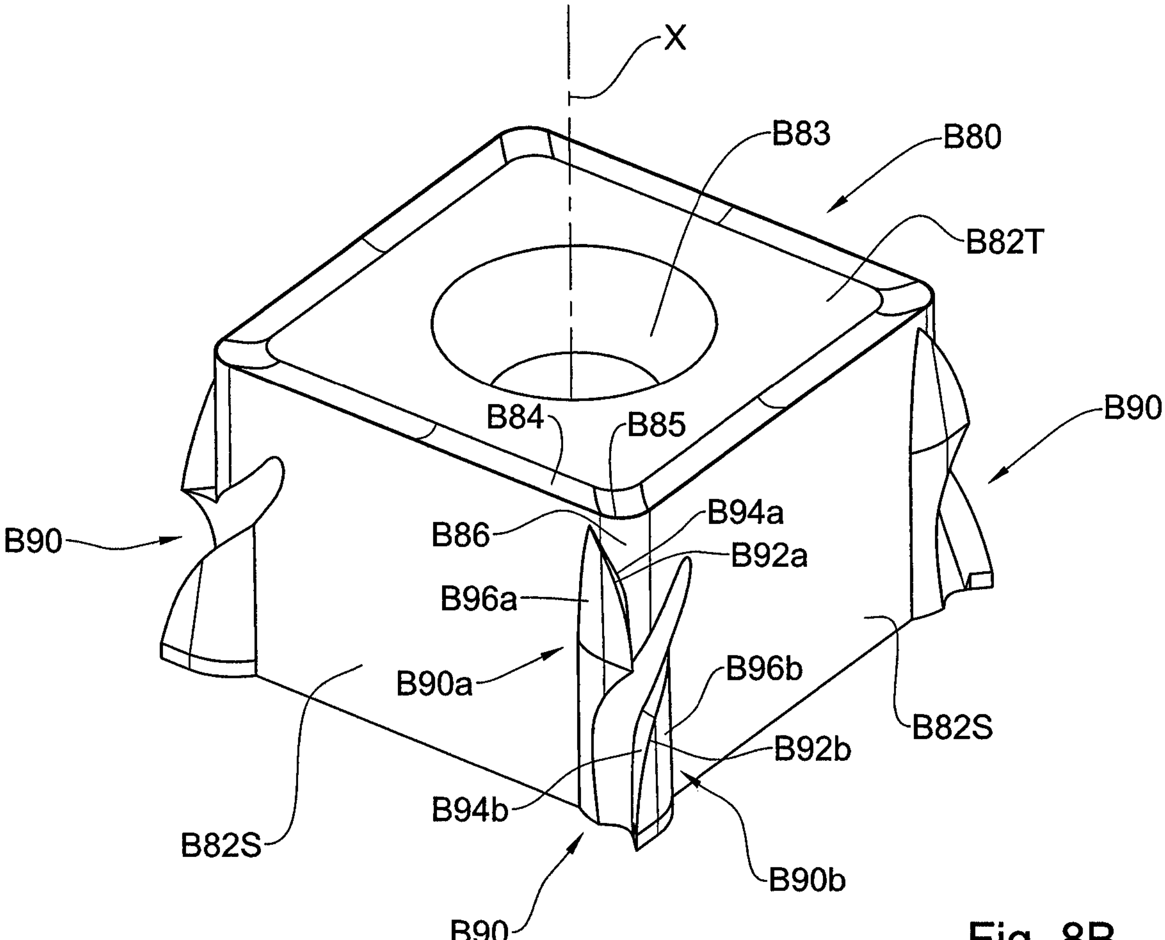

B70
B80
B90

Fig. 8A


X
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B82S
B90b
B90

Fig. 8B

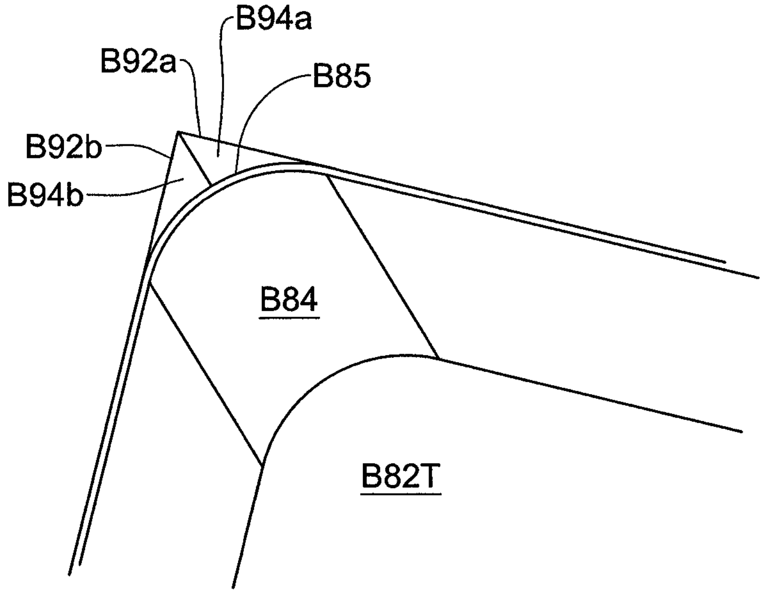

B94a
B92a
B85
B92b
B94b
B84
B82T

Fig. 8C

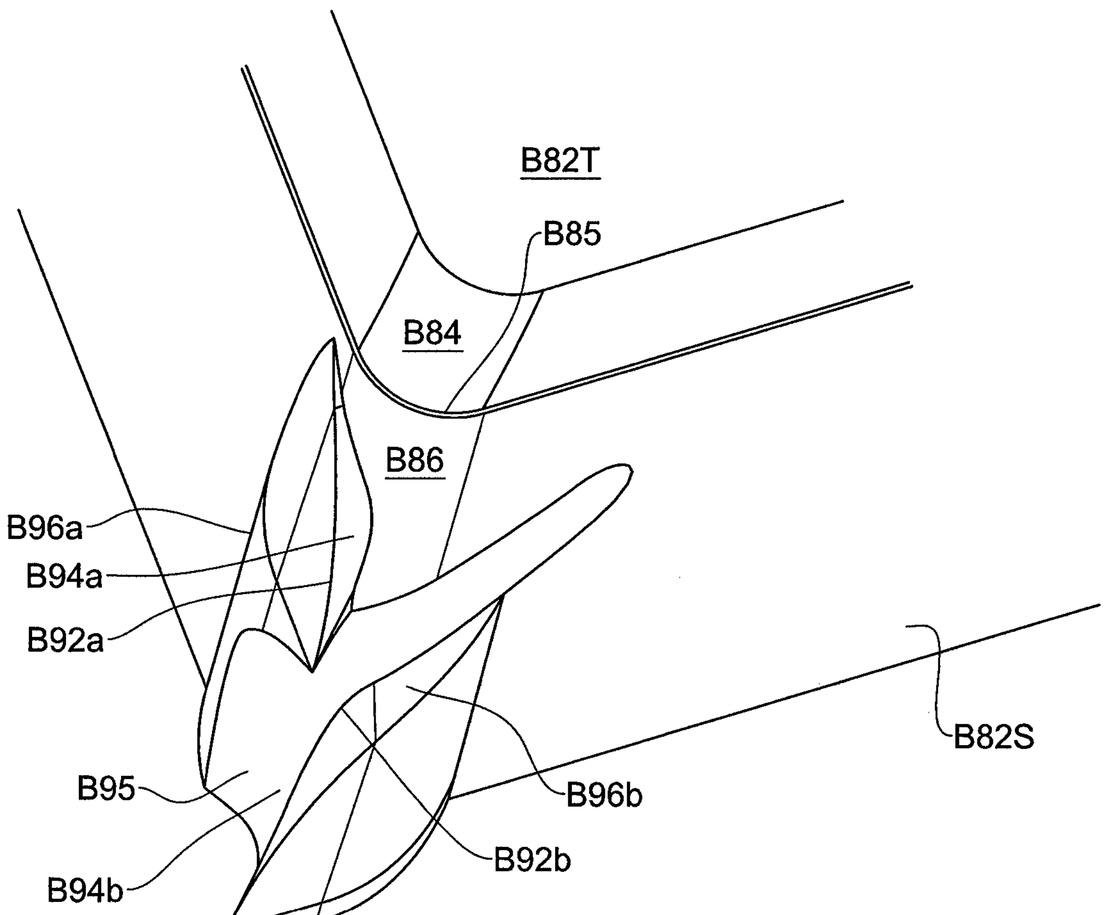

B82T
B85
B84
B86
B96a
B94a
B92a
B82S
B95
B96b
B92b
B94b

Fig. 8D

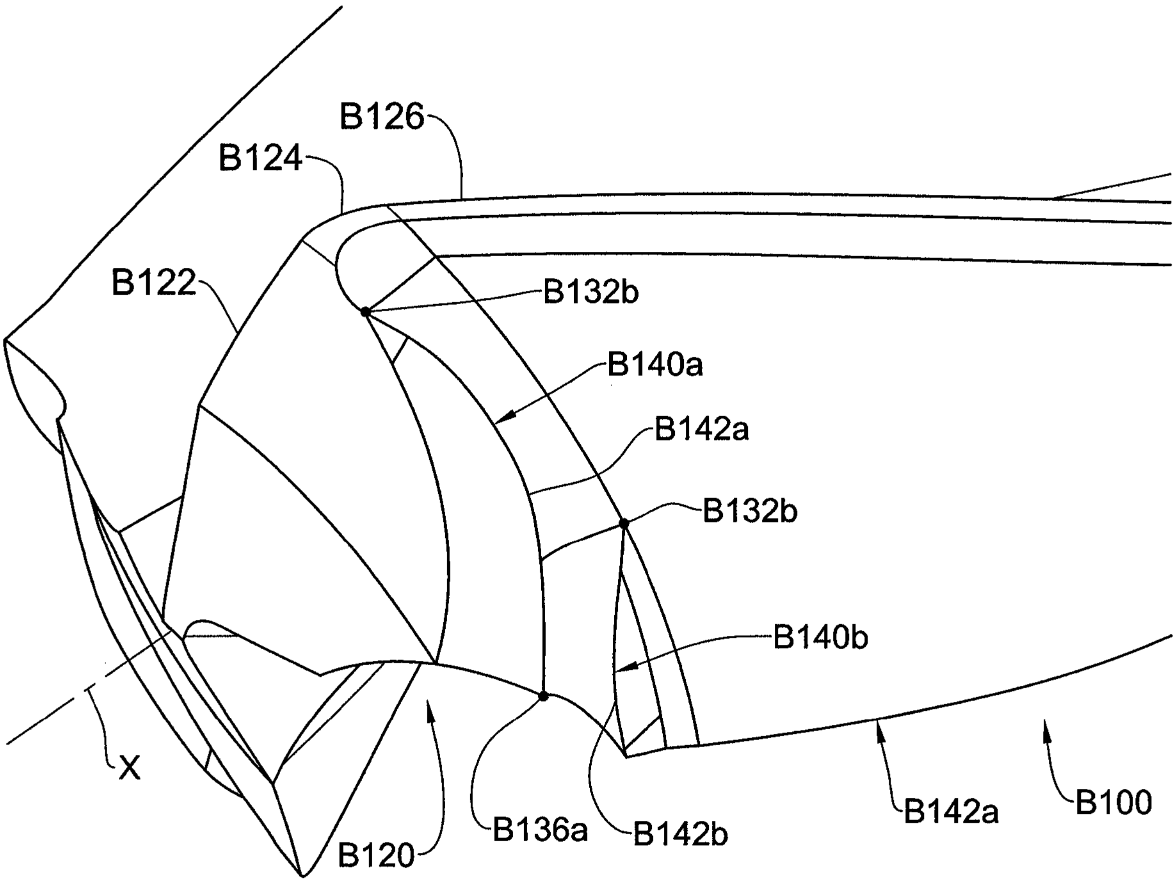

B126
B124
B122
B132b
B140a
B142a
B132b
B140b
X
B120
B136a
B142b
B142a
B100

Fig. 9A

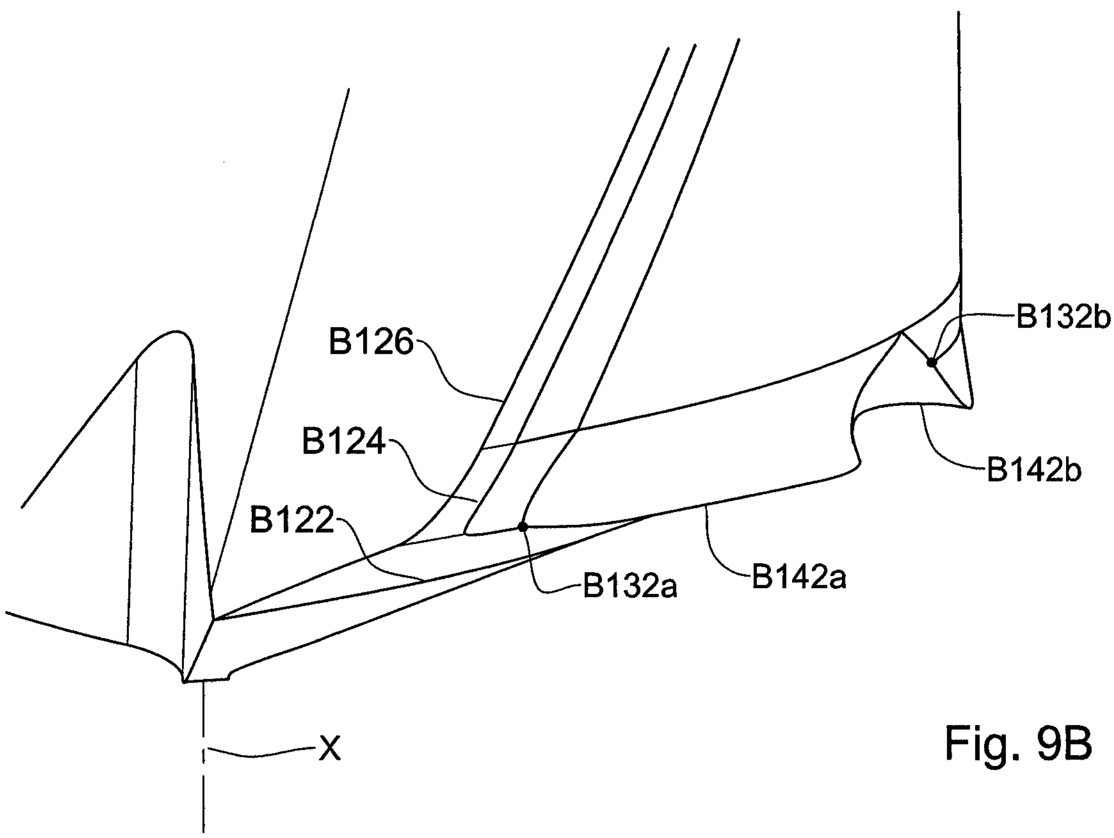

B126
B124
B122
B132b
B142b
B132a
B142a
X

Fig. 9B

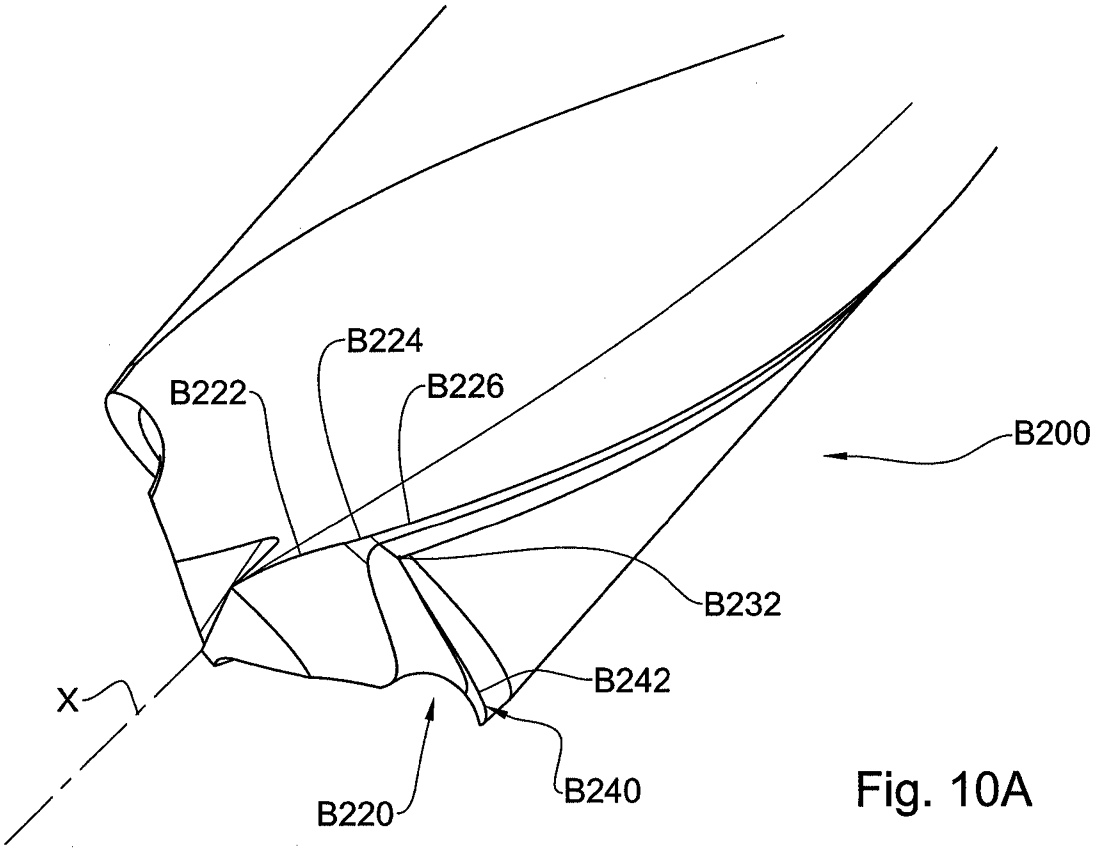


Fig. 10A

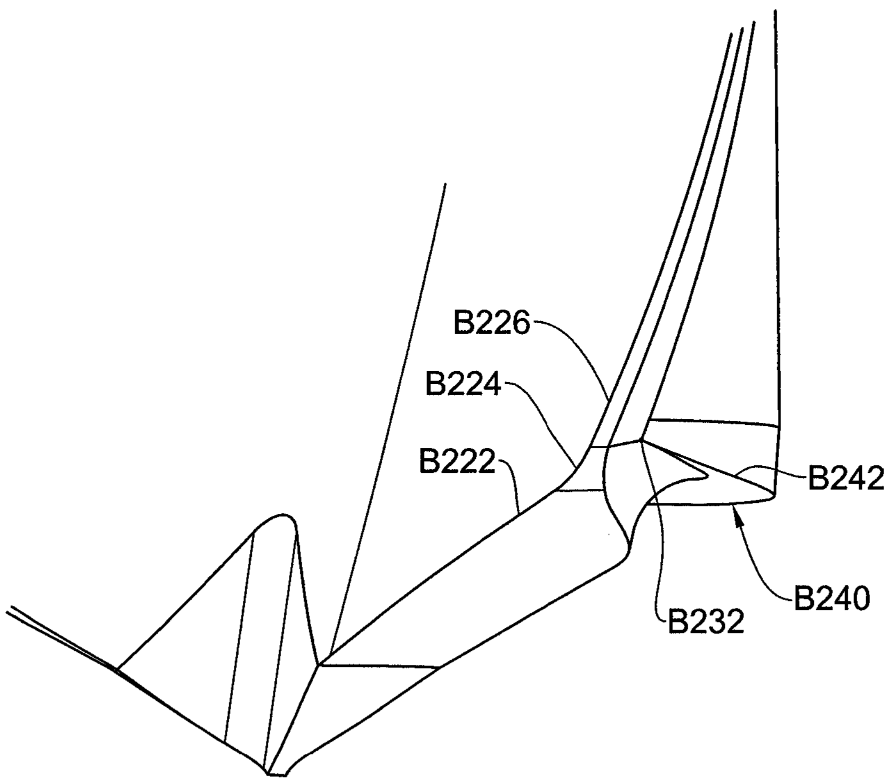


Fig. 10B

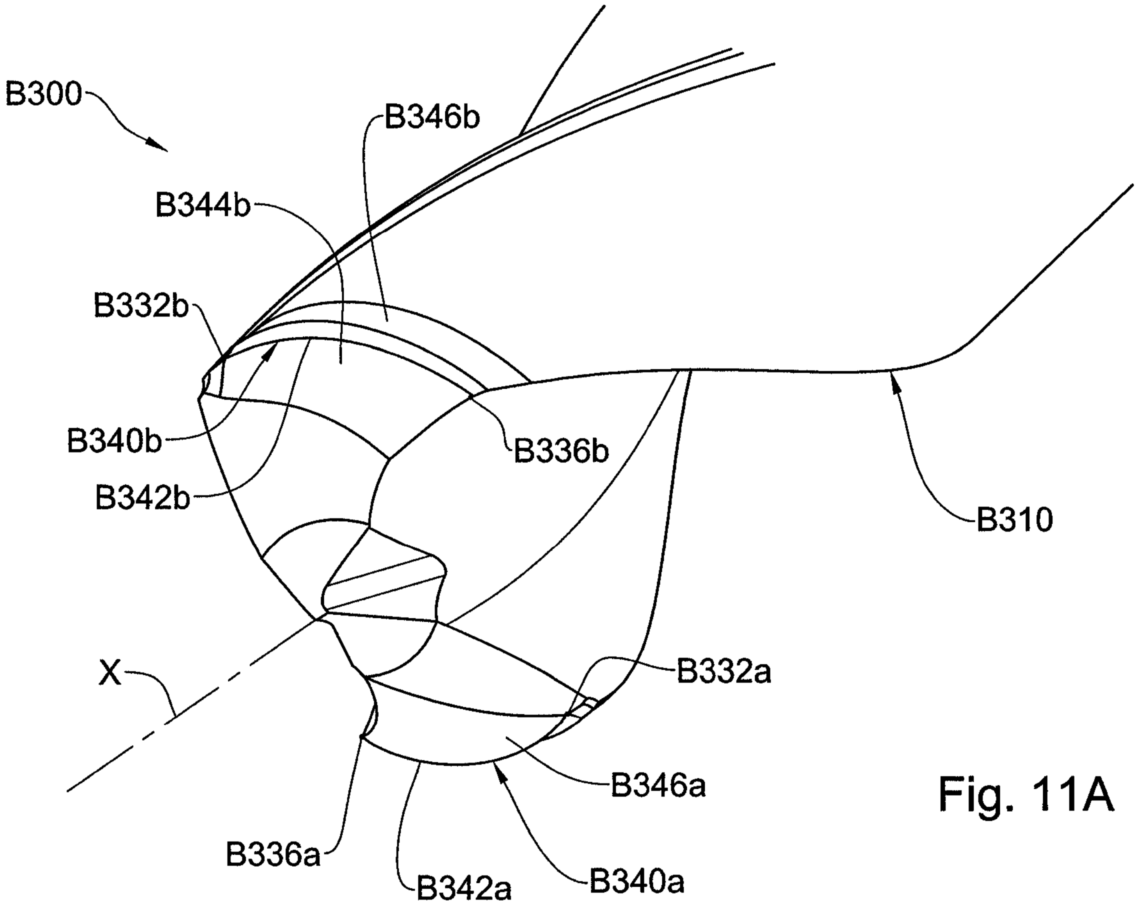


Fig. 11A

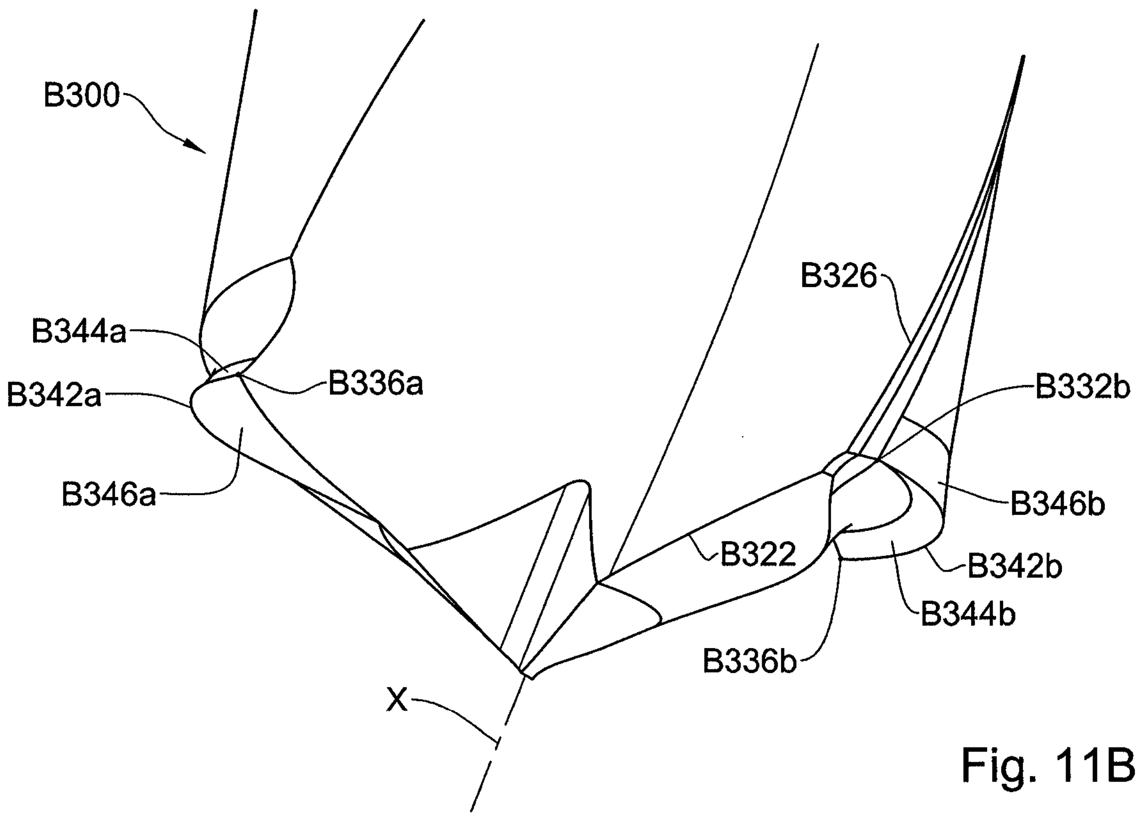


Fig. 11B

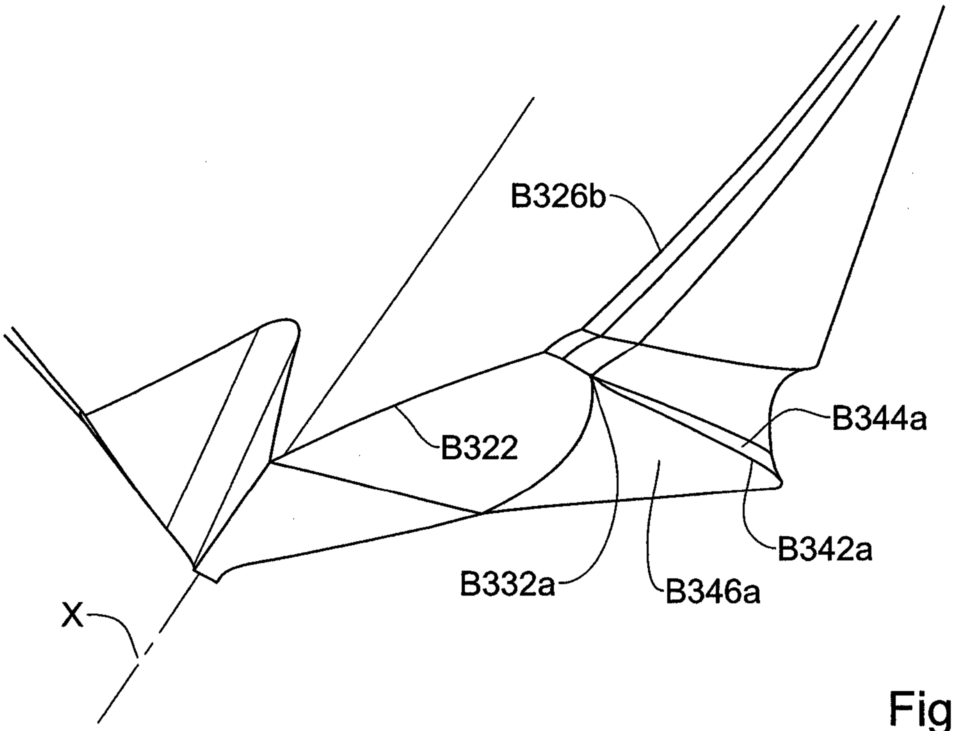


Fig. 11C

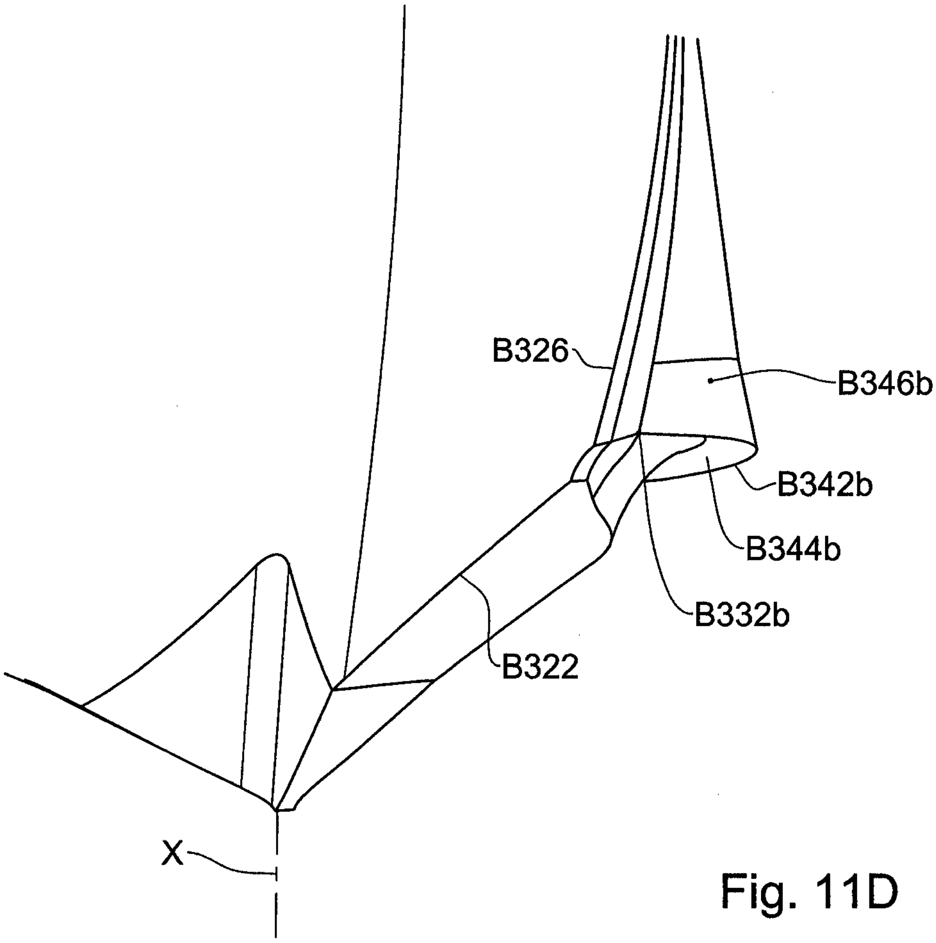


Fig. 11D

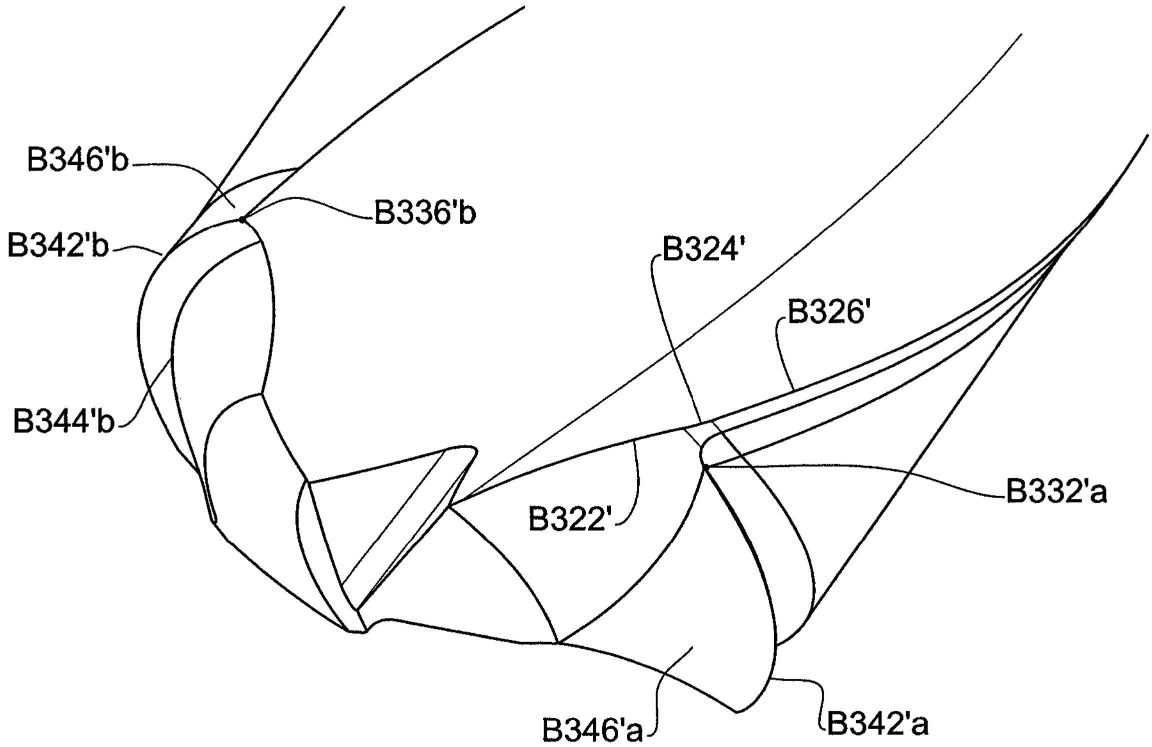


Fig. 12A

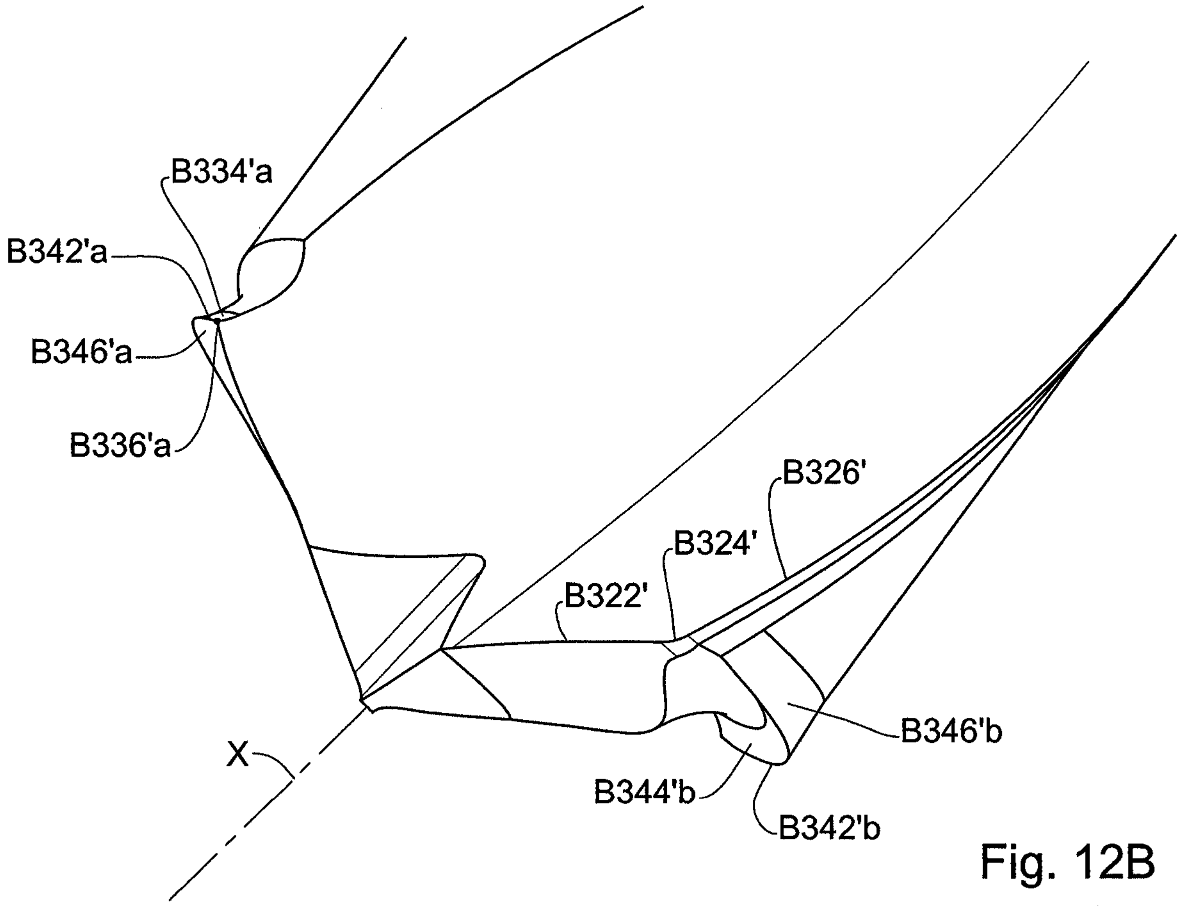


Fig. 12B

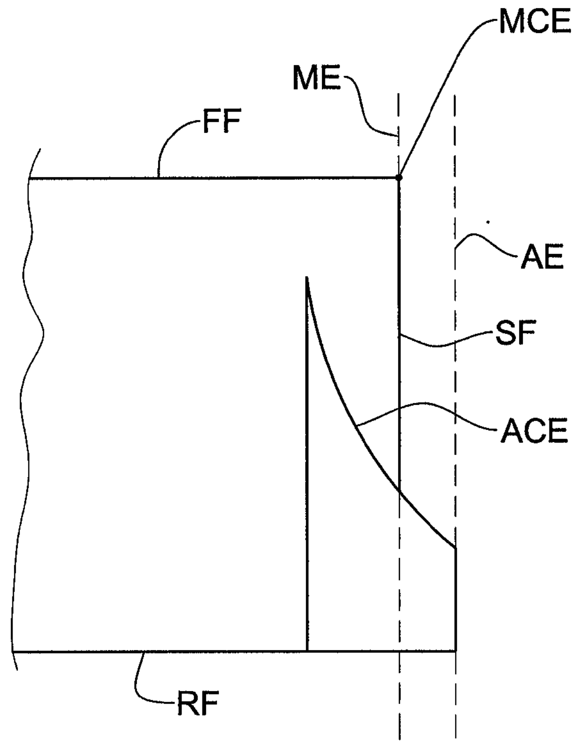


Fig. 13

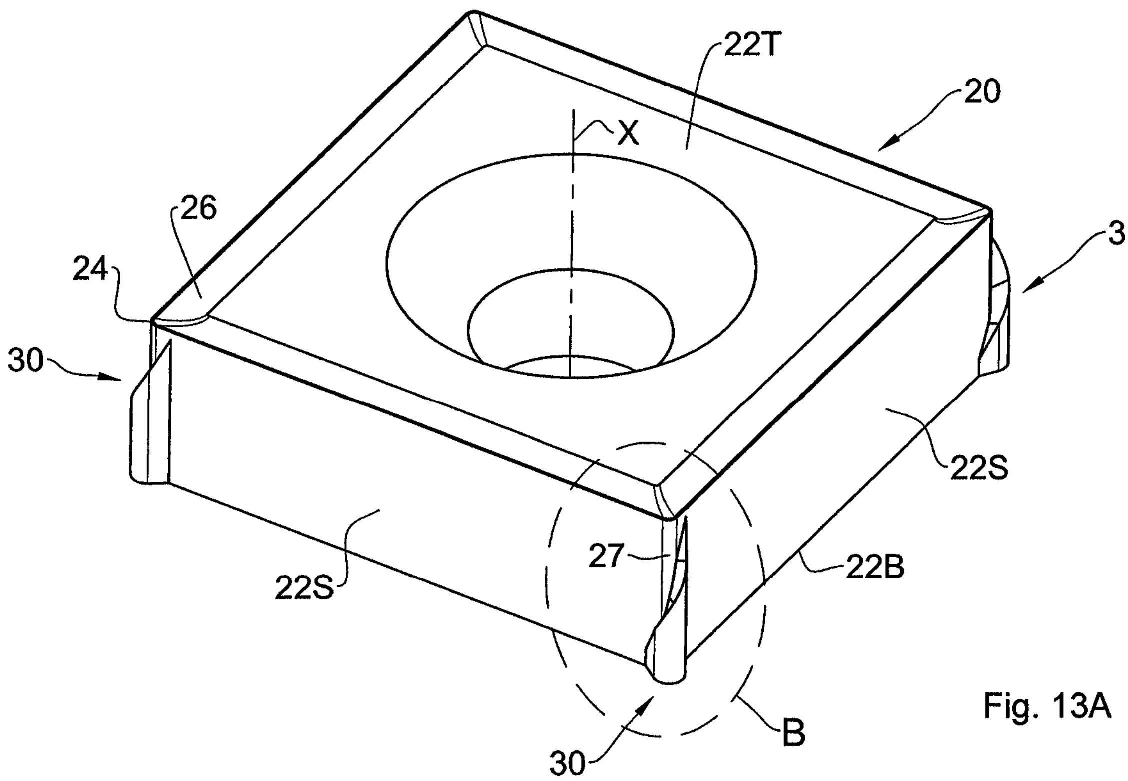


Fig. 13A

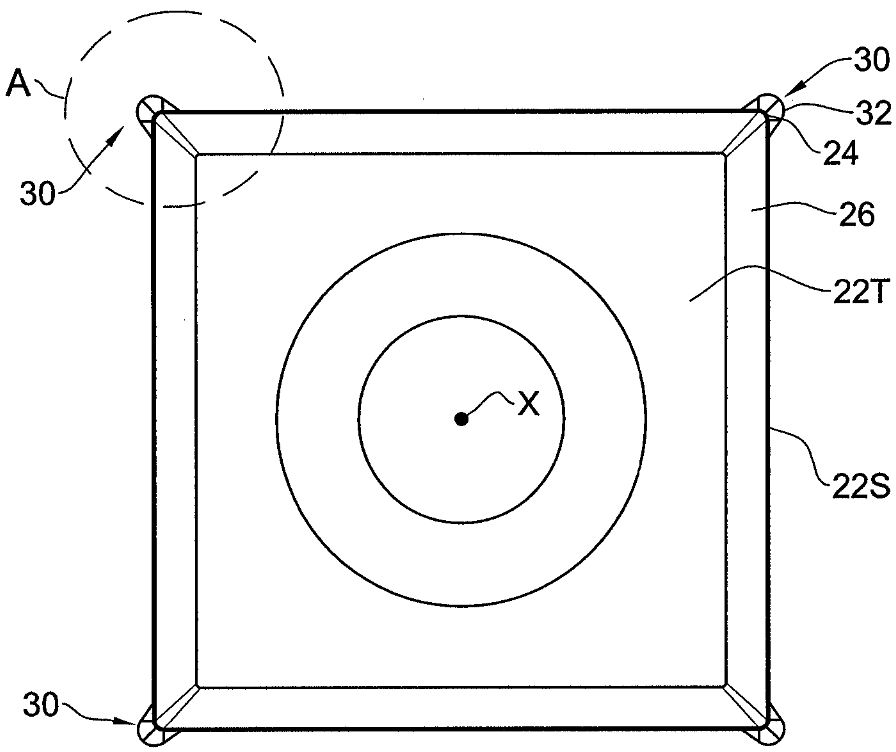


Fig. 13B

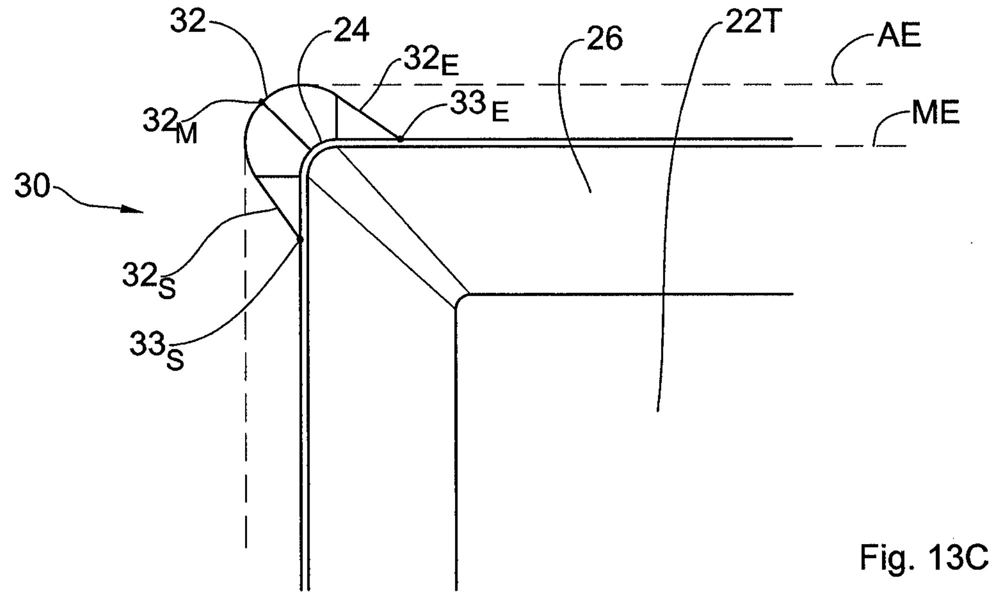


Fig. 13C

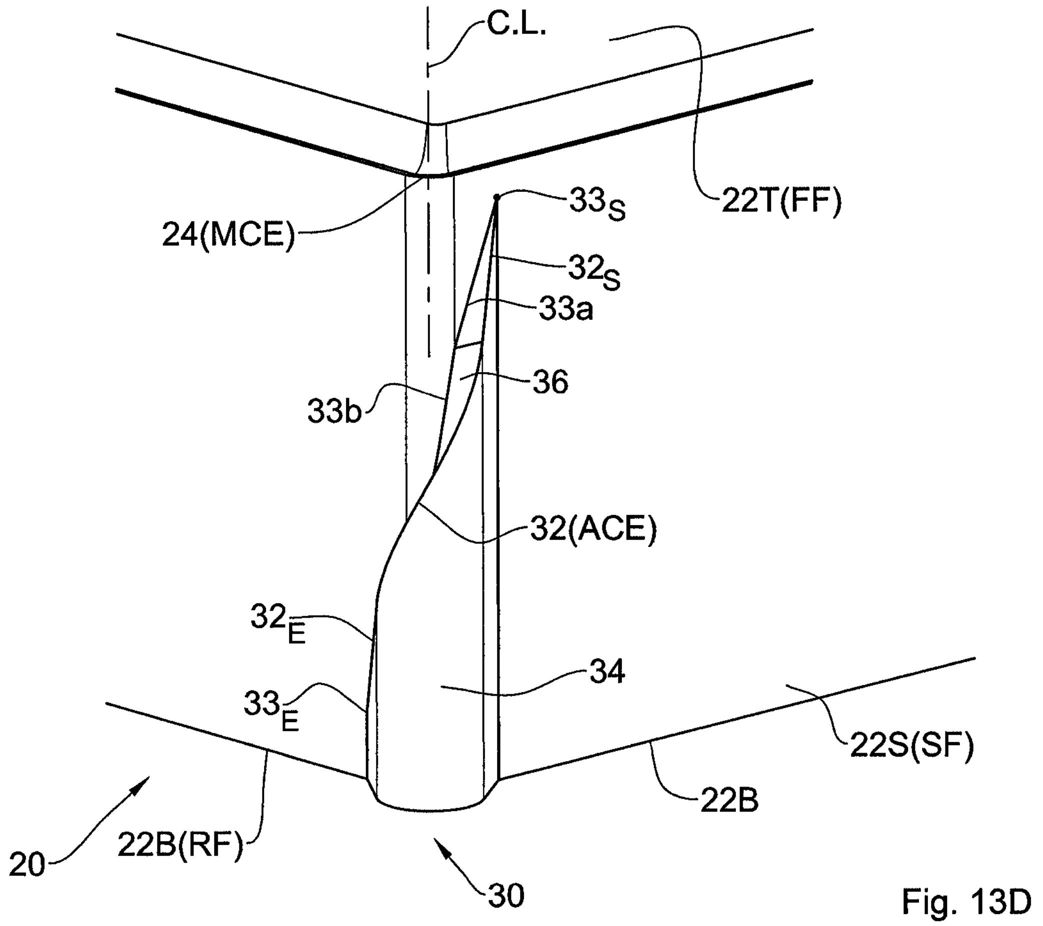


Fig. 13D

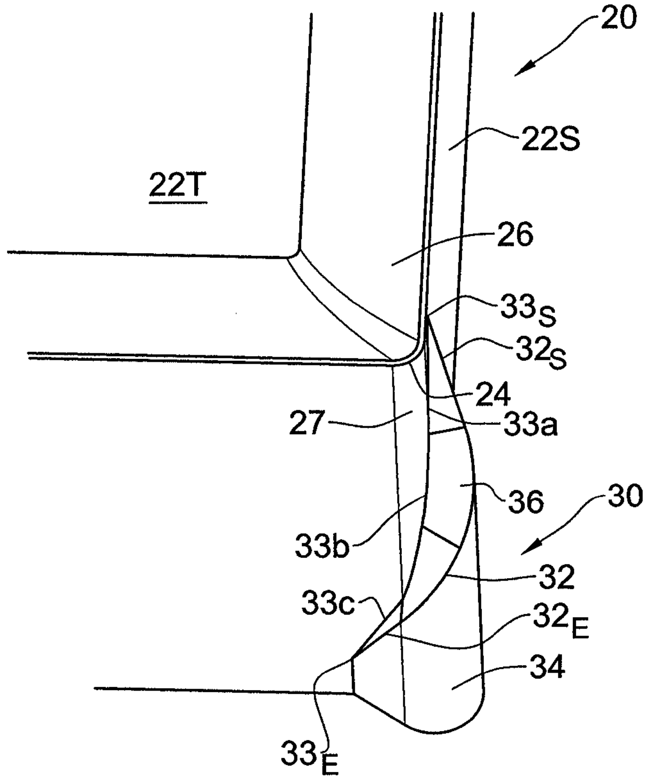


Fig. 13E

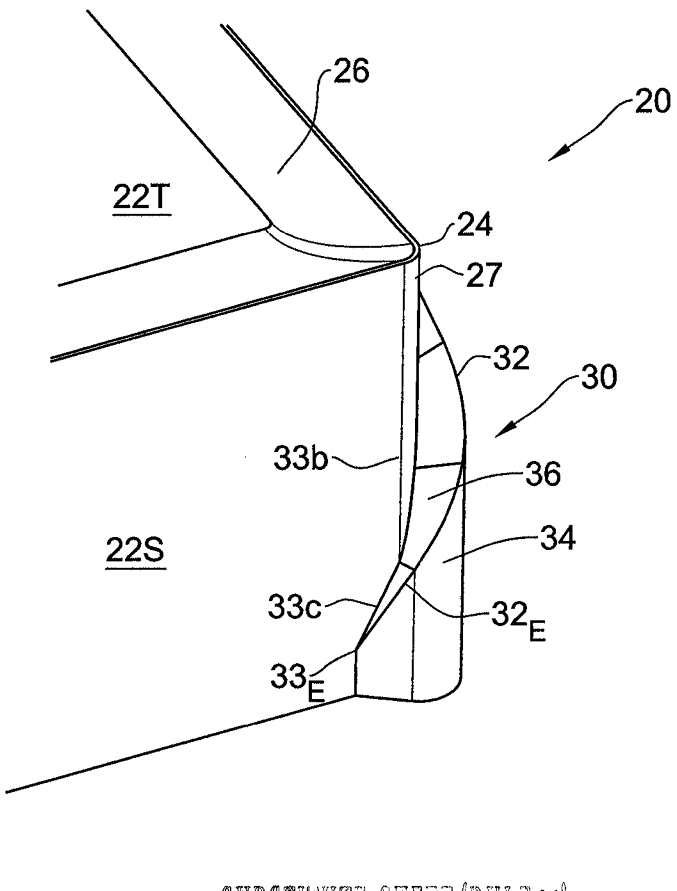


Fig. 13F

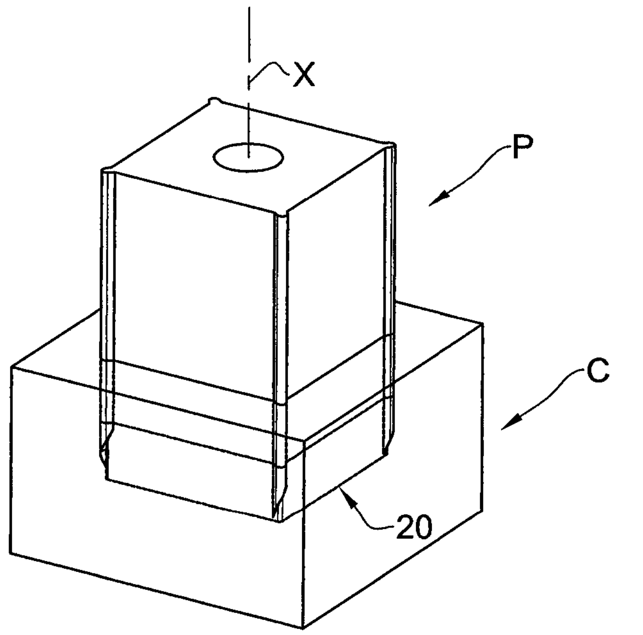


Fig. 13G

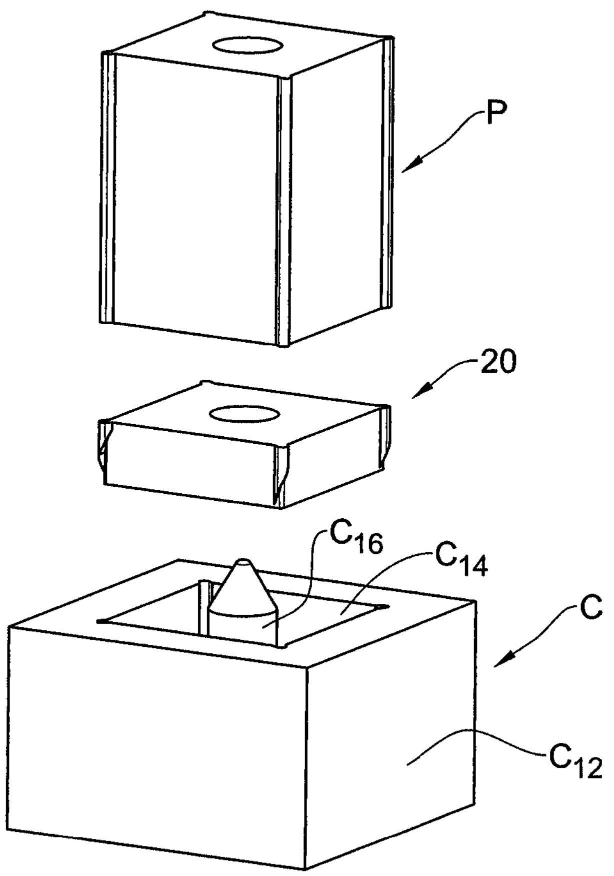


Fig. 13H

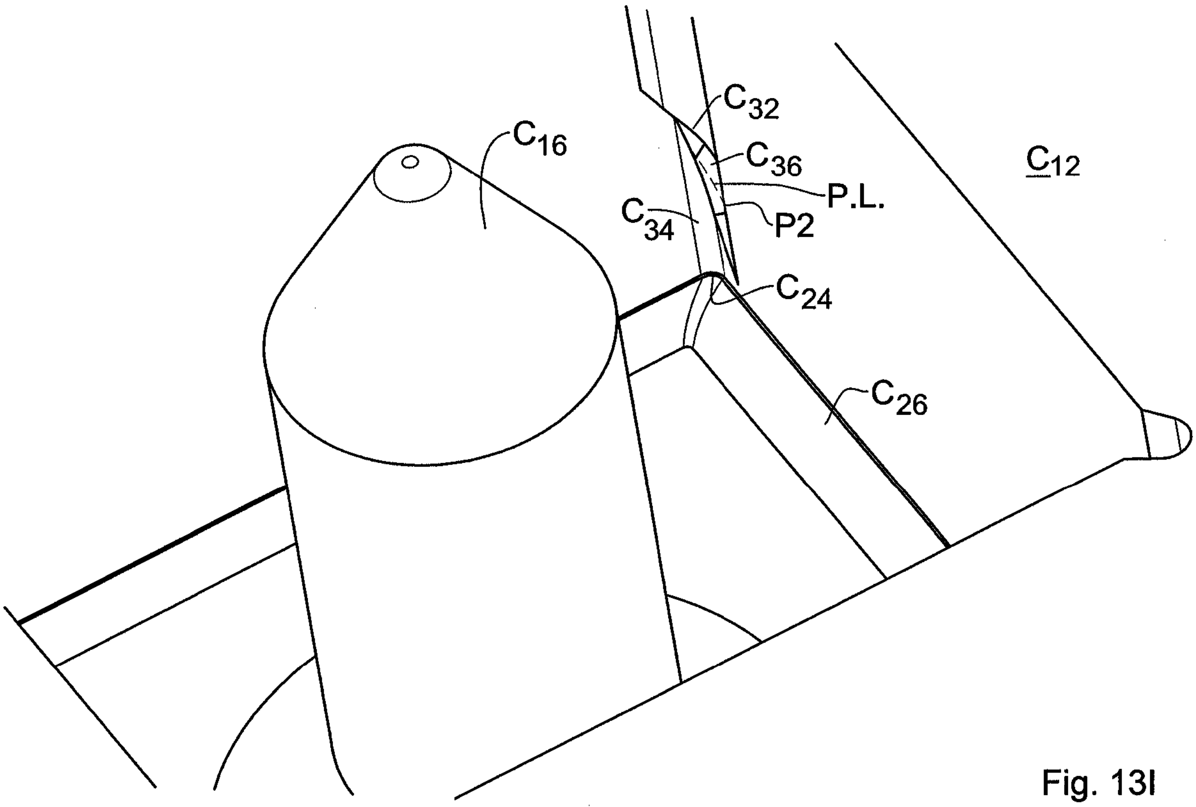


Fig. 13I

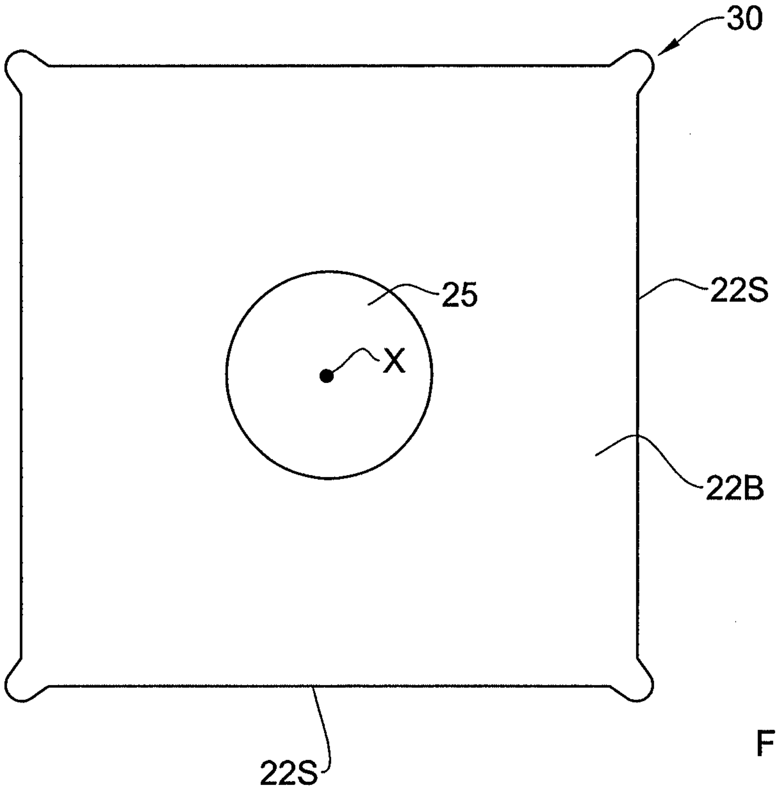


Fig. 13J

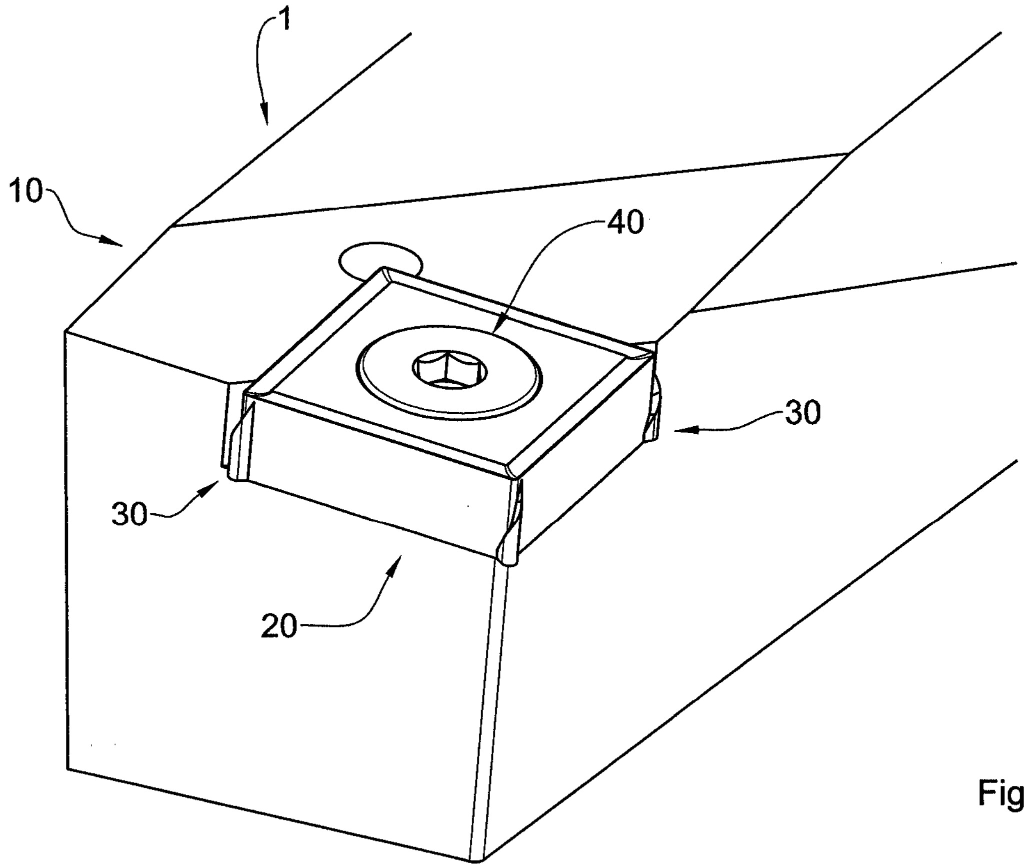


Fig. 13K

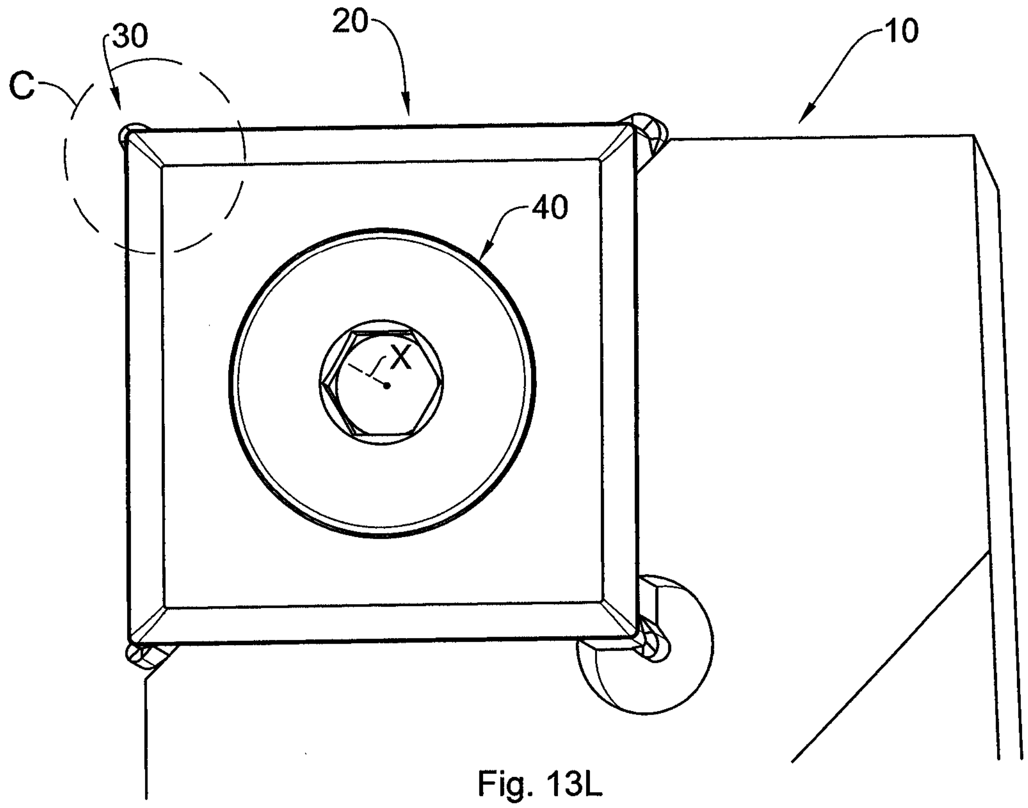


Fig. 13L

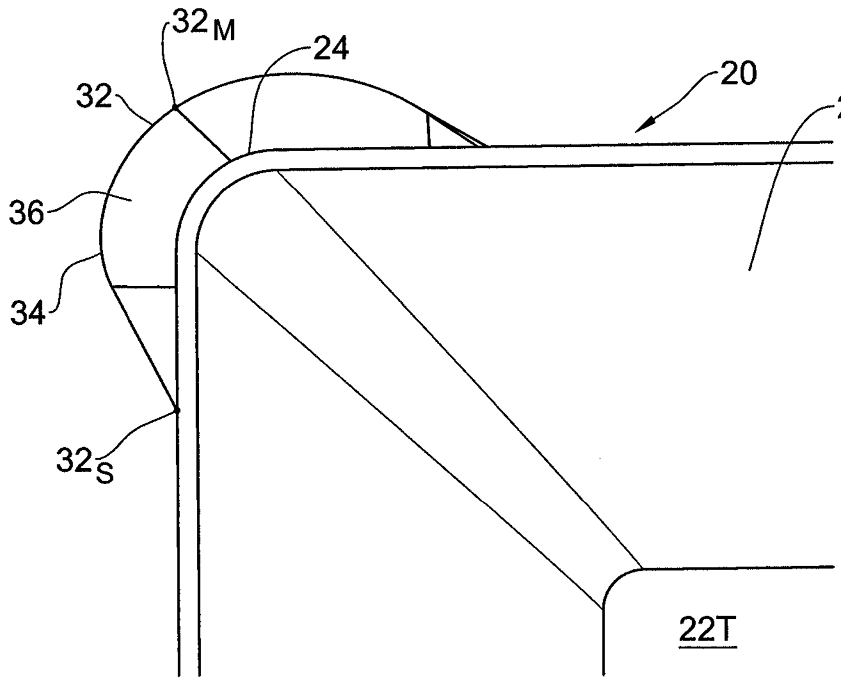


Fig. 13M

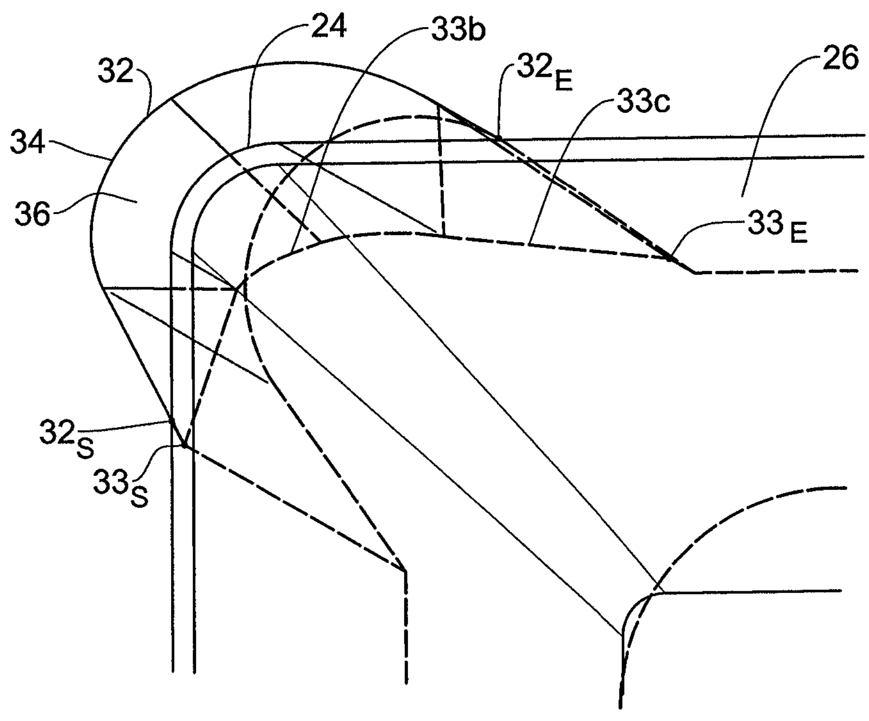


Fig. 13N

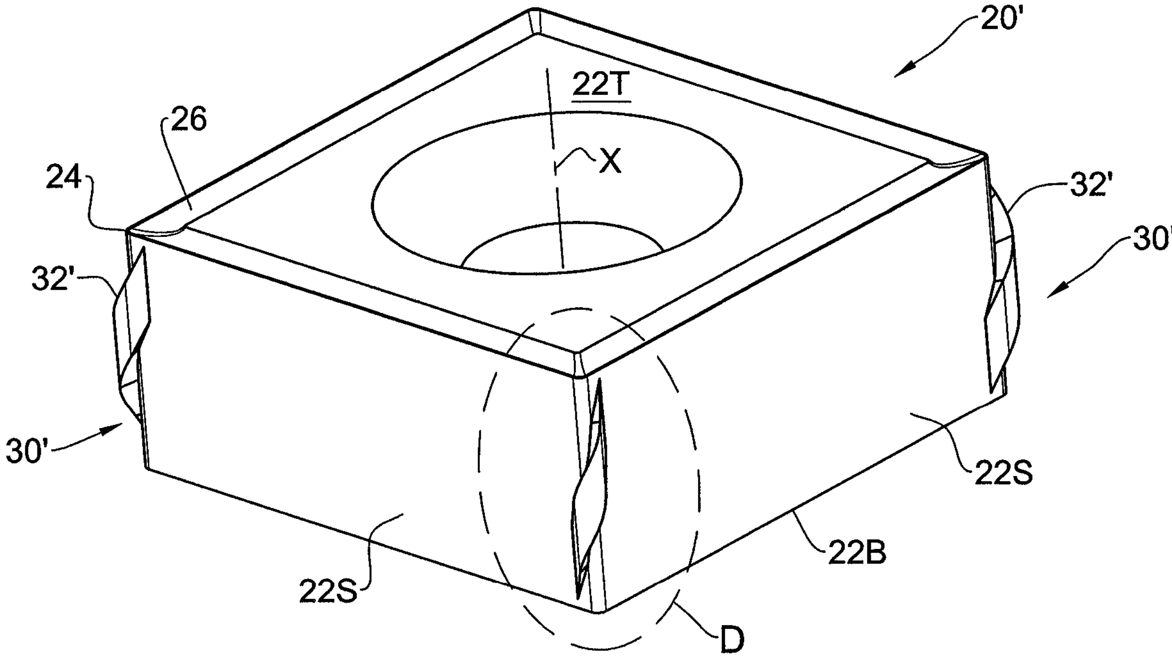


Fig. 14A

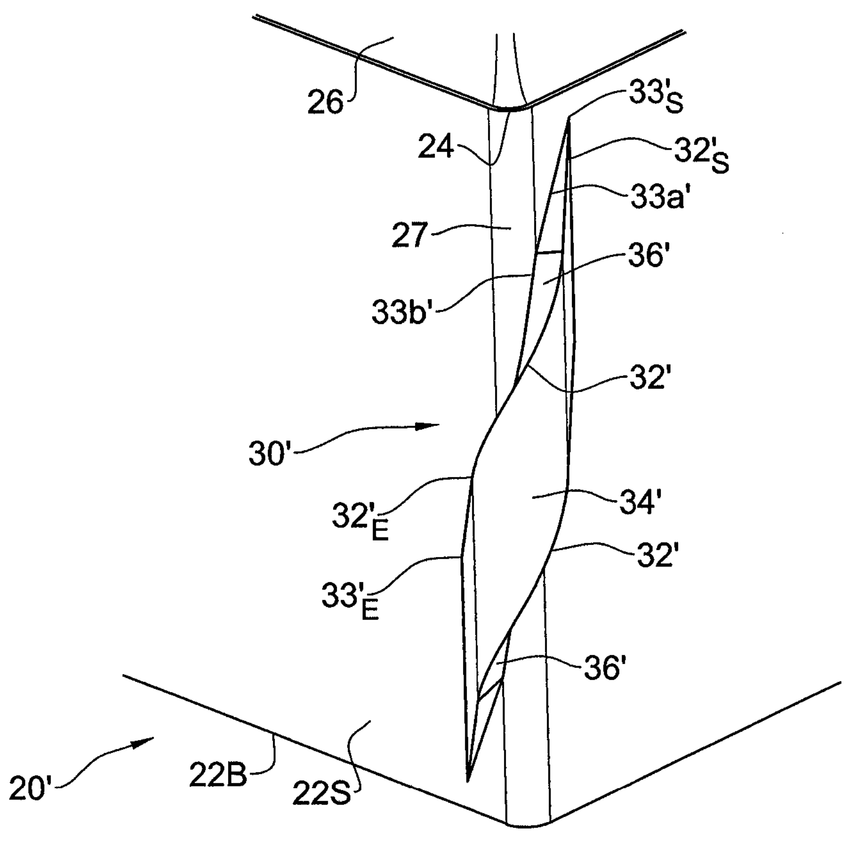


Fig. 14B

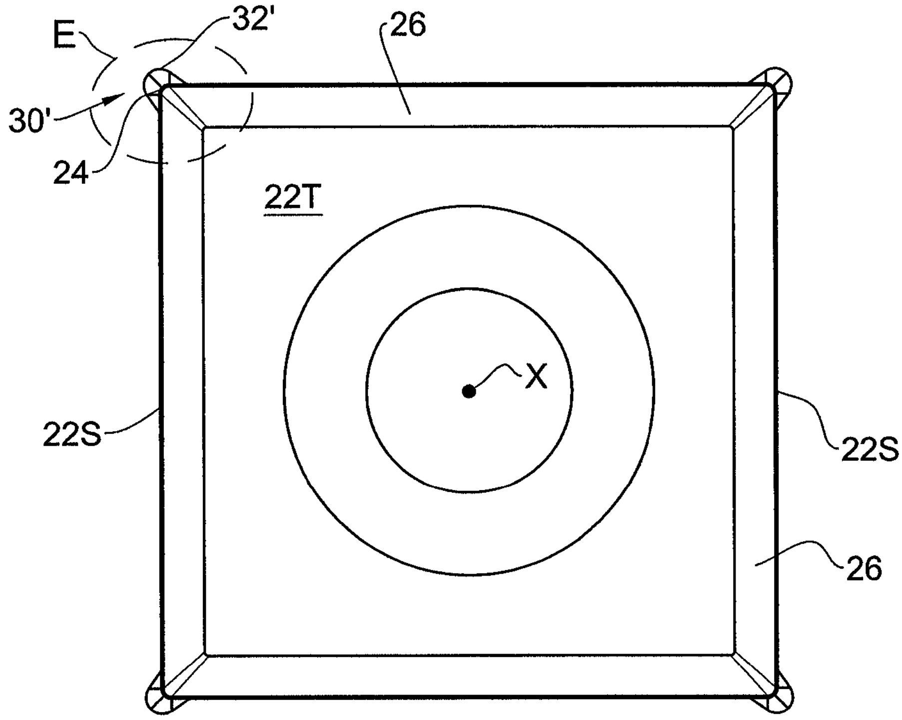


Fig. 14C

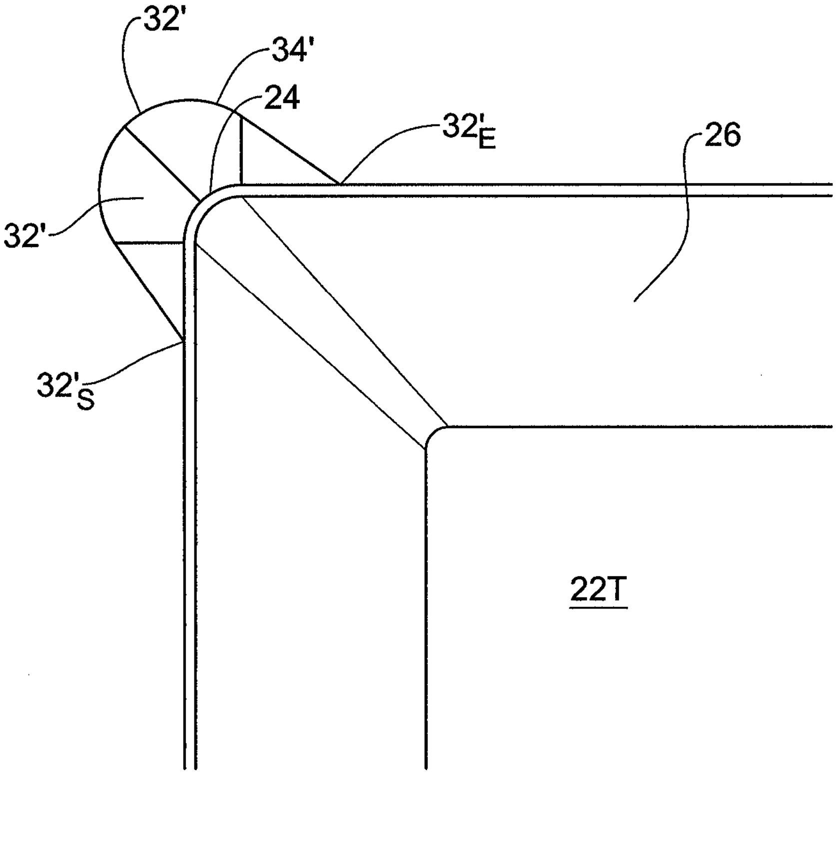


Fig. 14D

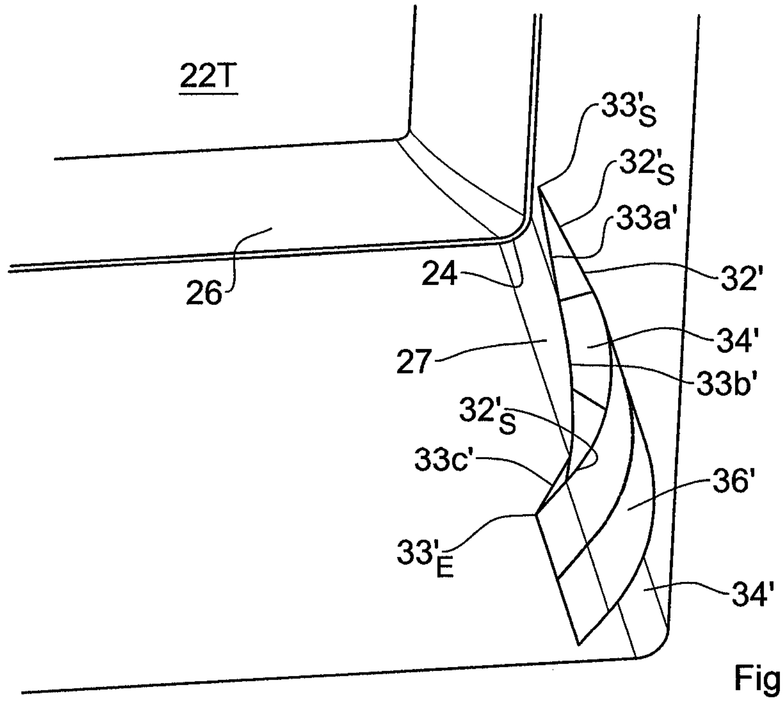


Fig. 14E

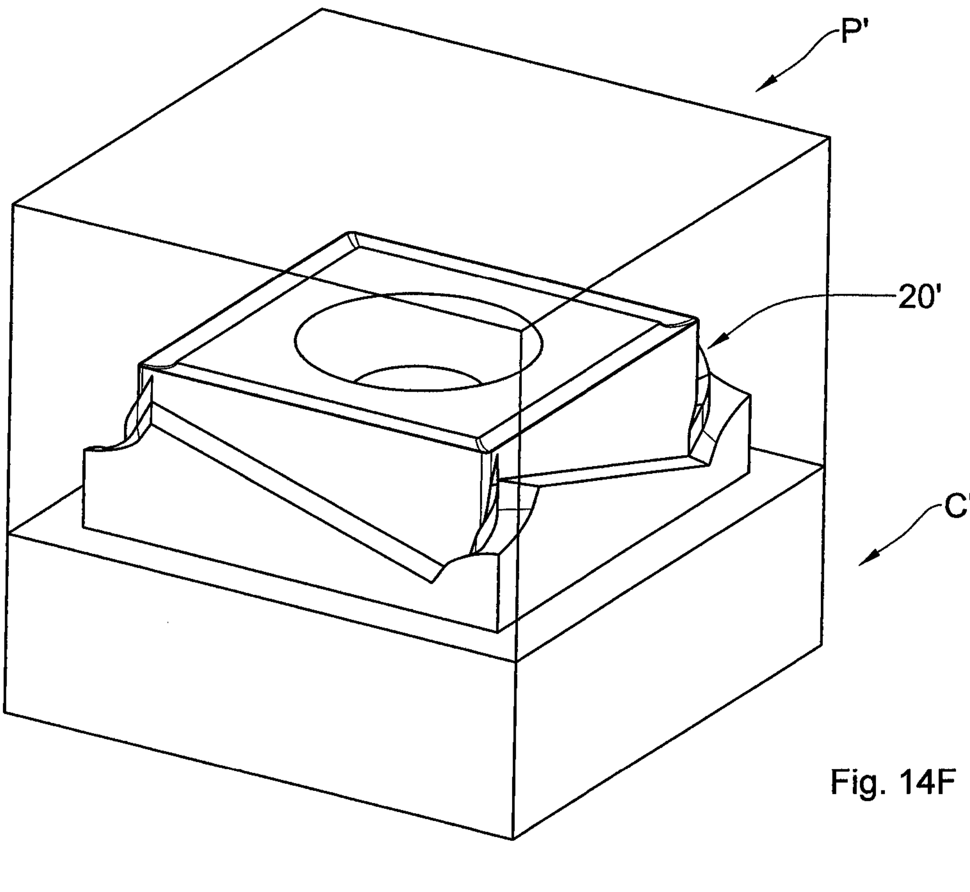


Fig. 14F

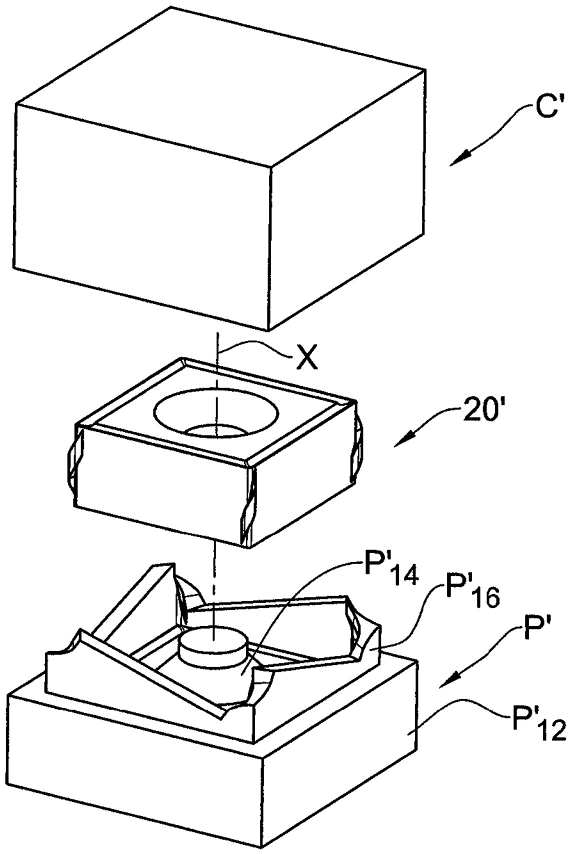


Fig. 14G

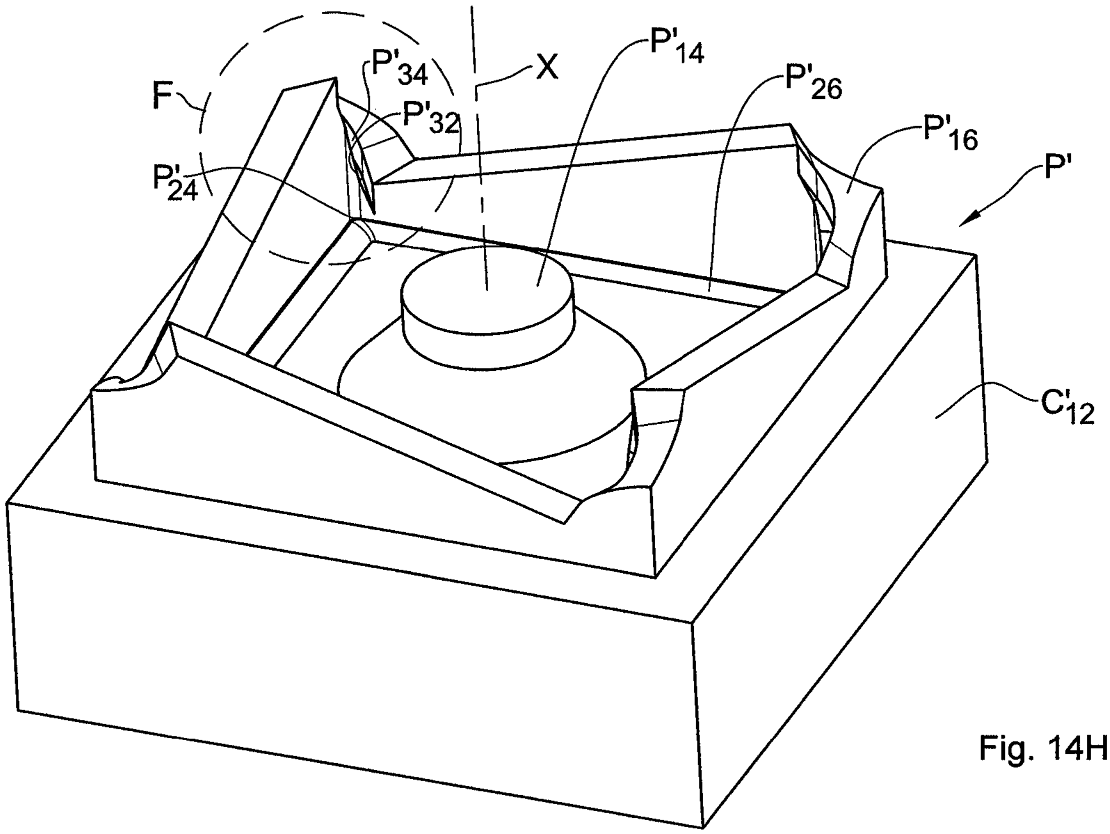


Fig. 14H

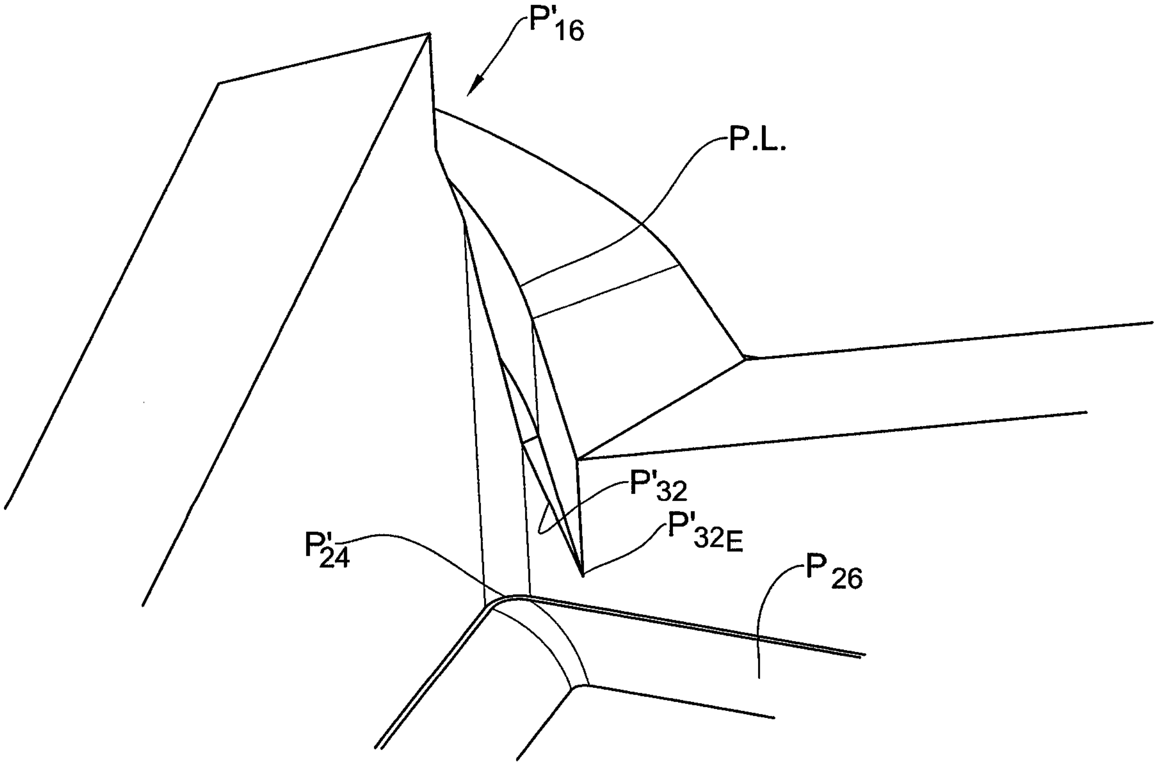


Fig. 14I

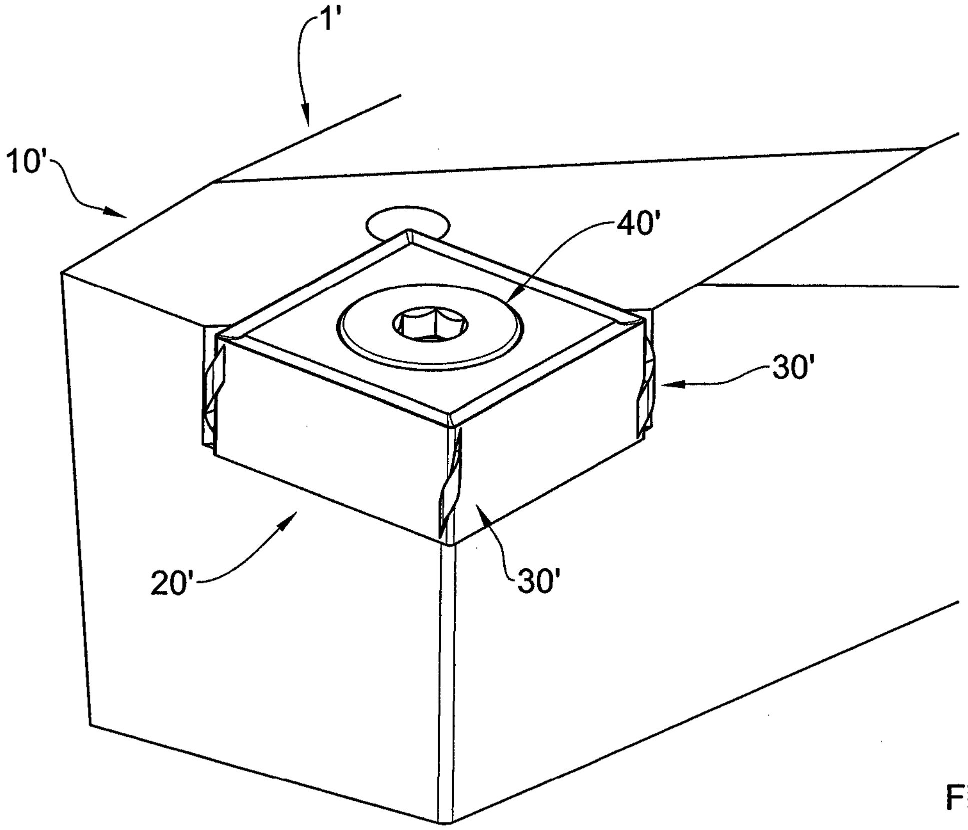


Fig. 14J

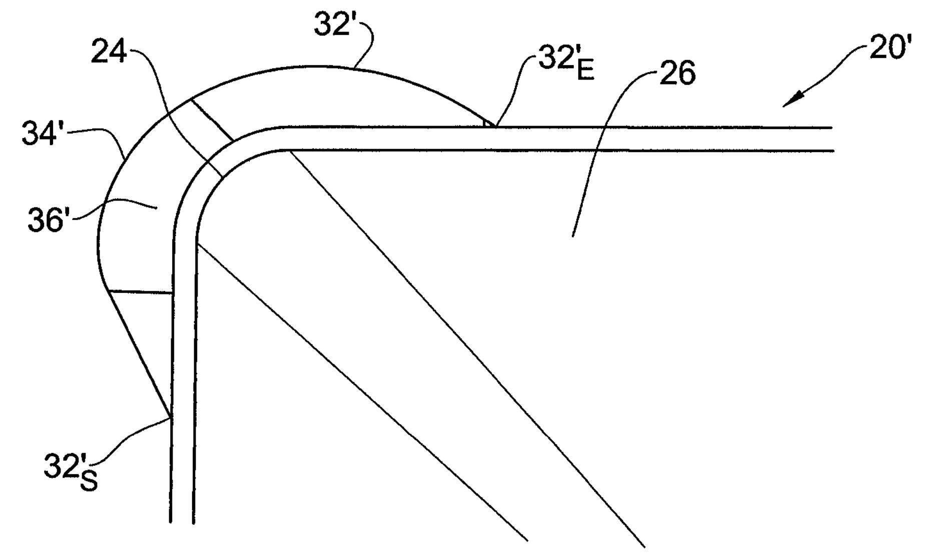


Fig. 14K

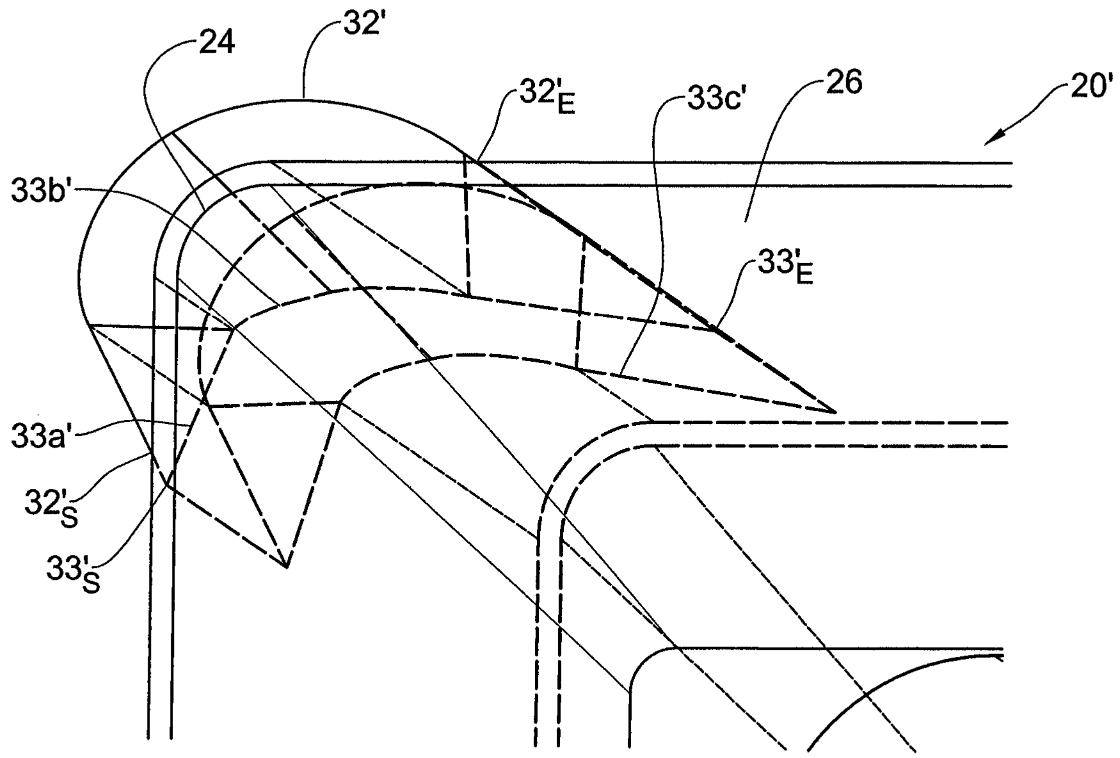


Fig. 14L

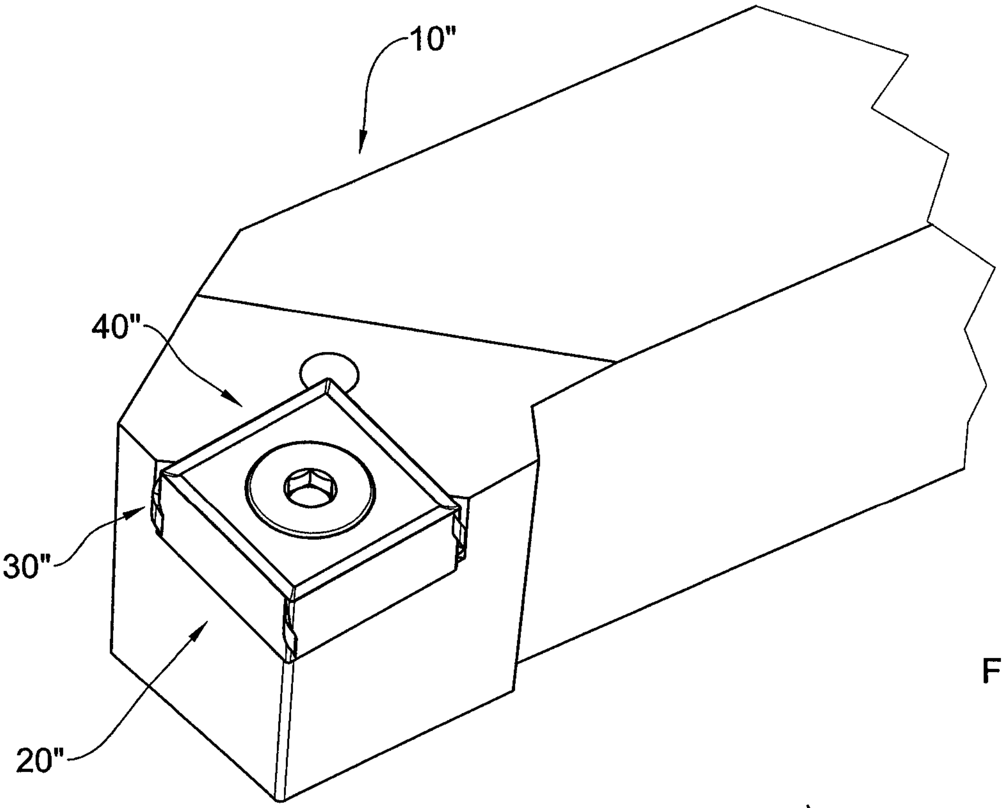


Fig. 15A

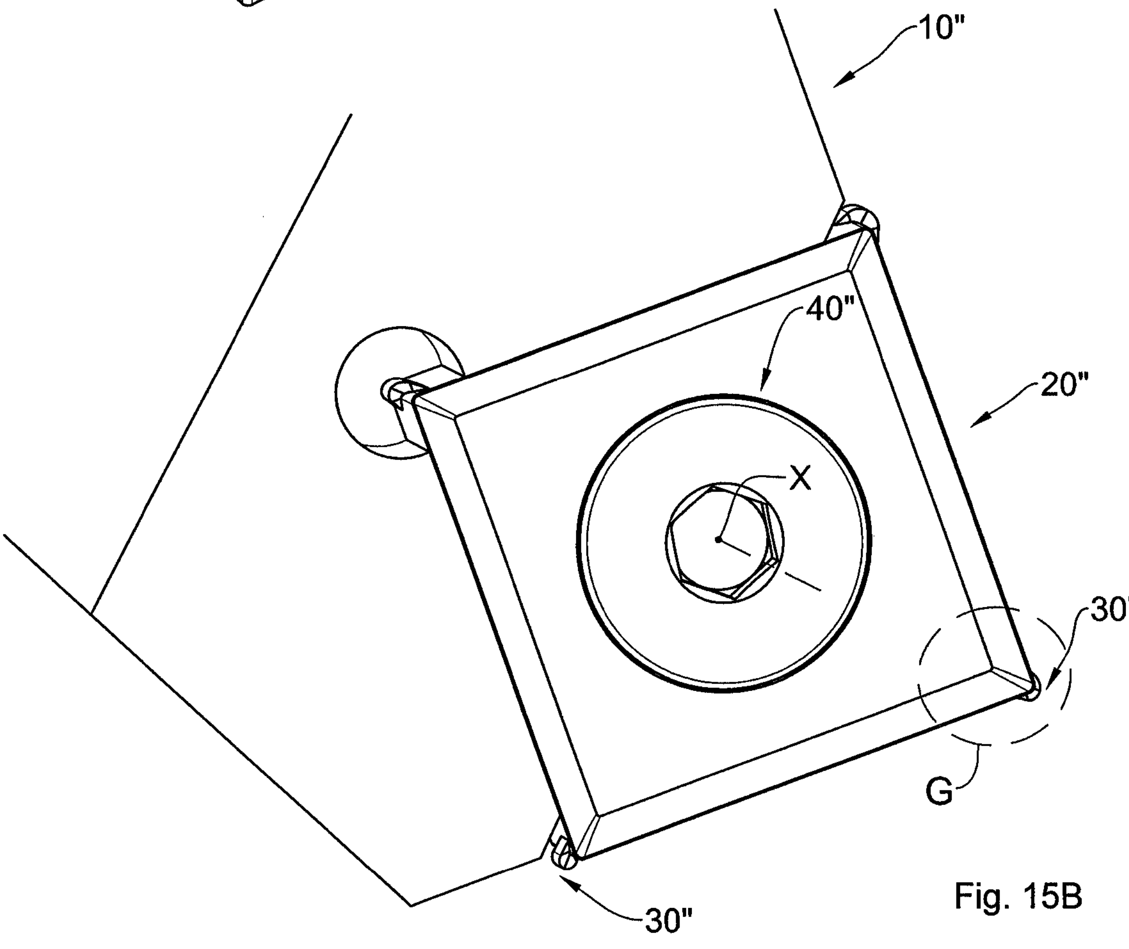


Fig. 15B

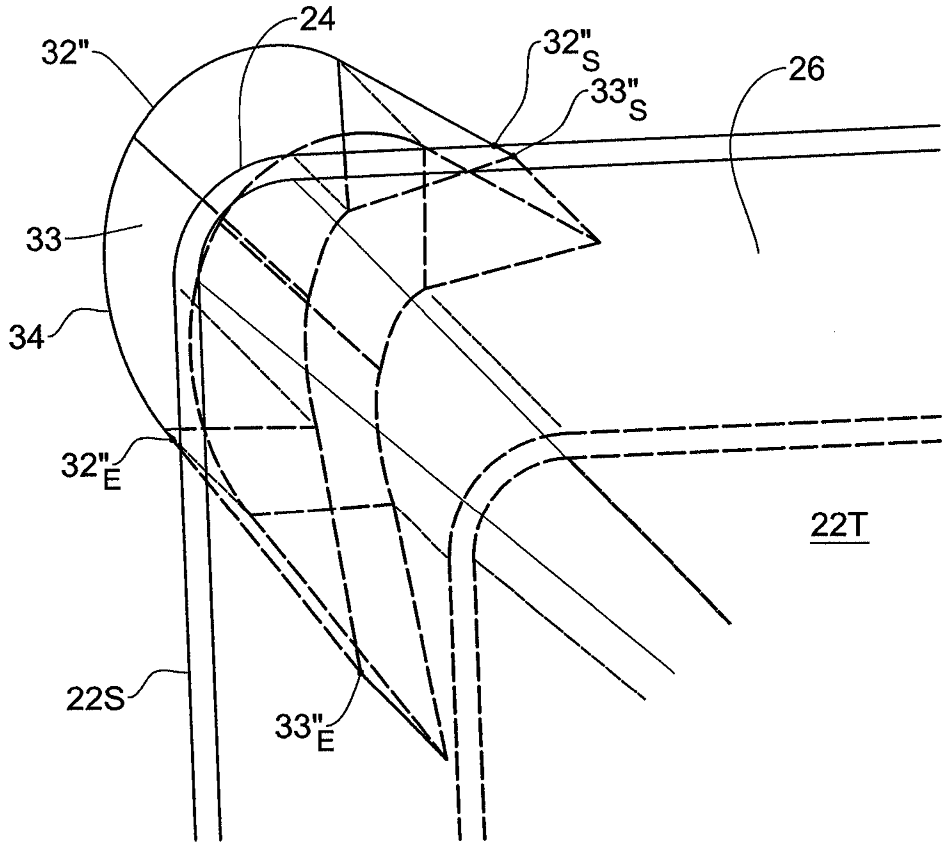


Fig. 15C

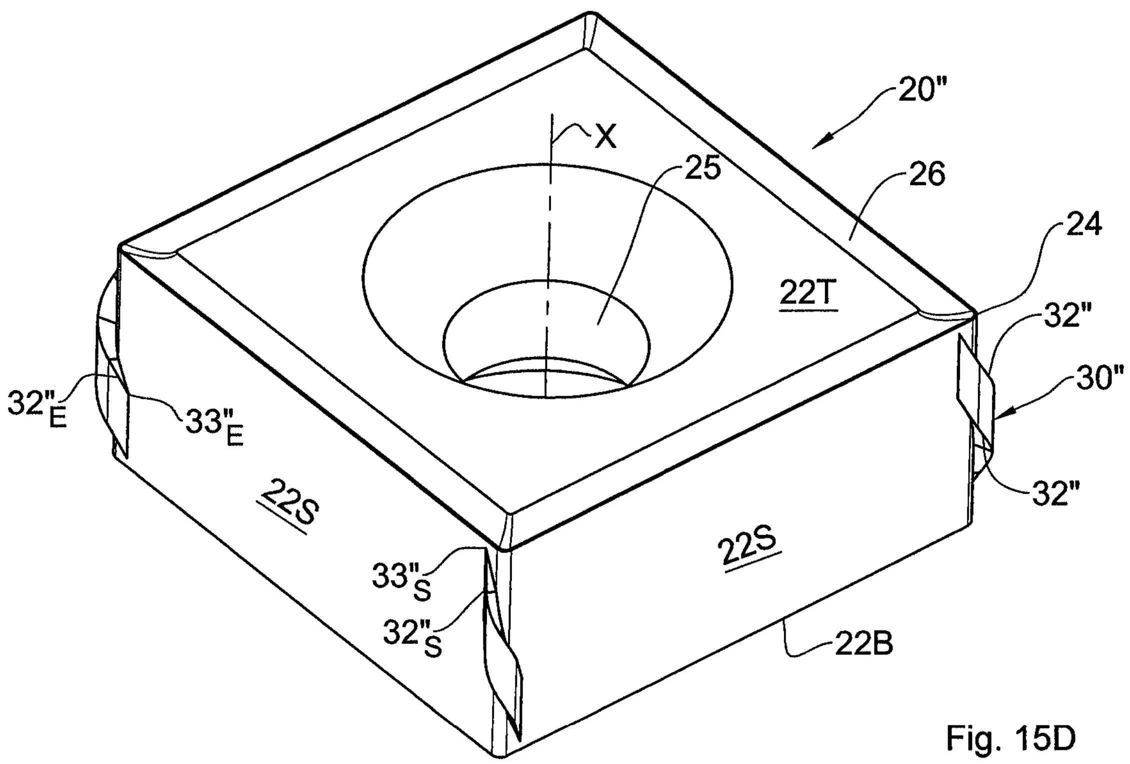


Fig. 15D

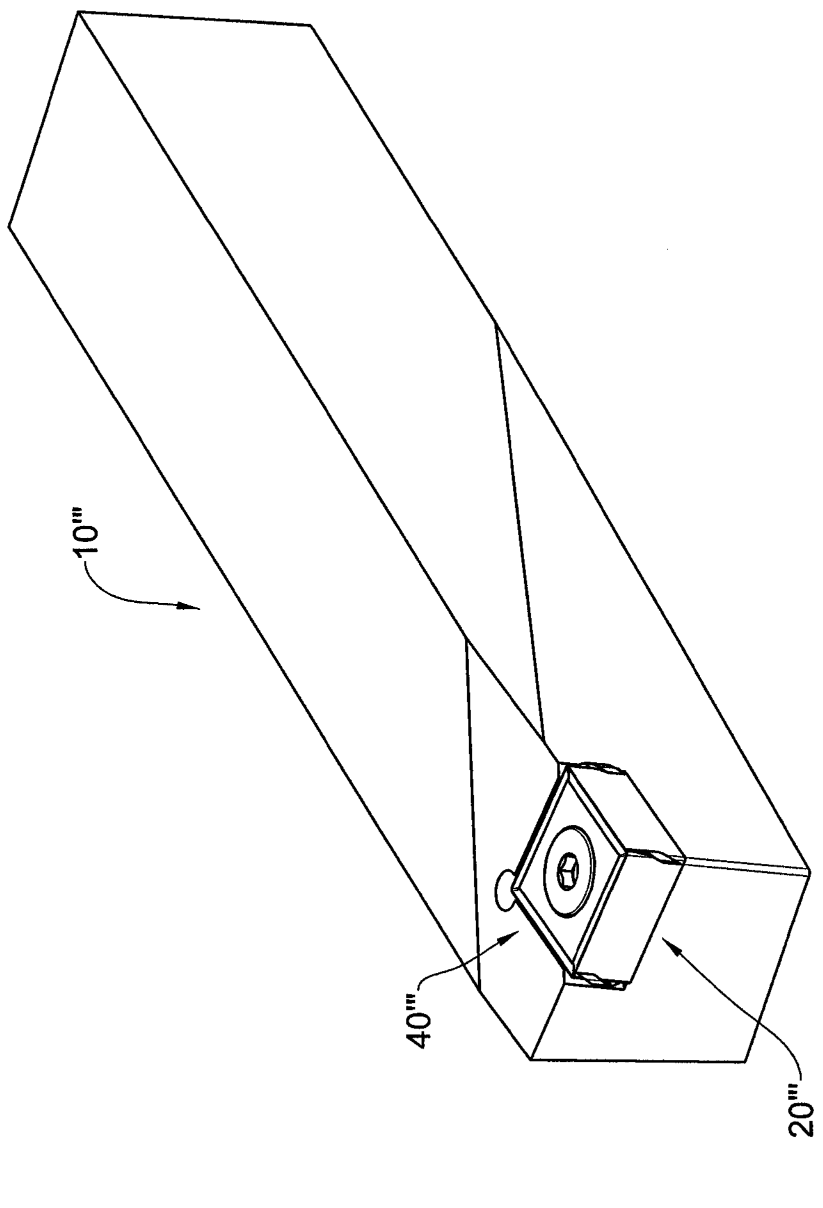


Fig. 16A

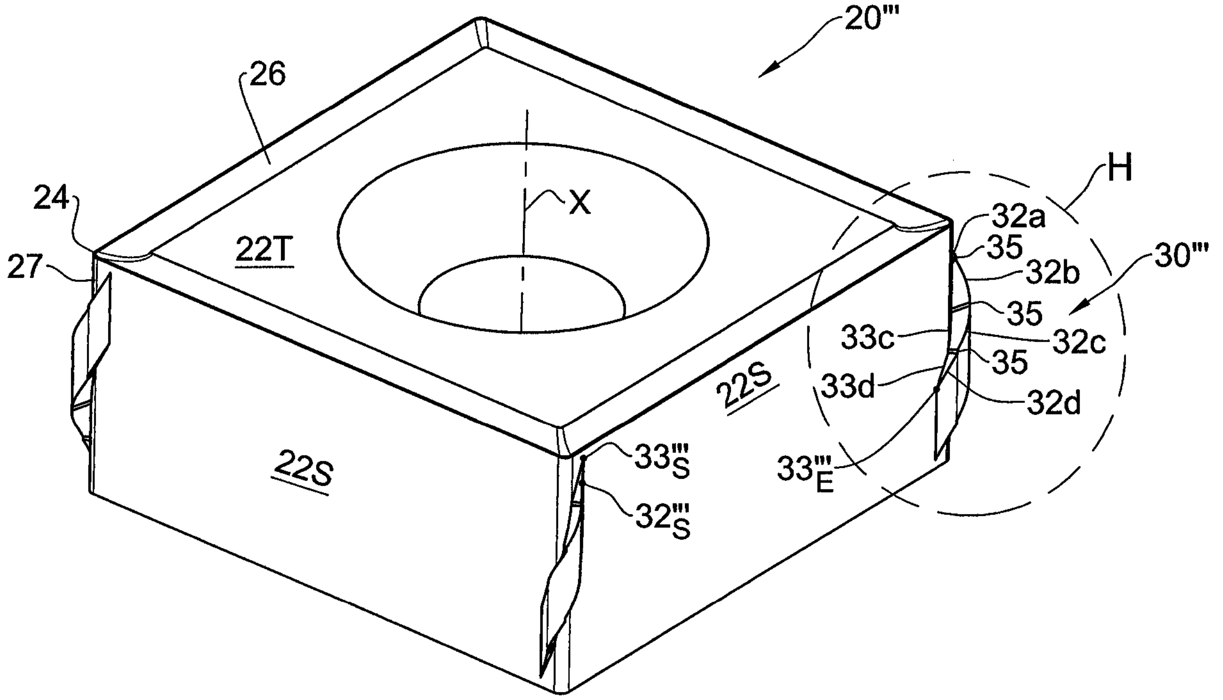


Fig. 16B

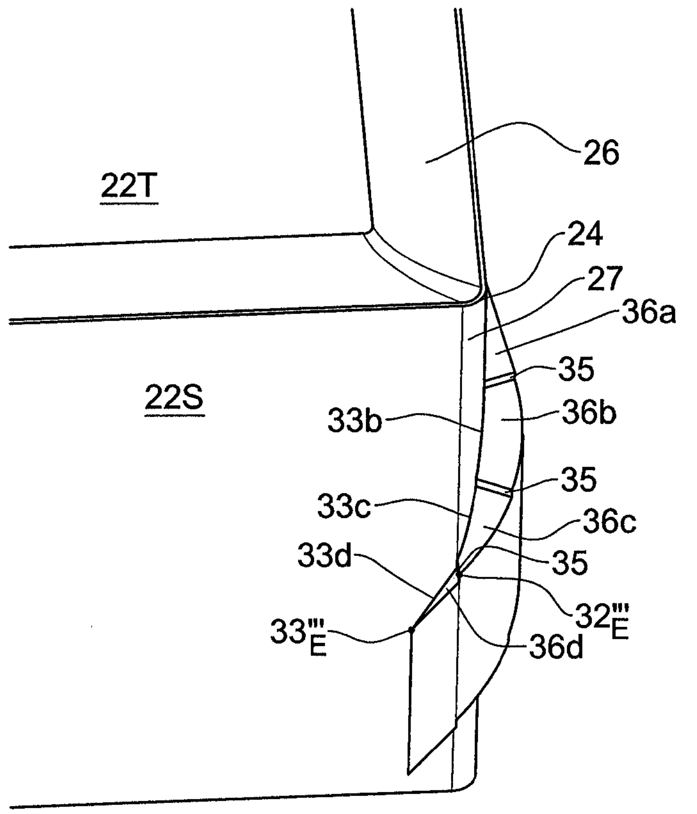


Fig. 16C

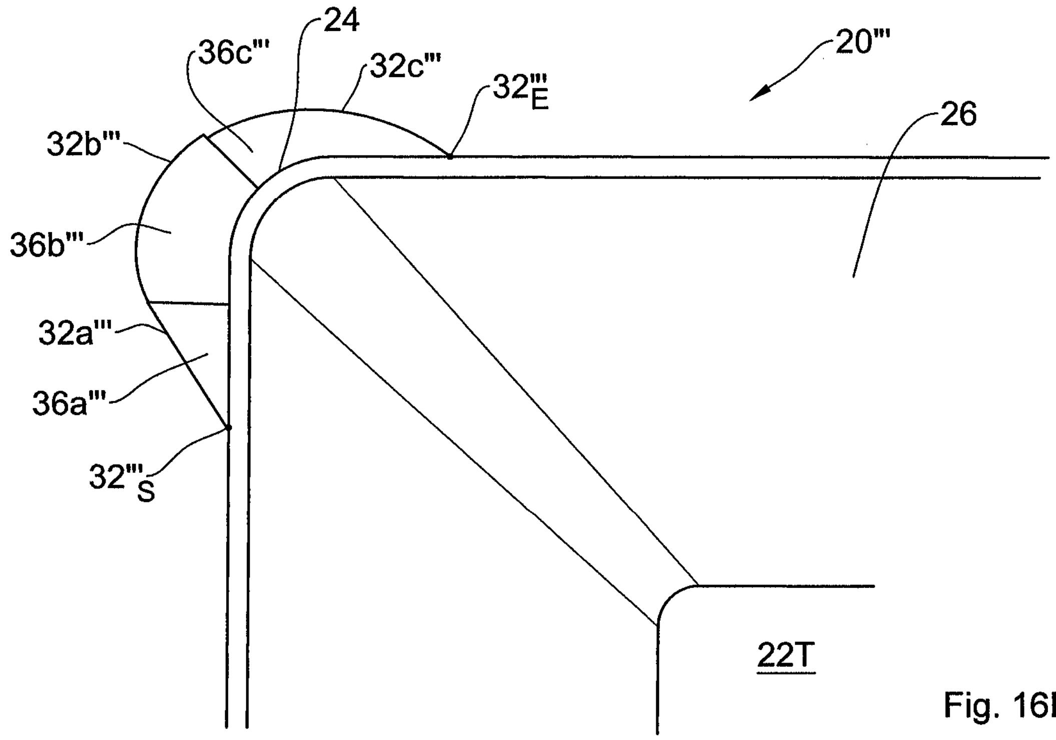


Fig. 16D

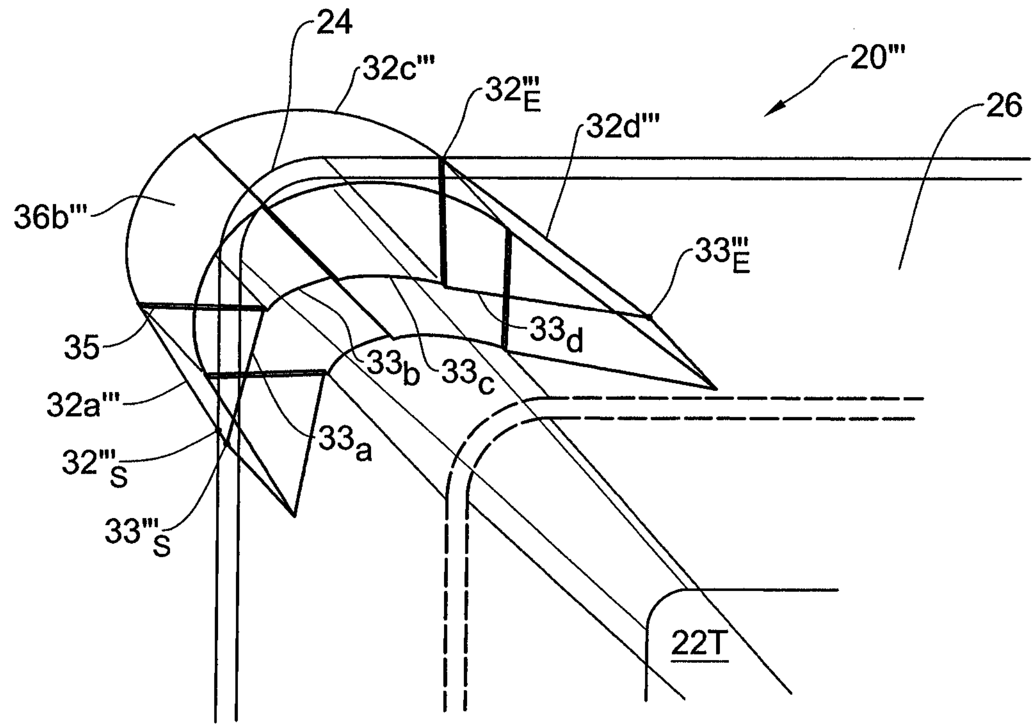


Fig. 16E

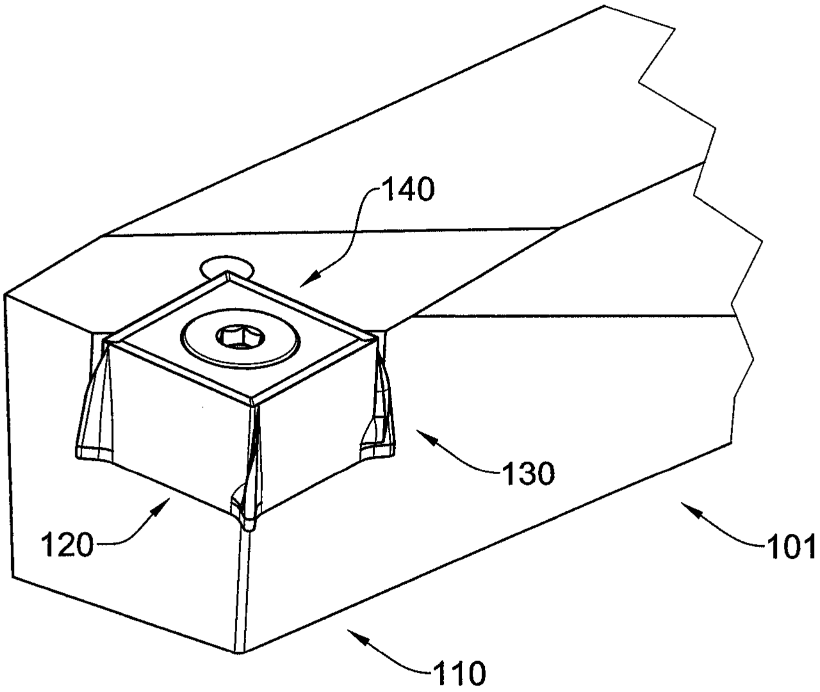


Fig. 17A

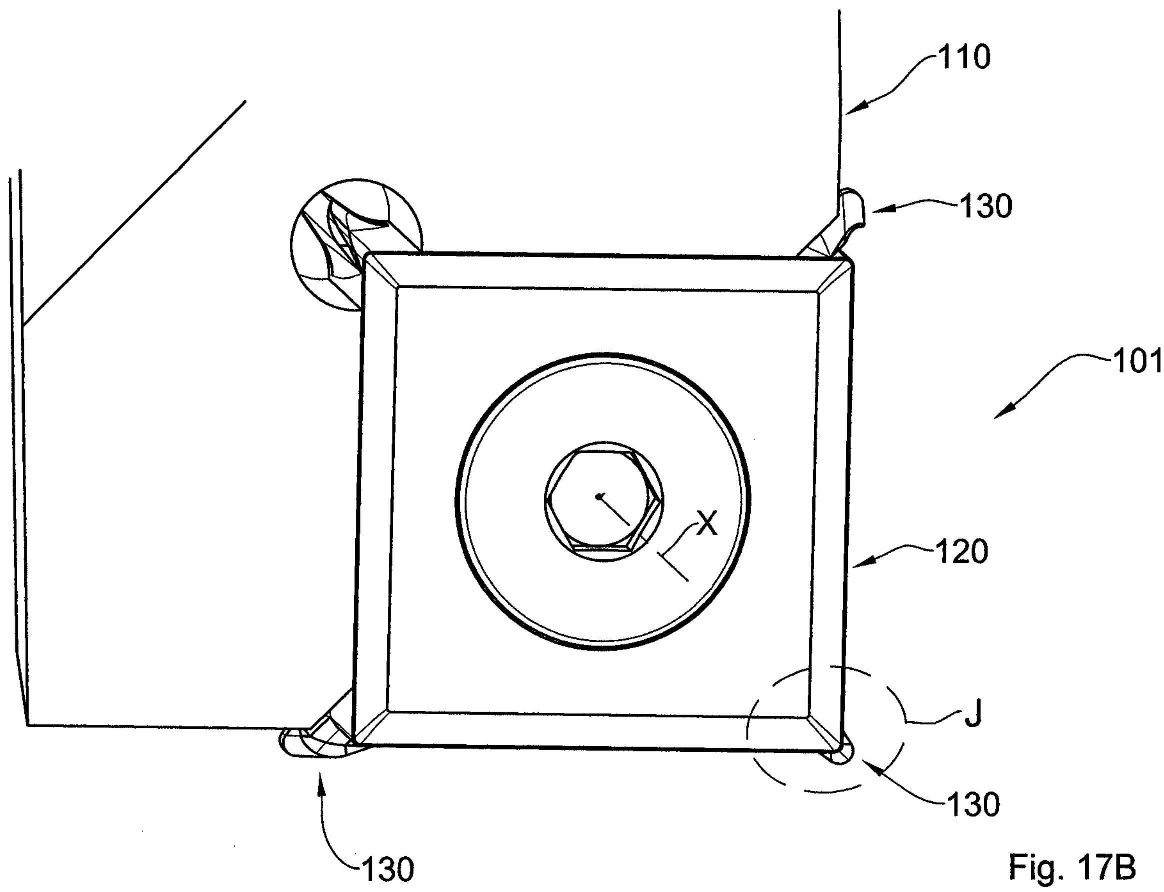


Fig. 17B

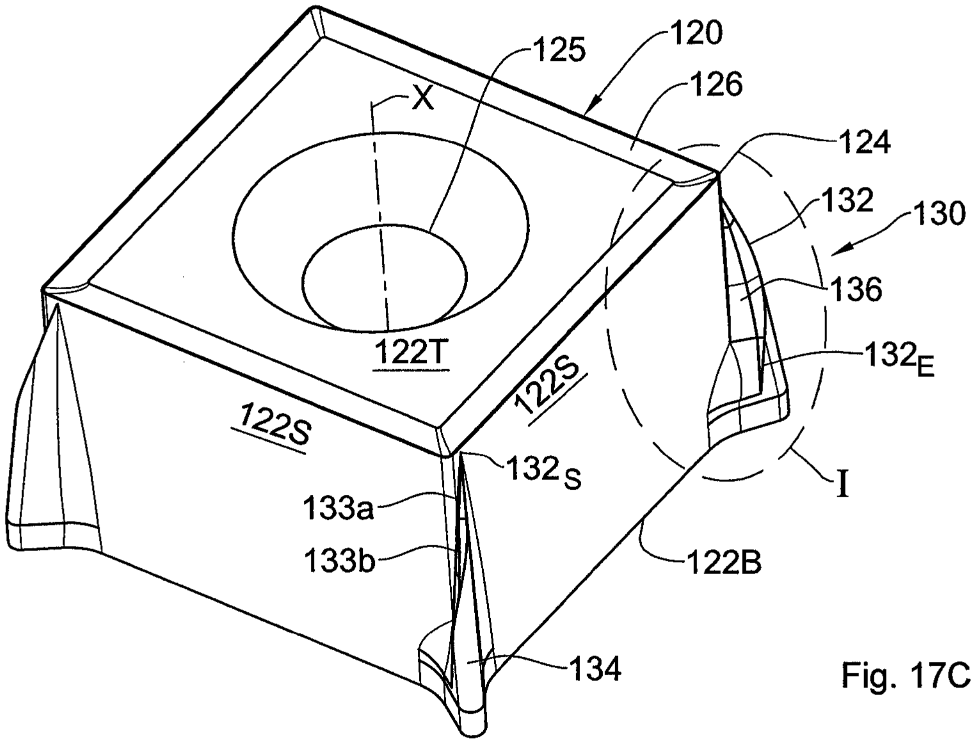


Fig. 17C

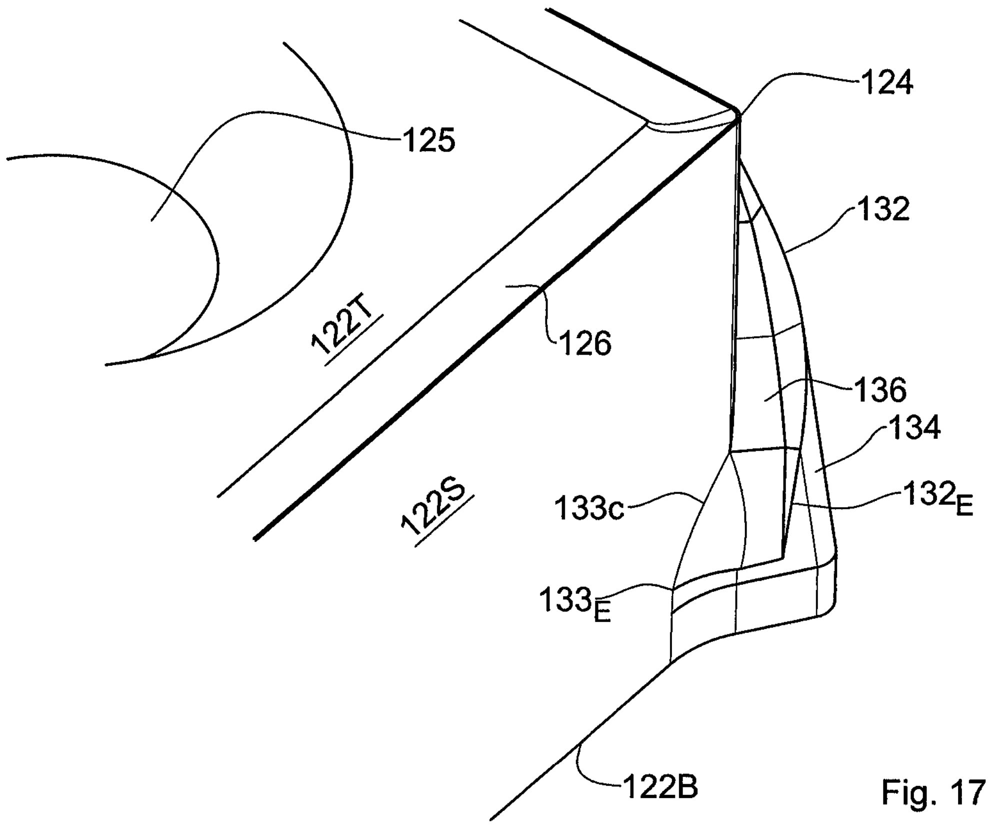


Fig. 17D

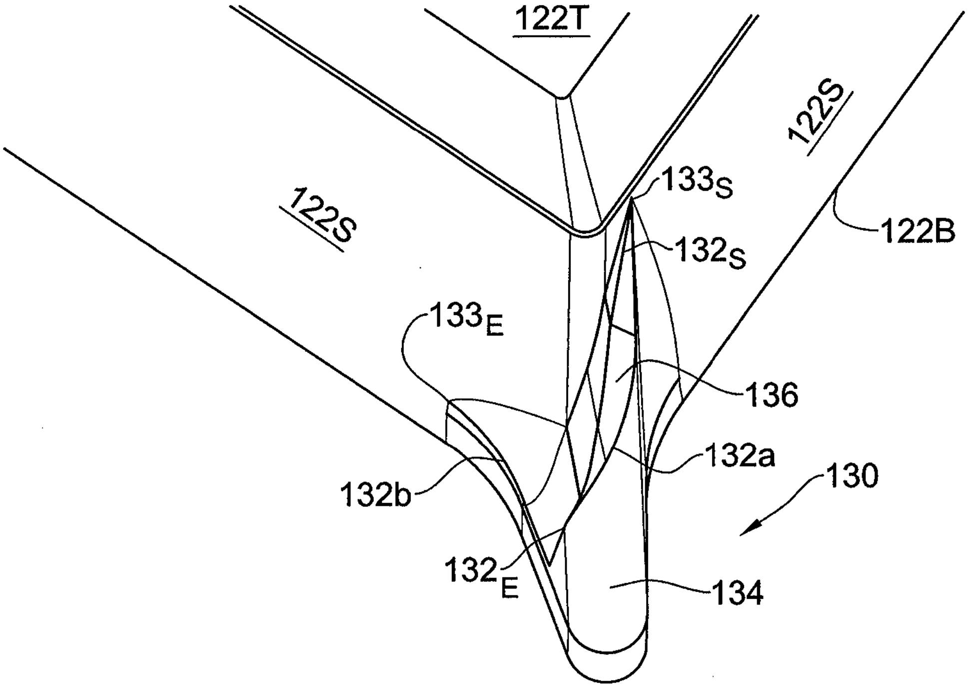


Fig. 17E

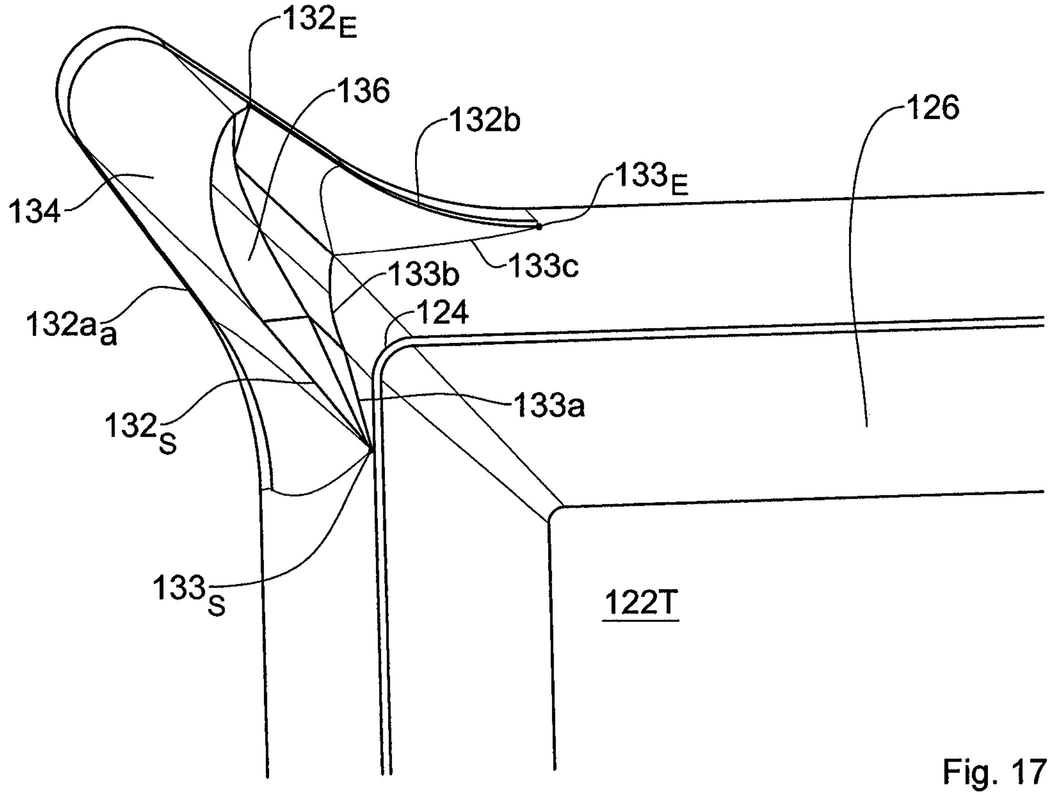


Fig. 17F

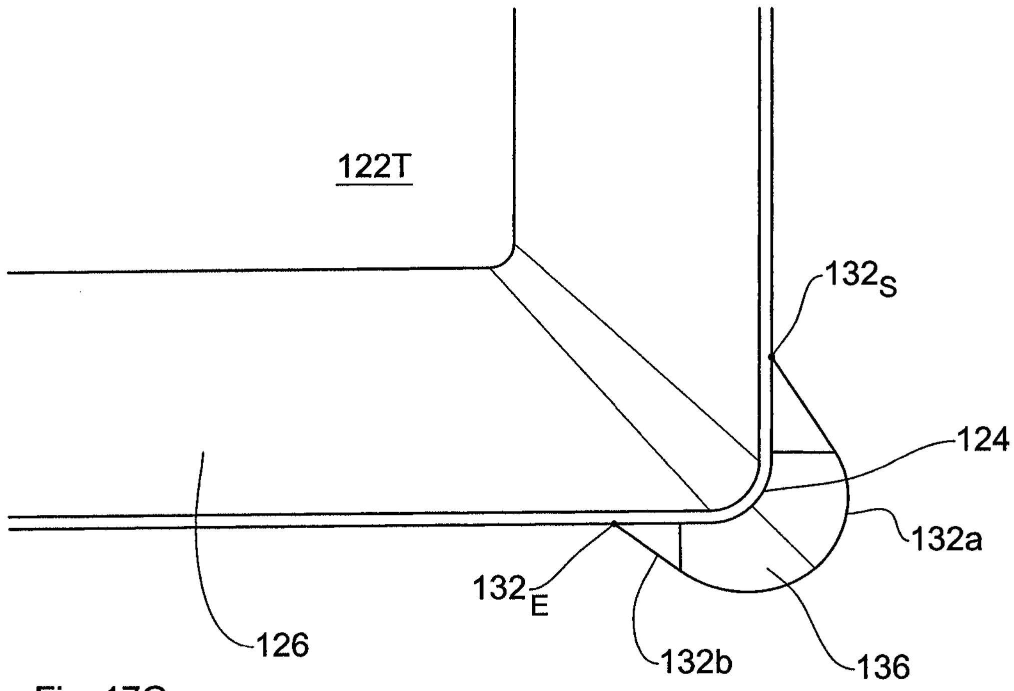


Fig. 17G

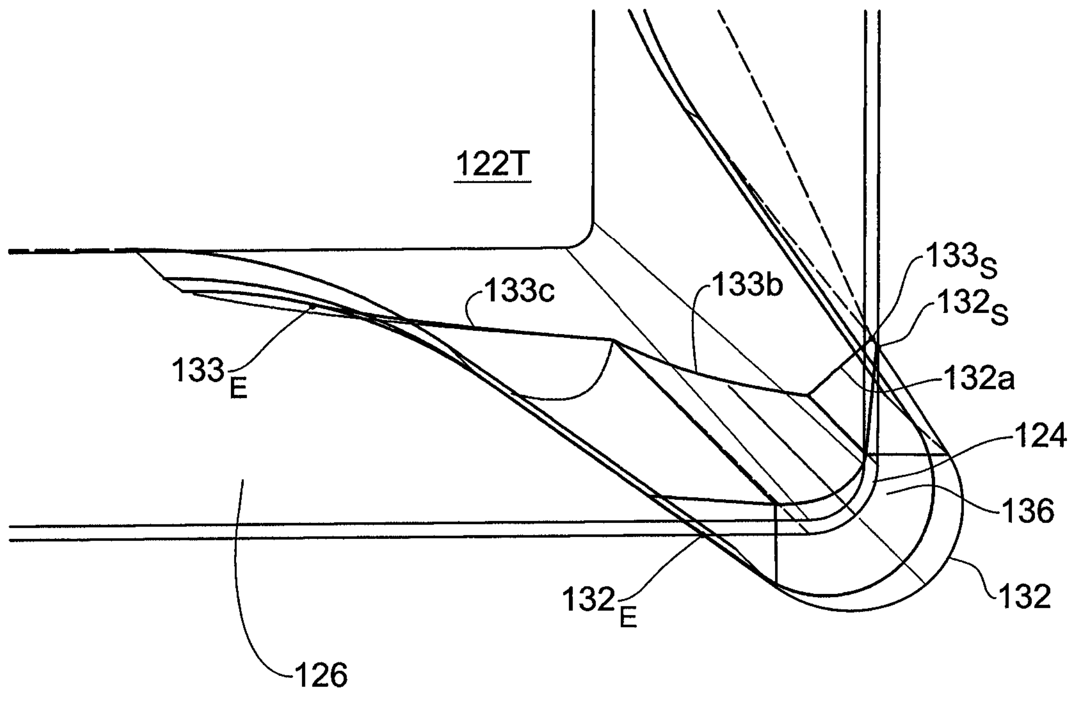
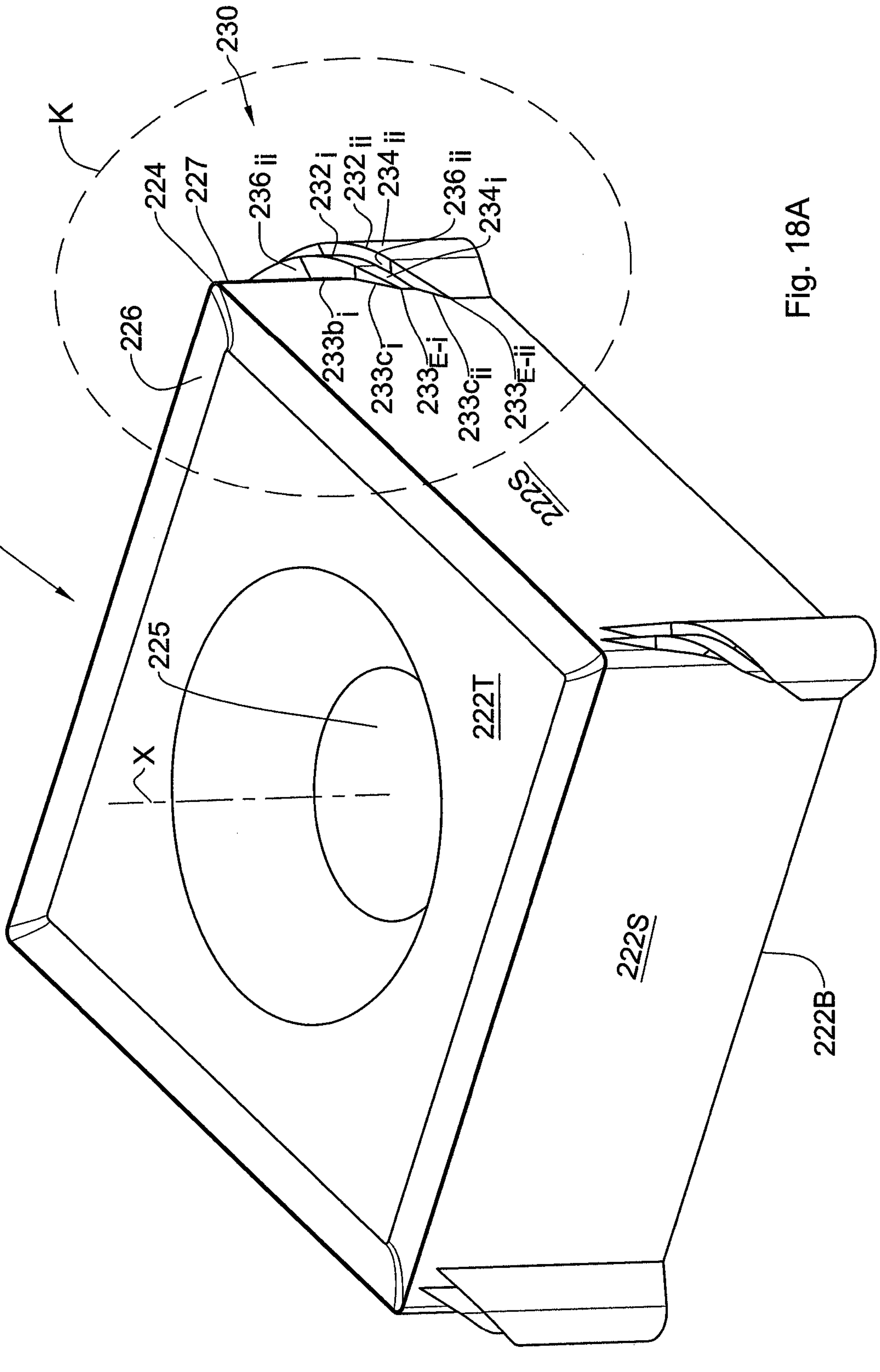


Fig. 17H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225
222T
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222S
222B

Fig. 18A

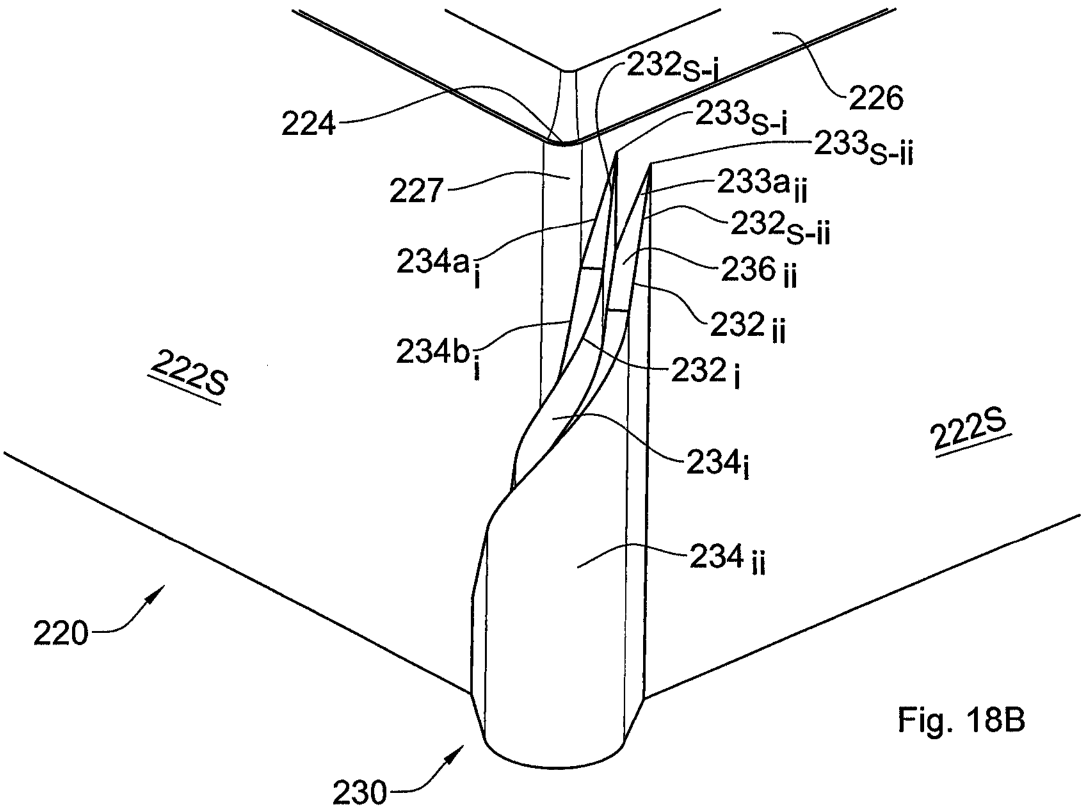


Fig. 18B

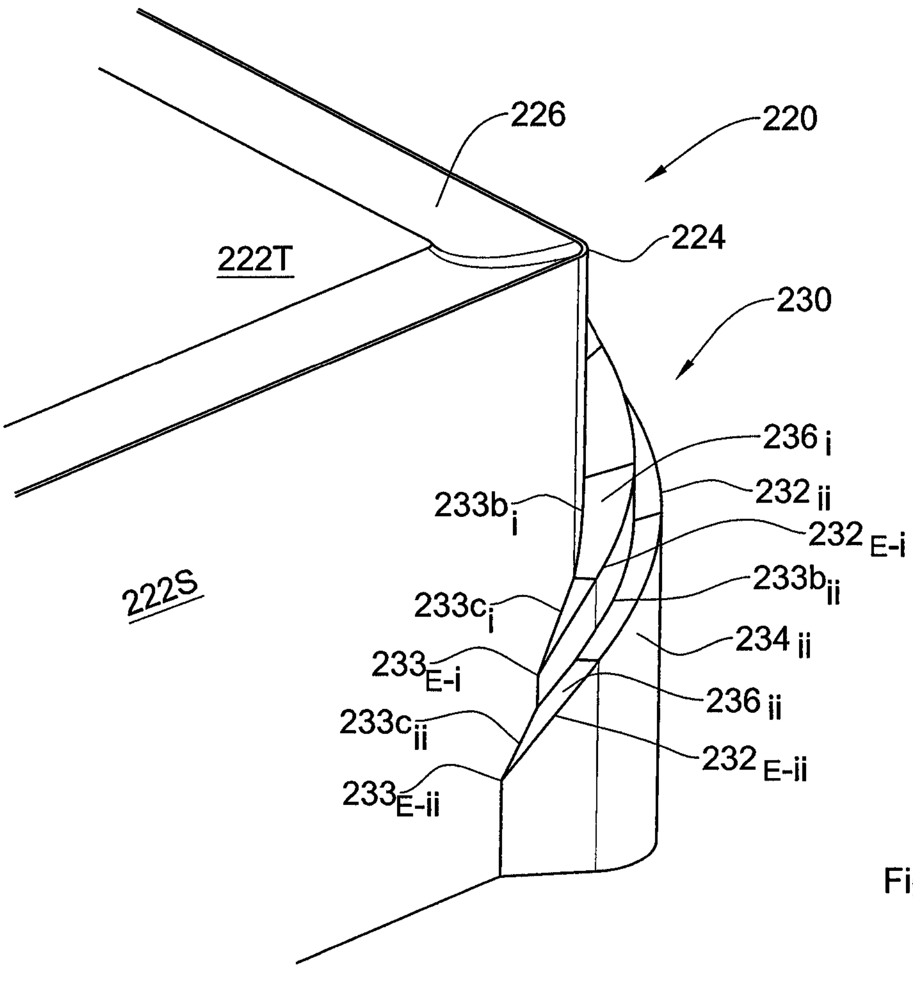


Fig. 18C

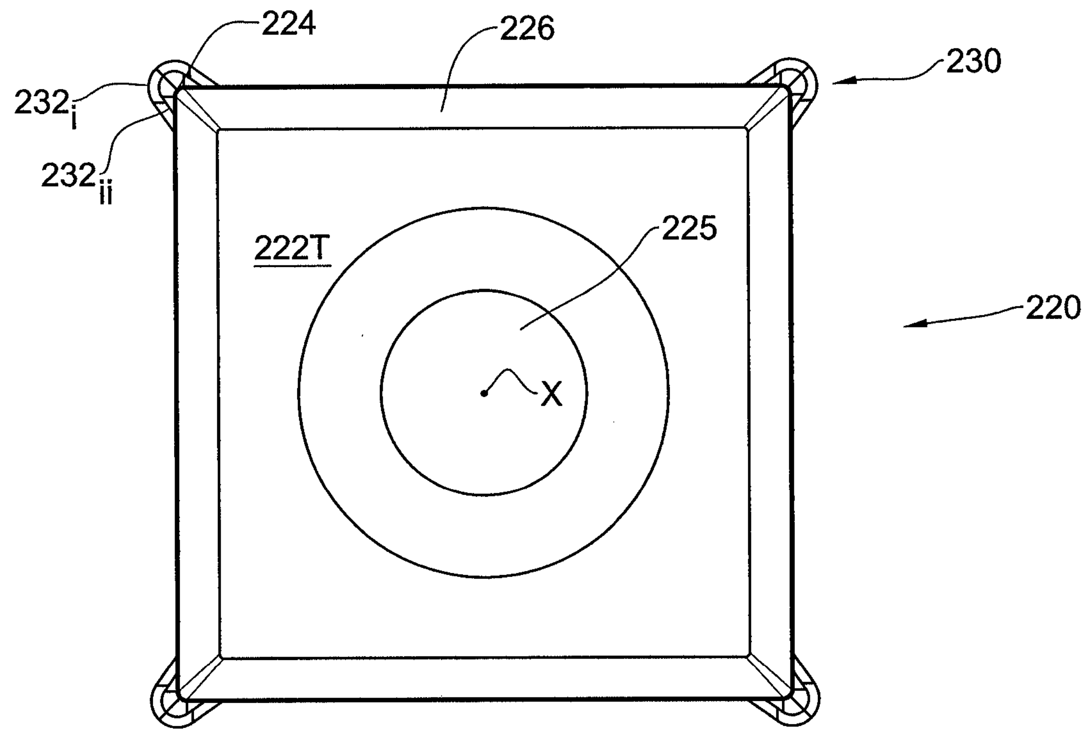


Fig. 18D

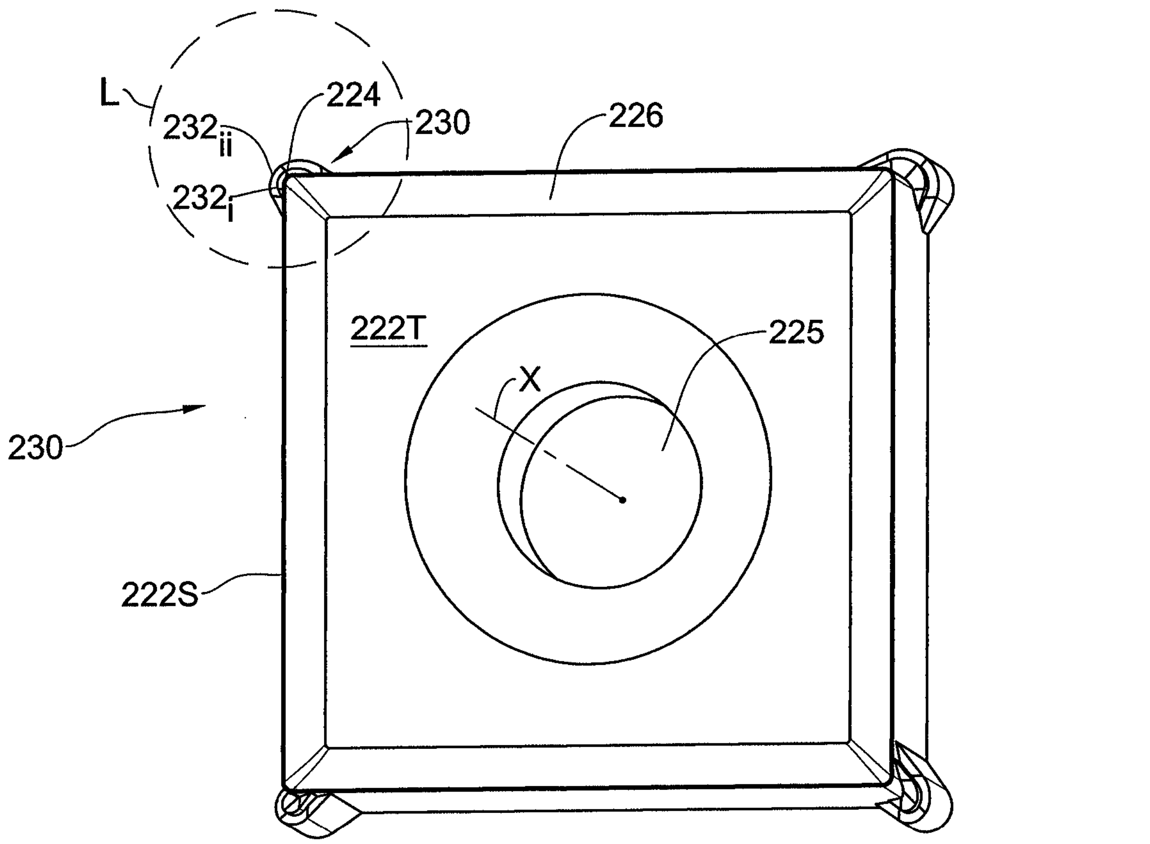


Fig. 18E

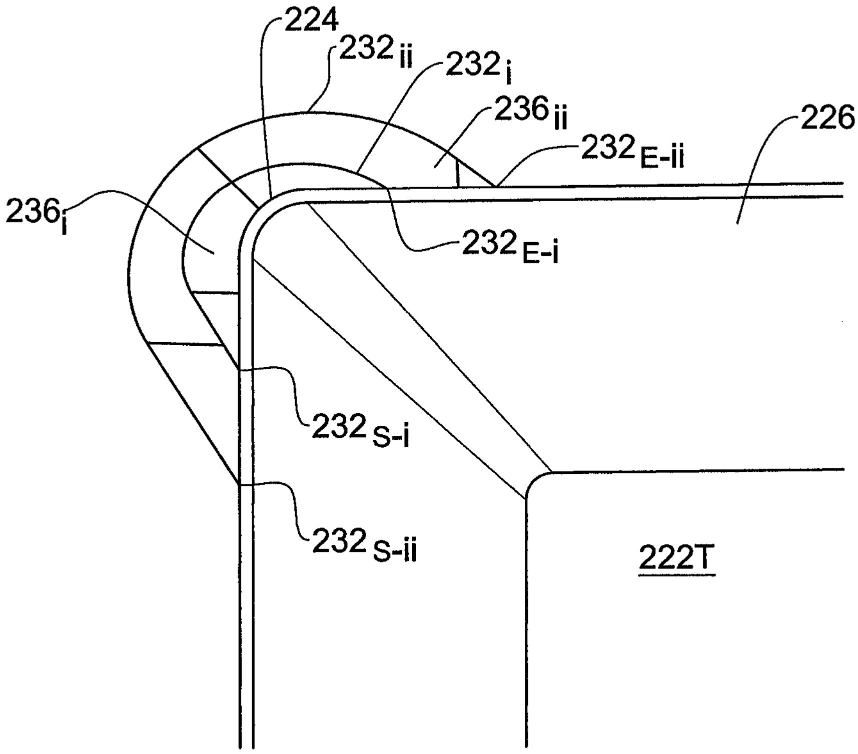


Fig. 18F

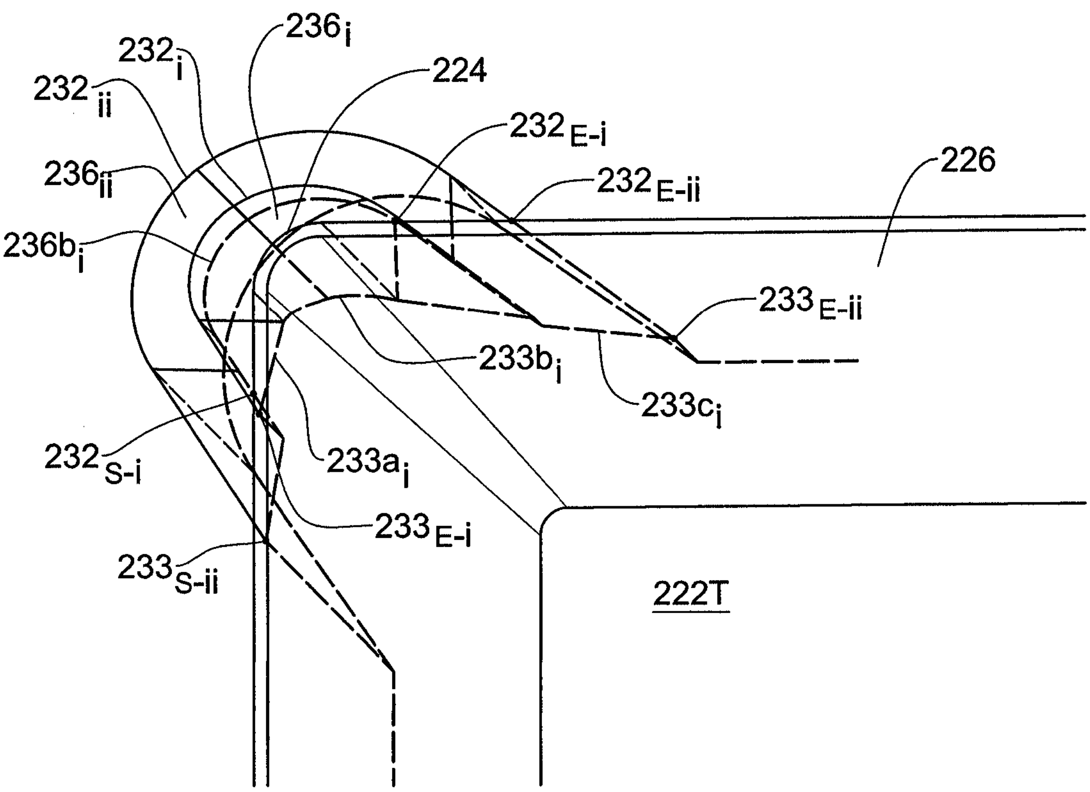


Fig. 18G

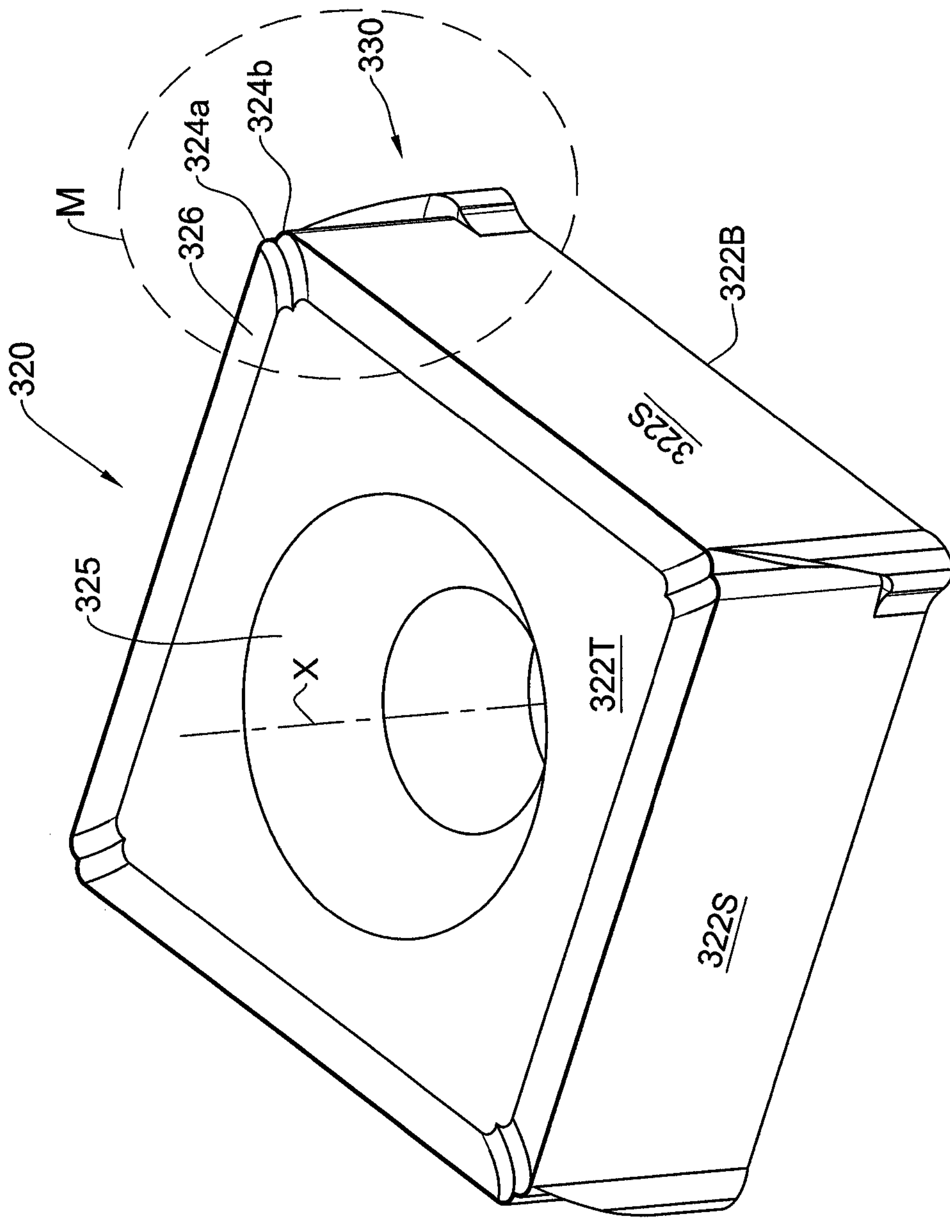


Fig. 19A

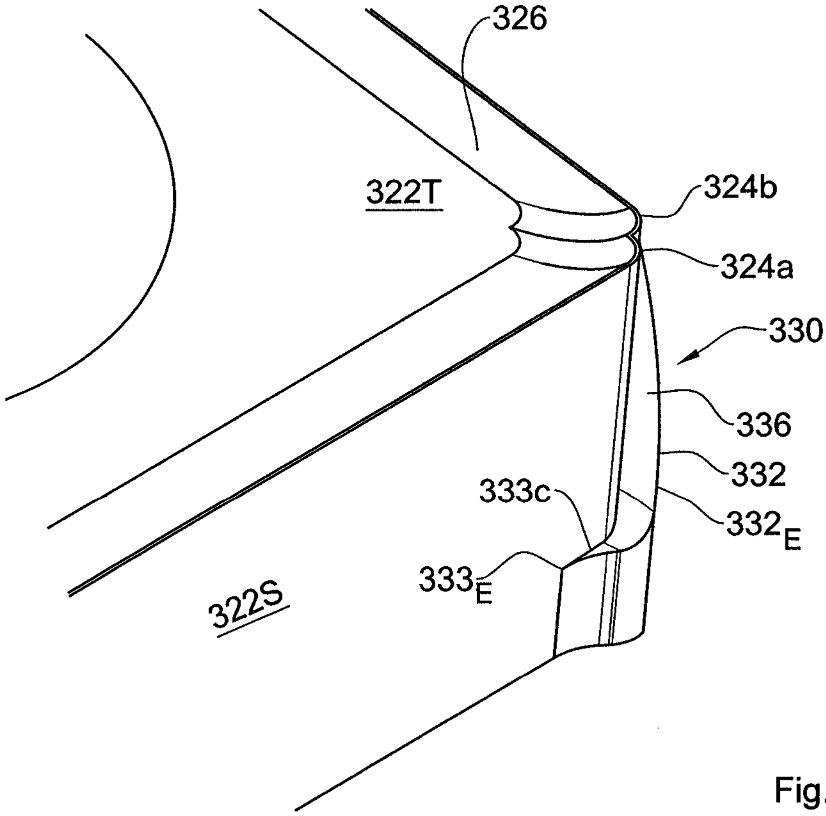


Fig. 19B

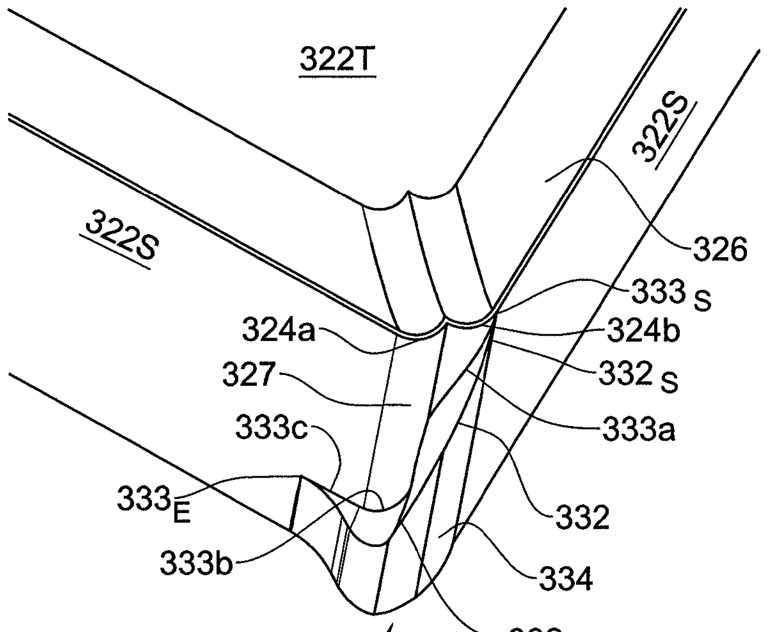


Fig. 19C

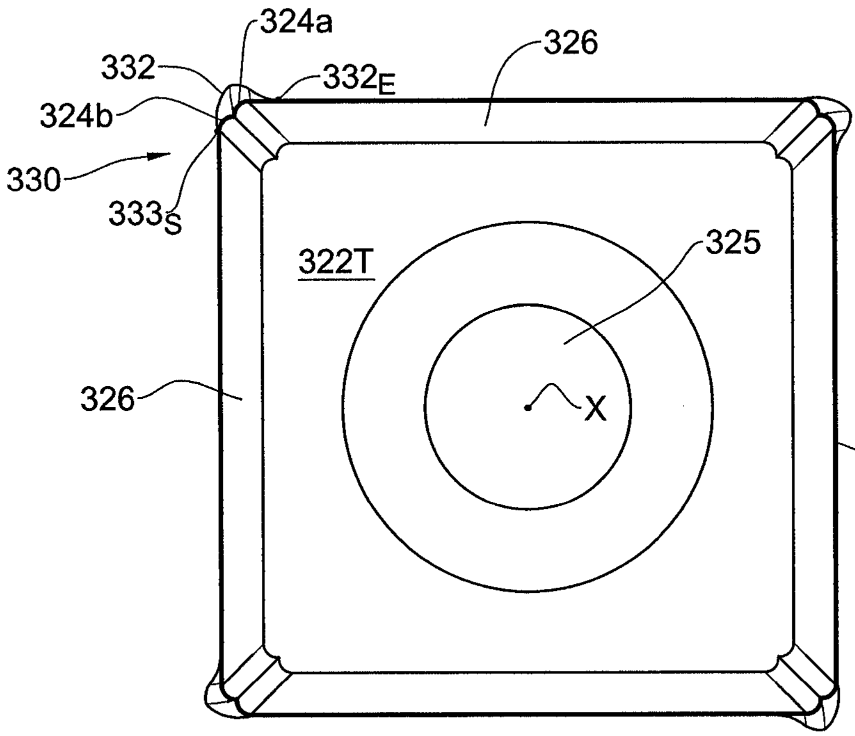


Fig. 19D

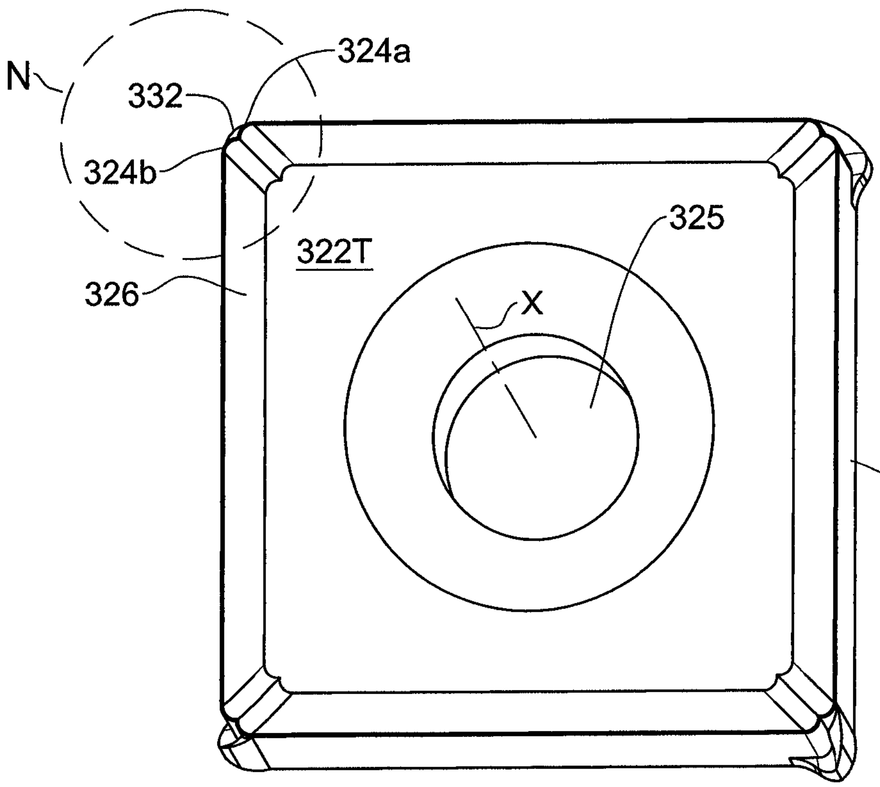


Fig. 19E

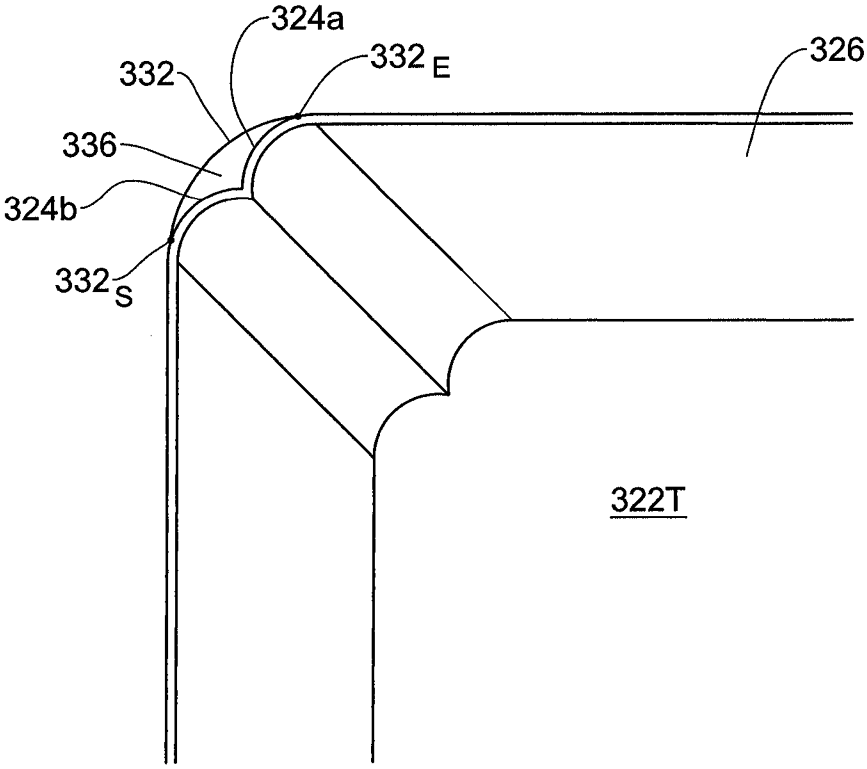


Fig. 19F

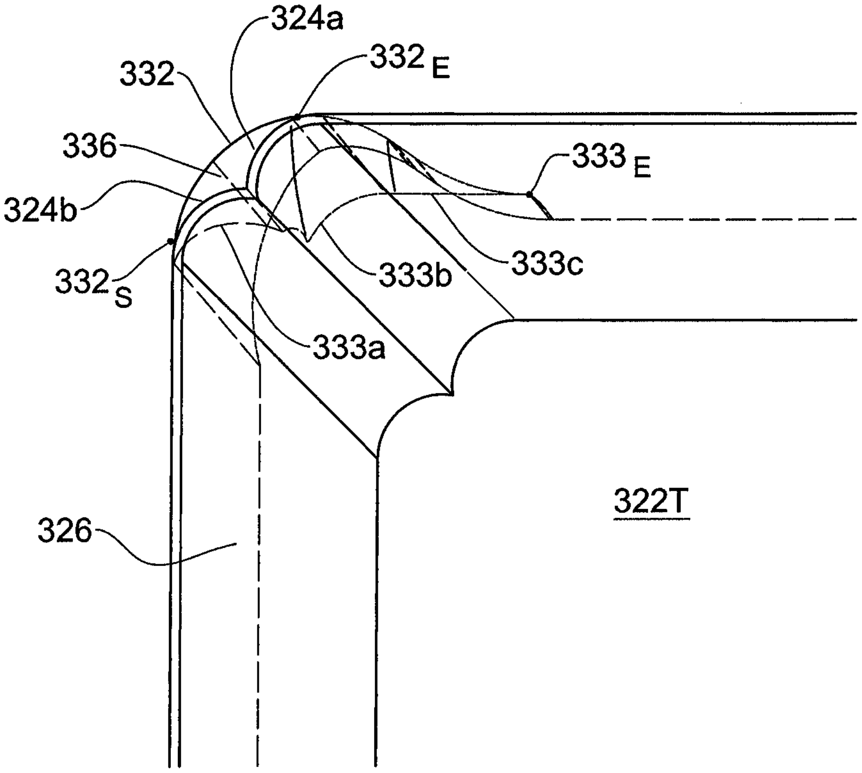
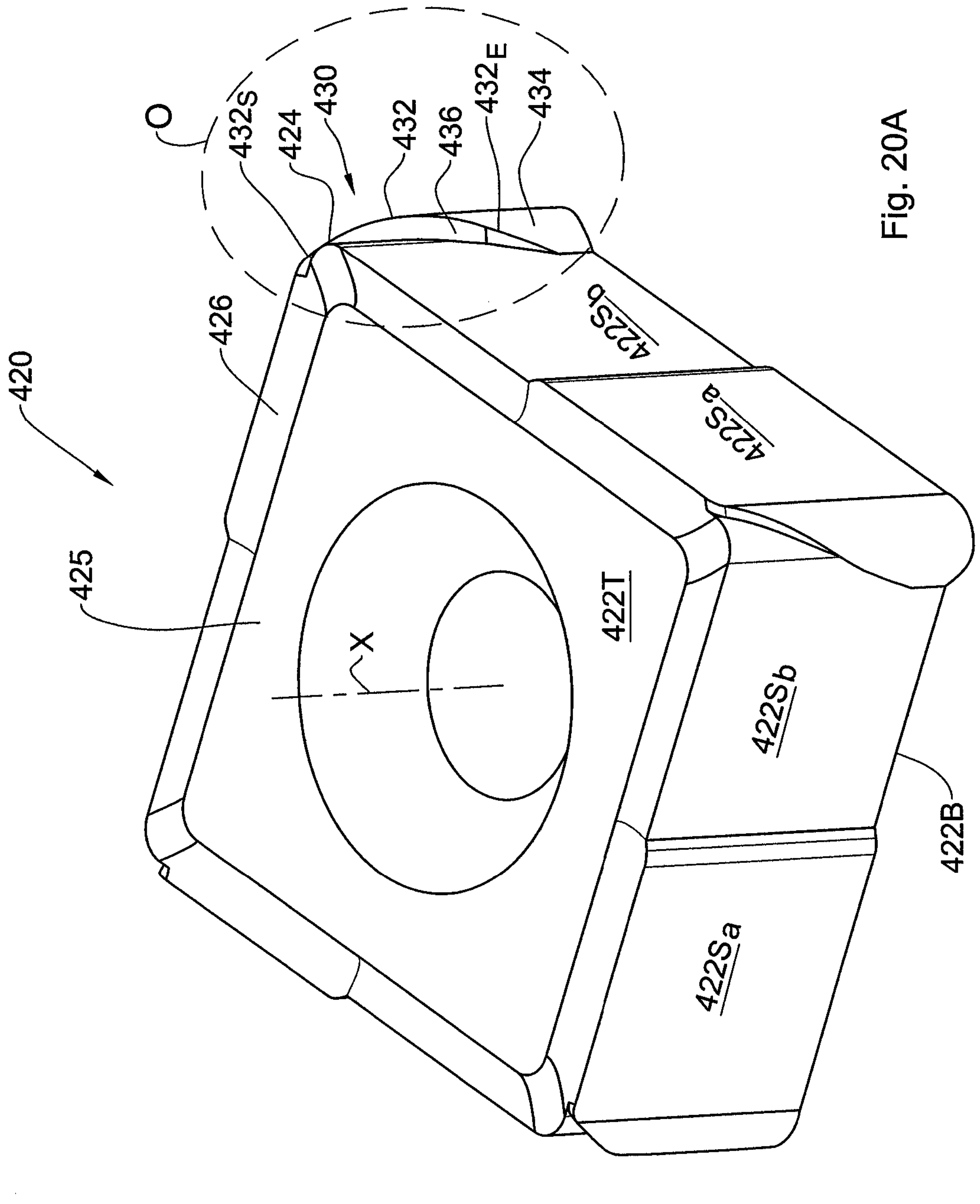


Fig. 19G


420
426
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432E
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422T
X
422B

Fig. 20A

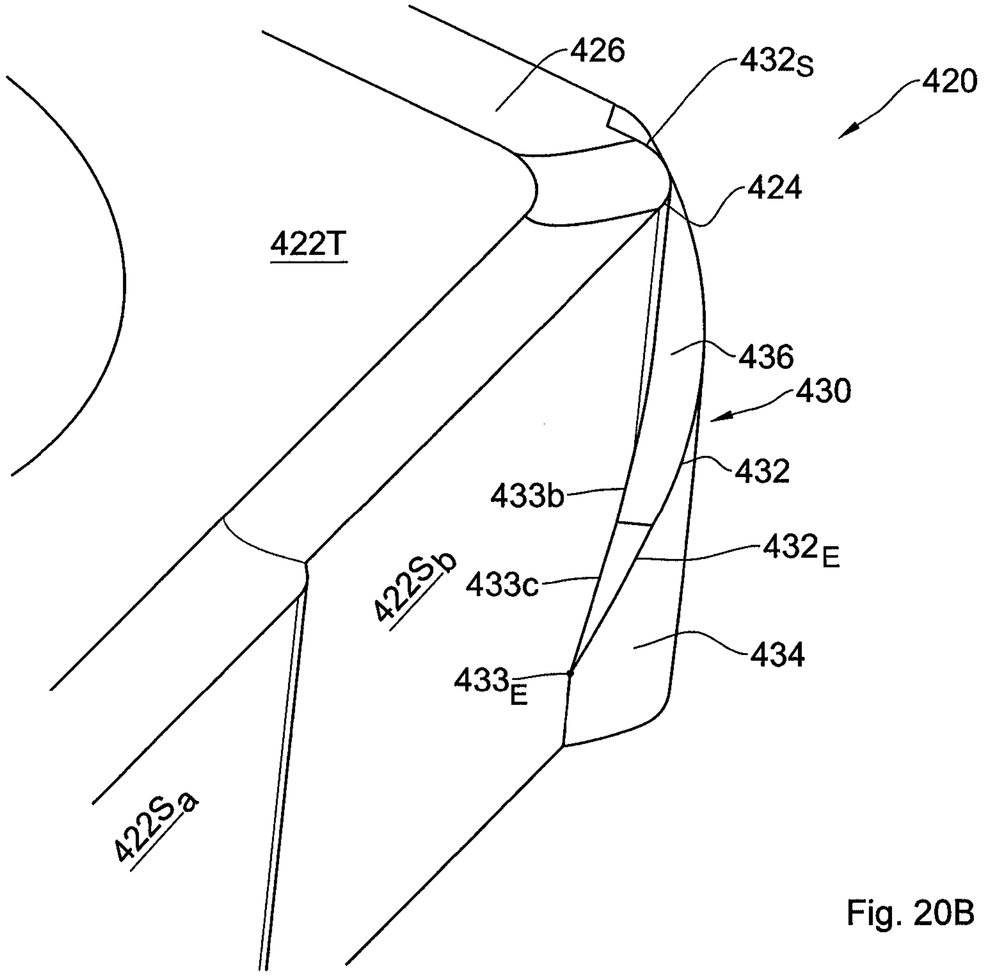


Fig. 20B

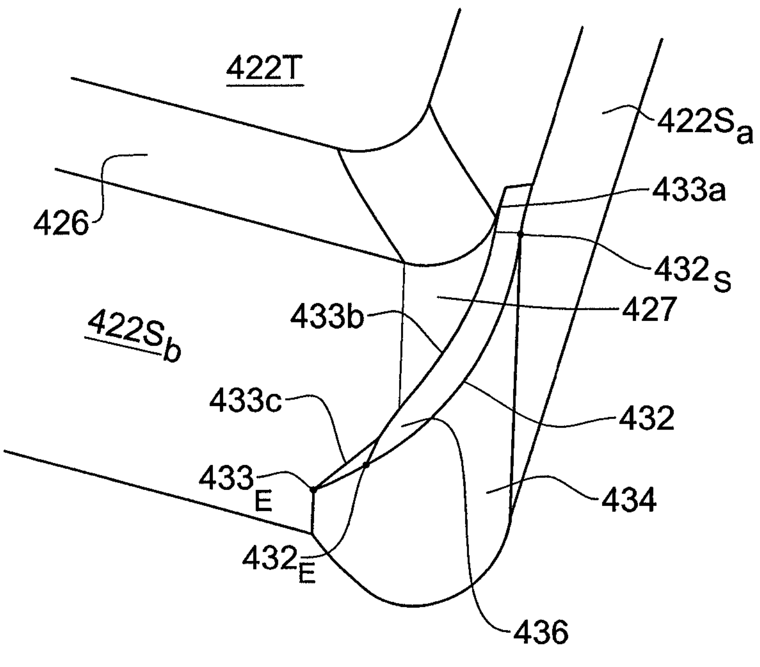


Fig. 20C

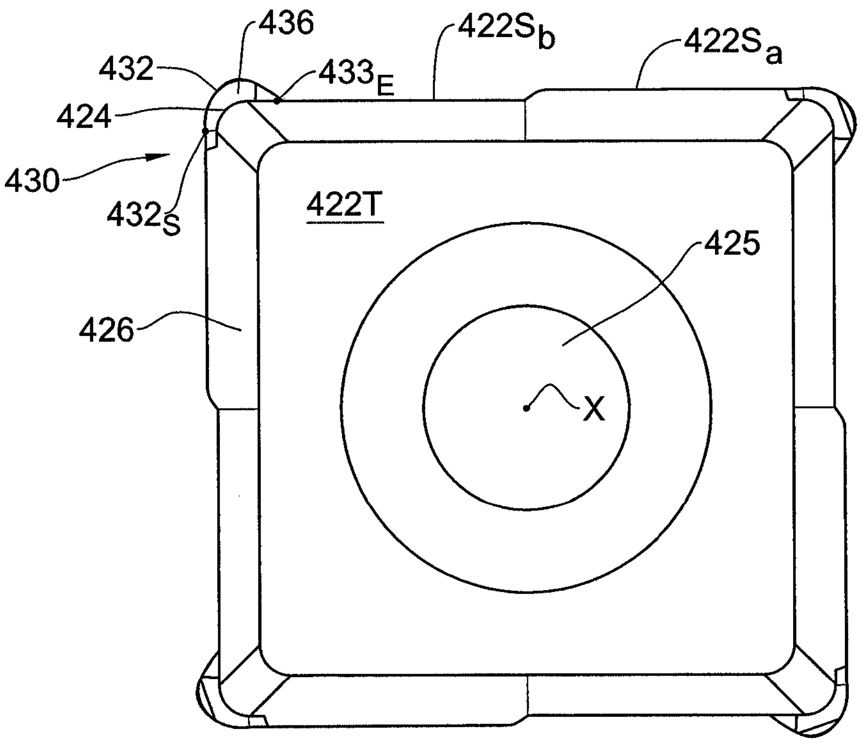


Fig. 20D

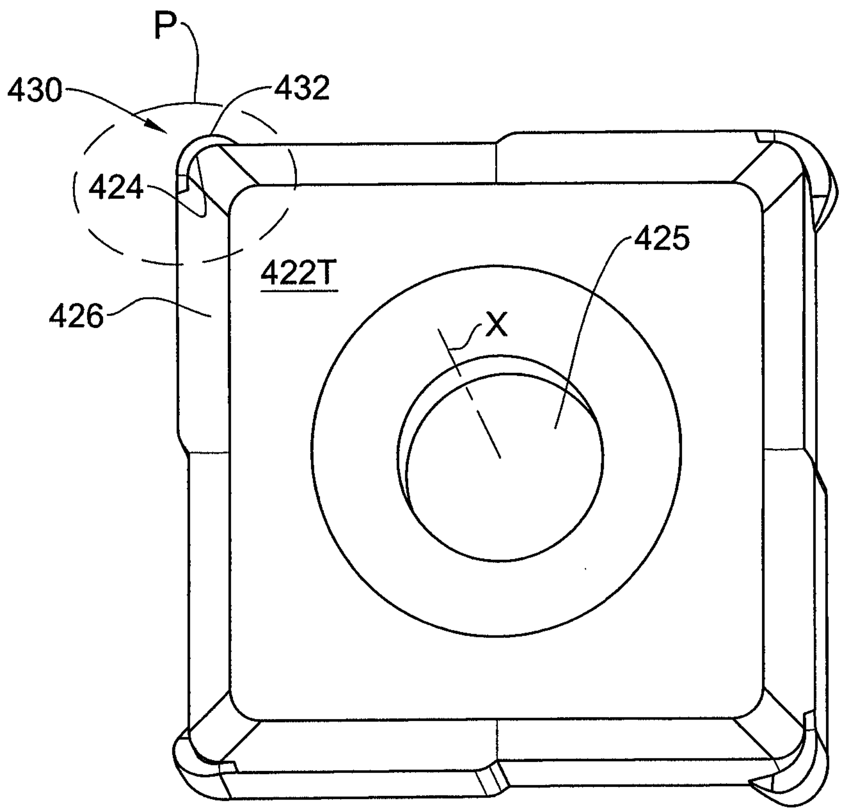


Fig. 20E

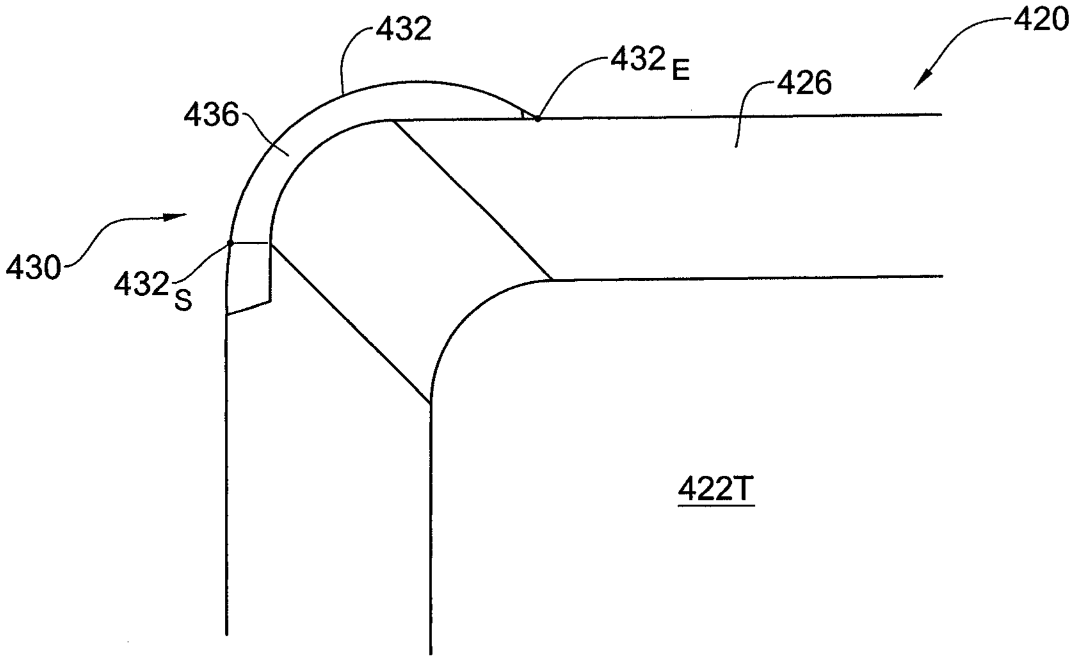


Fig. 20F

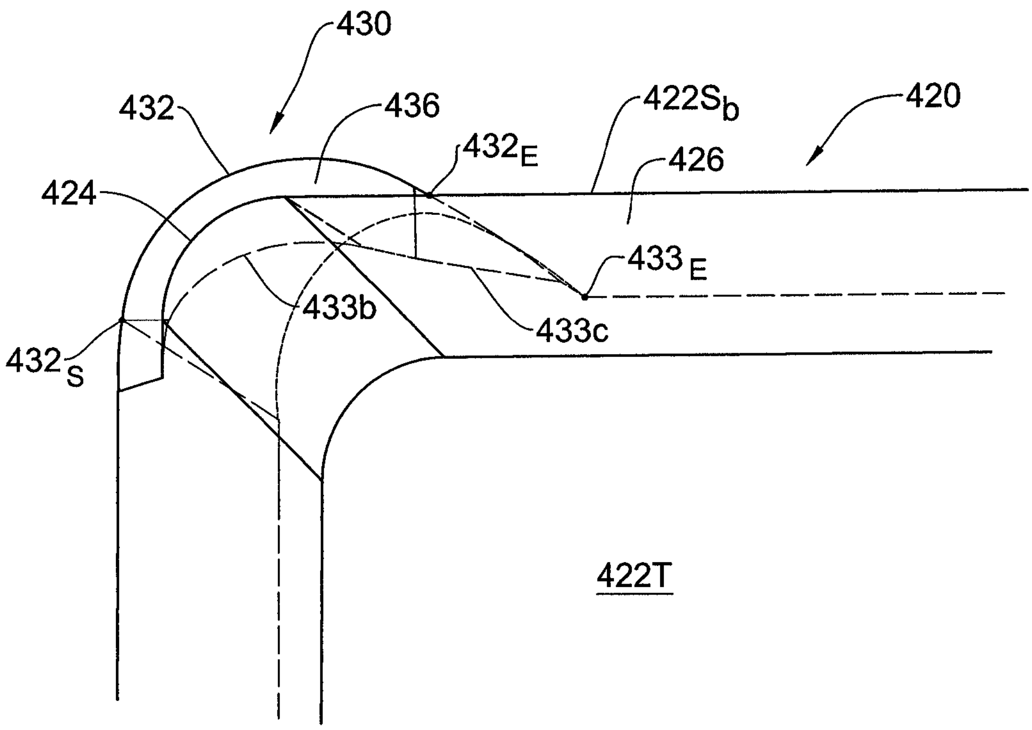


Fig. 20G

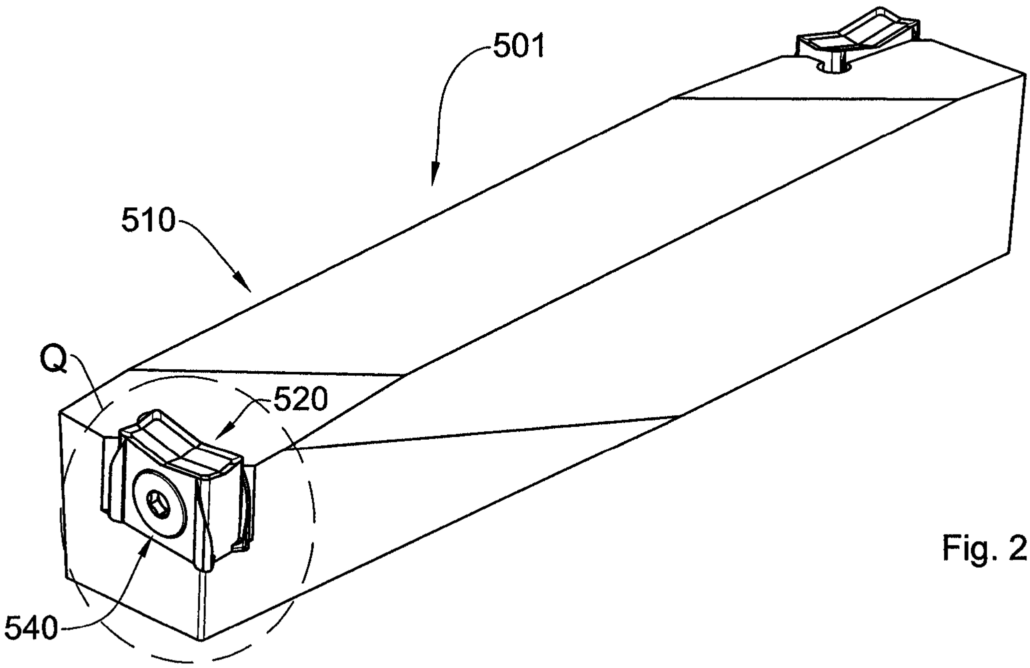


Fig. 21A

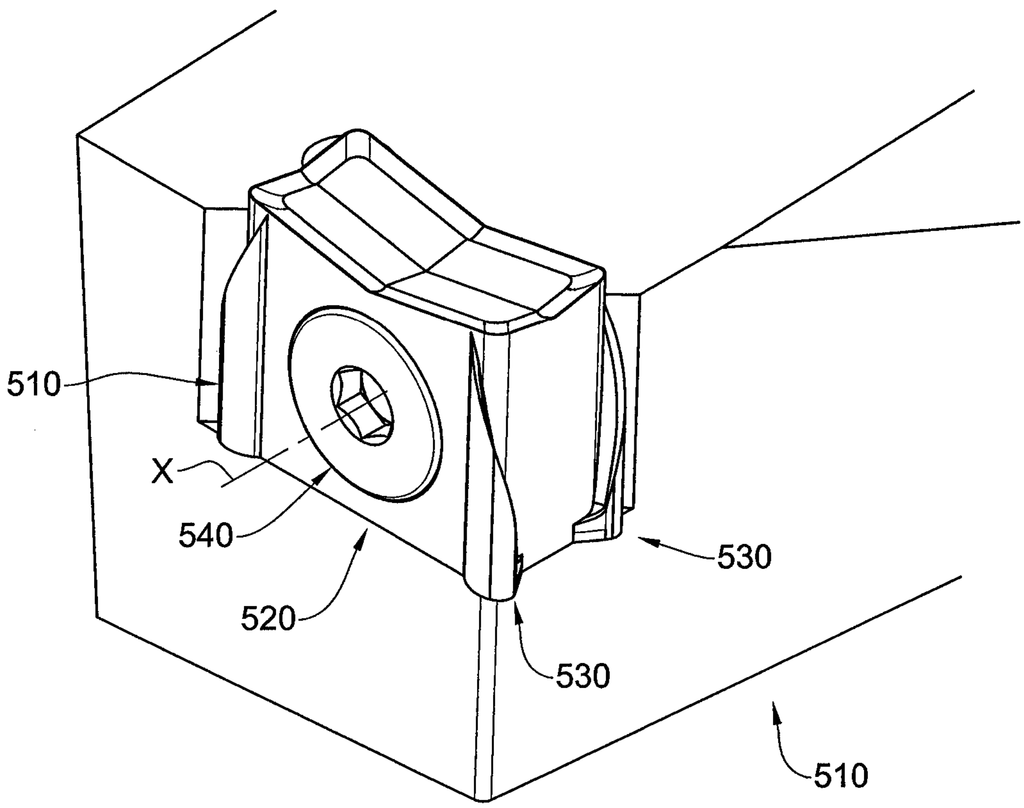


Fig. 21B

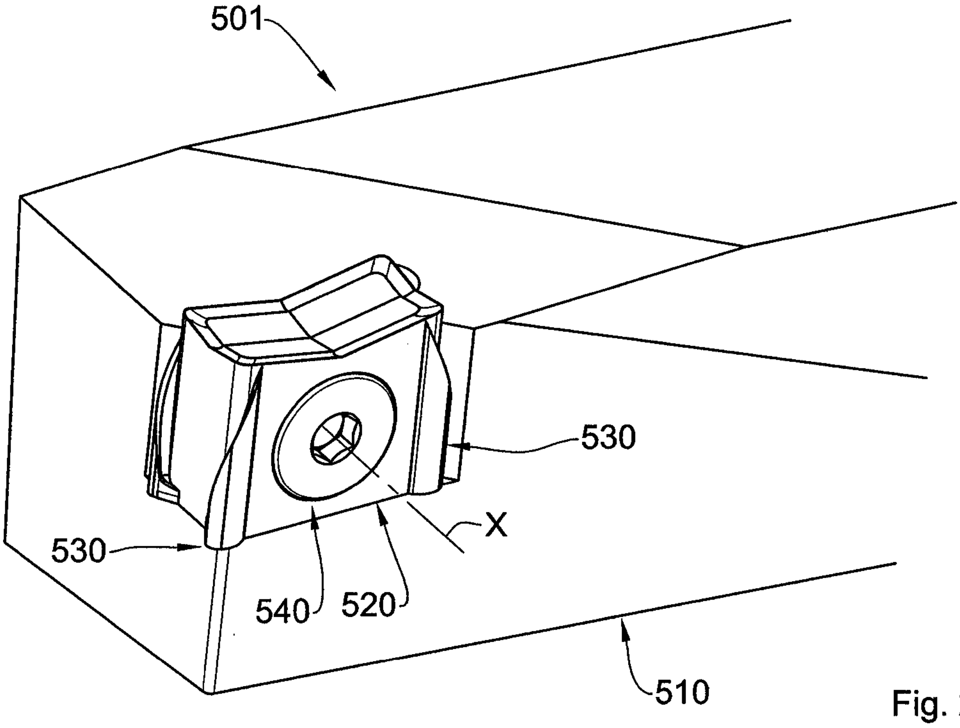


Fig. 21C

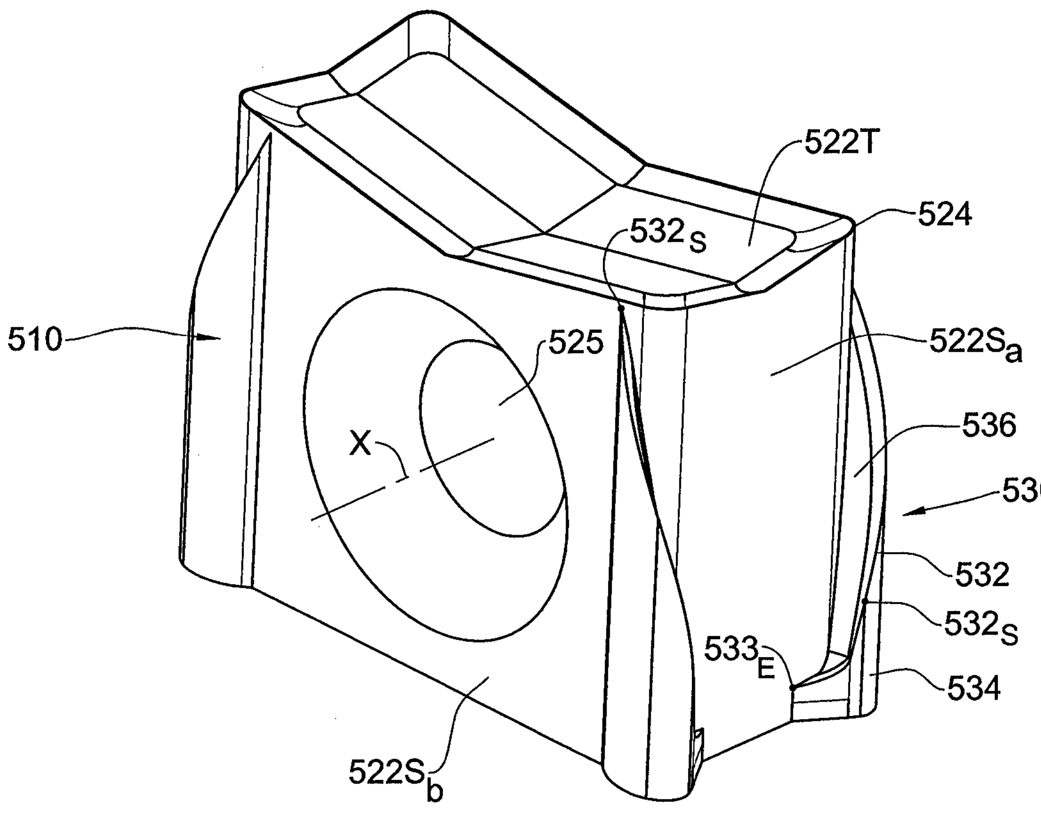


Fig. 21D

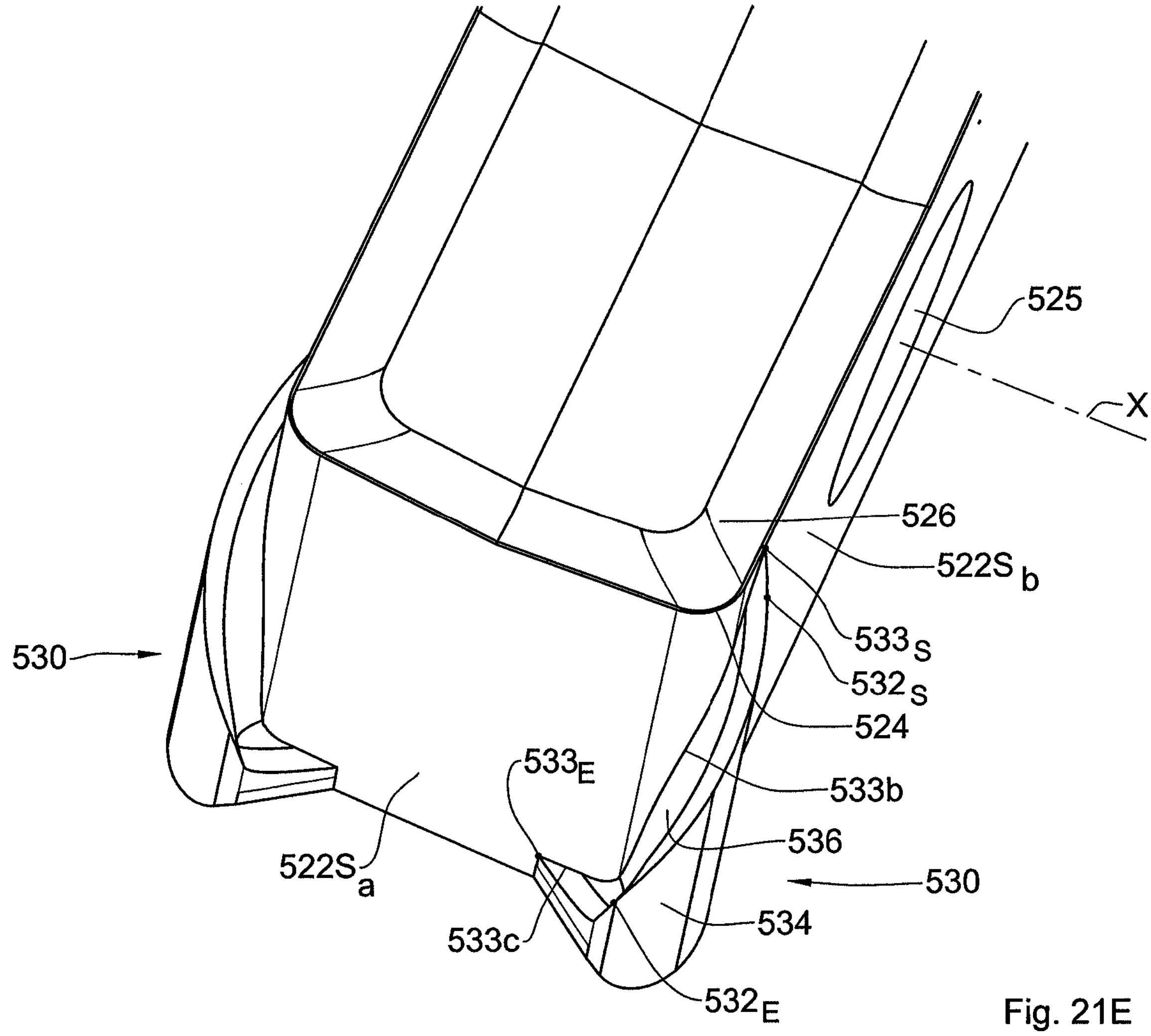


Fig. 21E

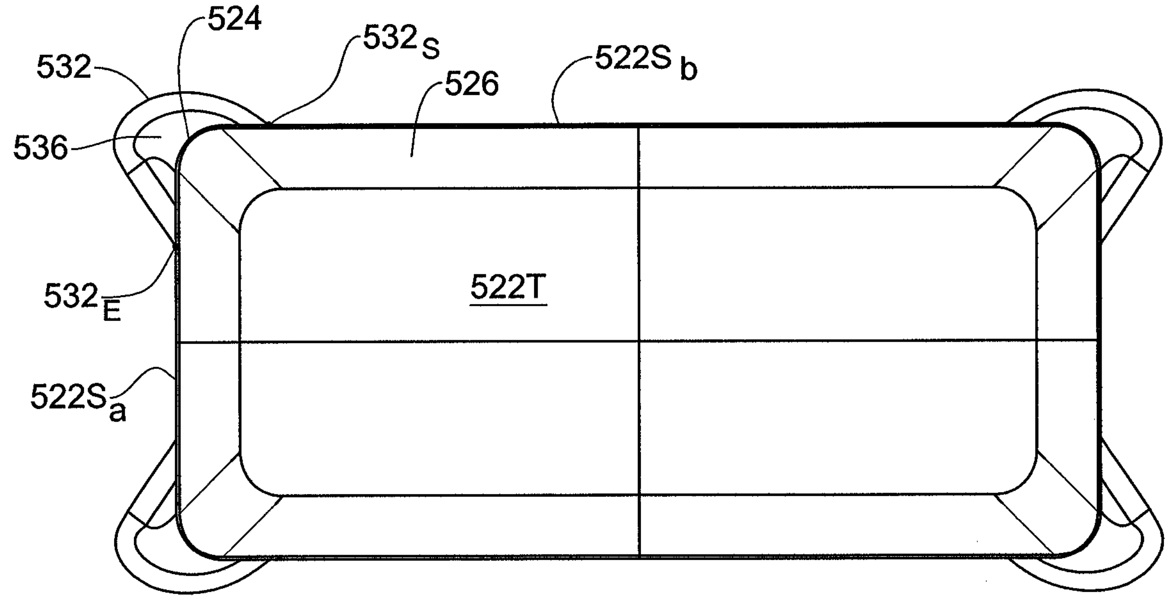


Fig. 21F

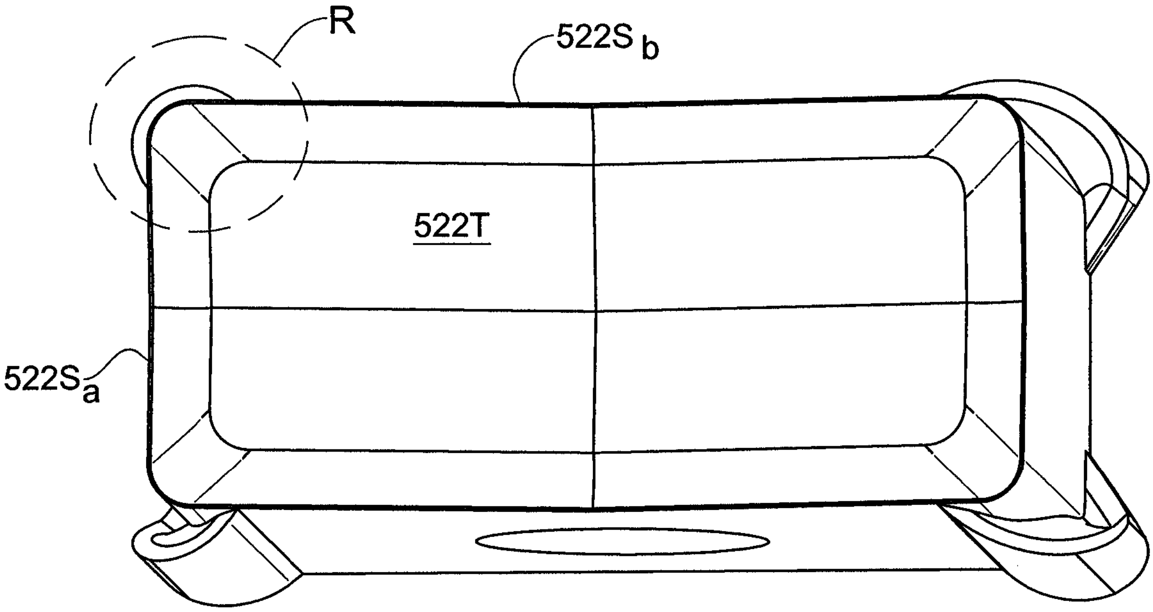


Fig. 21G

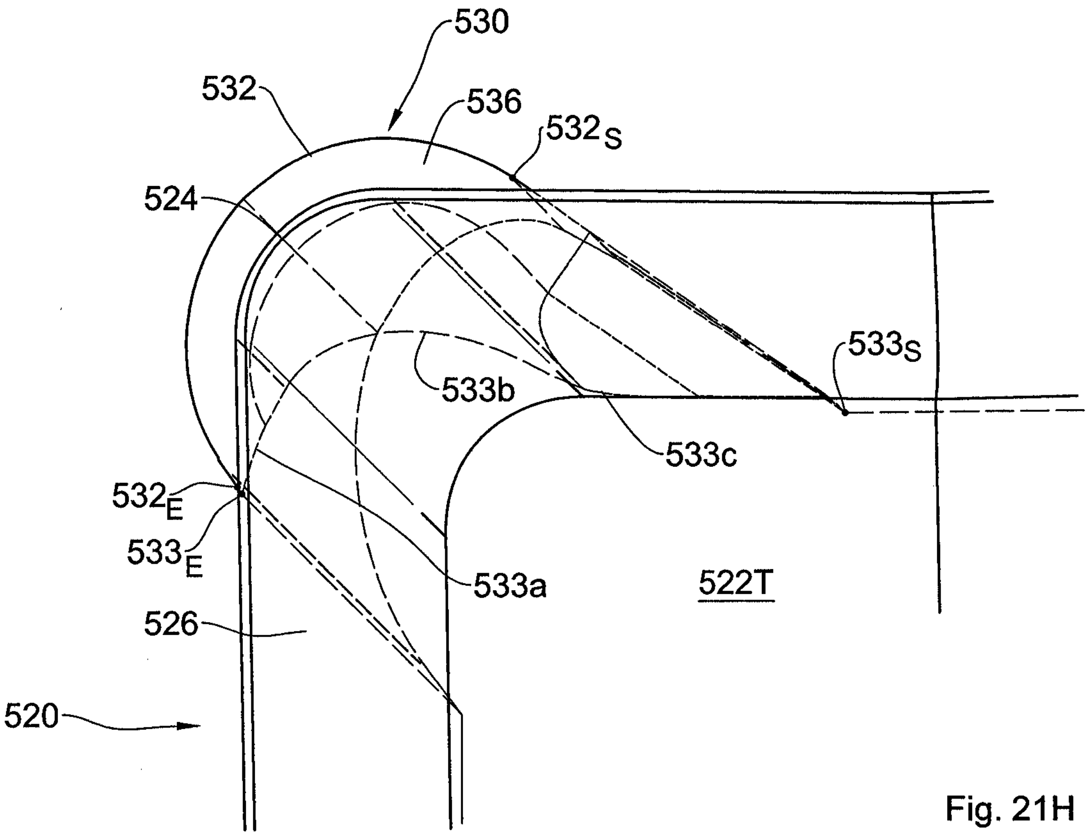


Fig. 21H

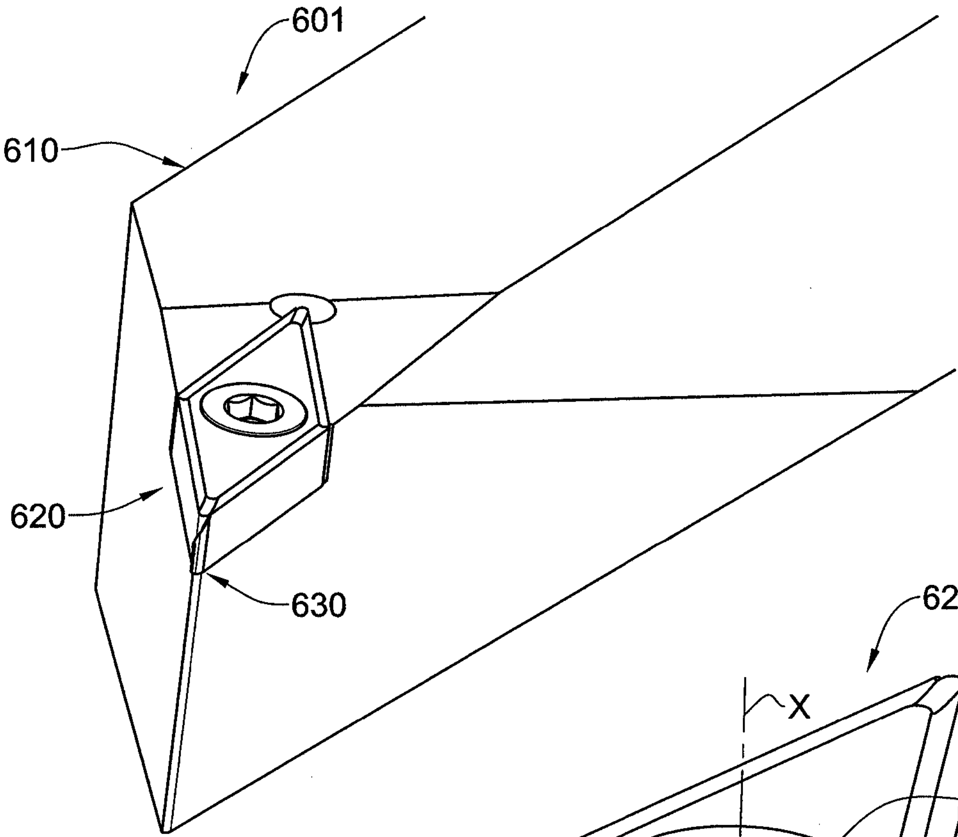


Fig. 22A

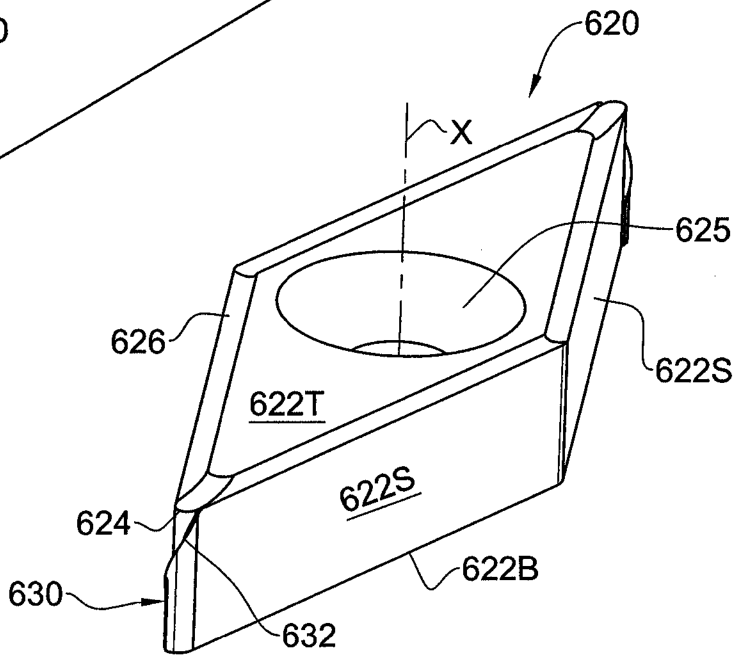


Fig. 22B

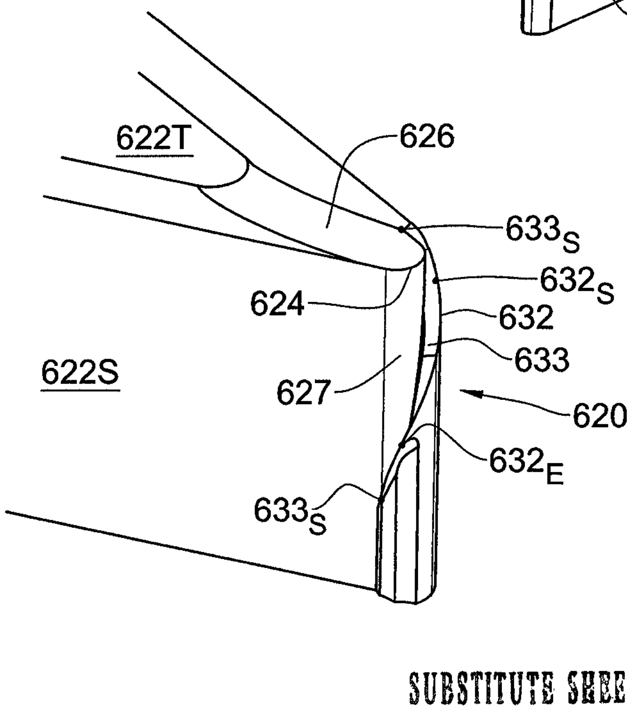


Fig. 22C

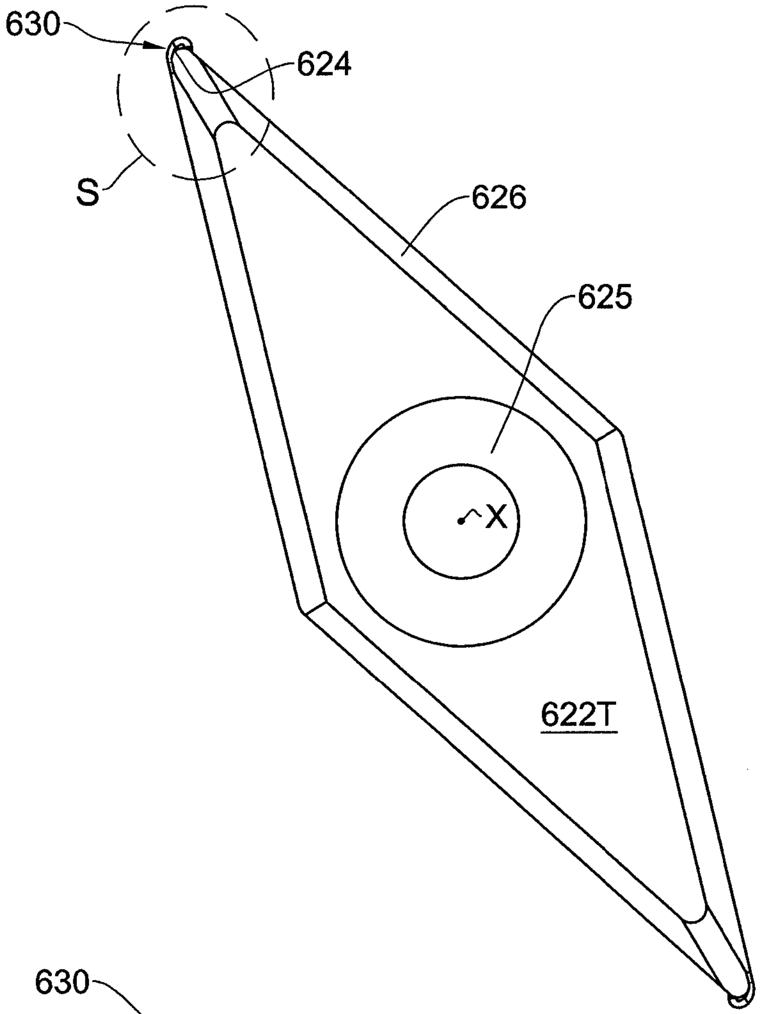


Fig. 22D

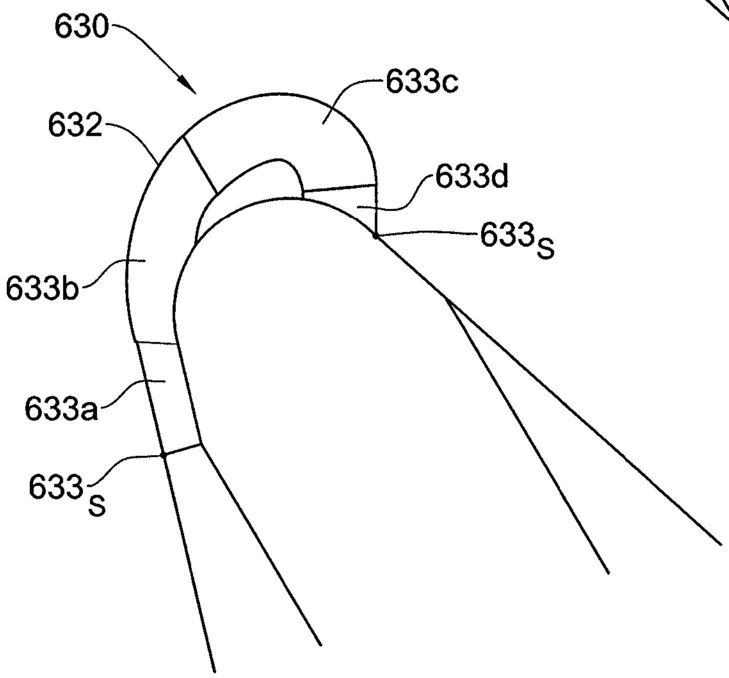


Fig. 22E

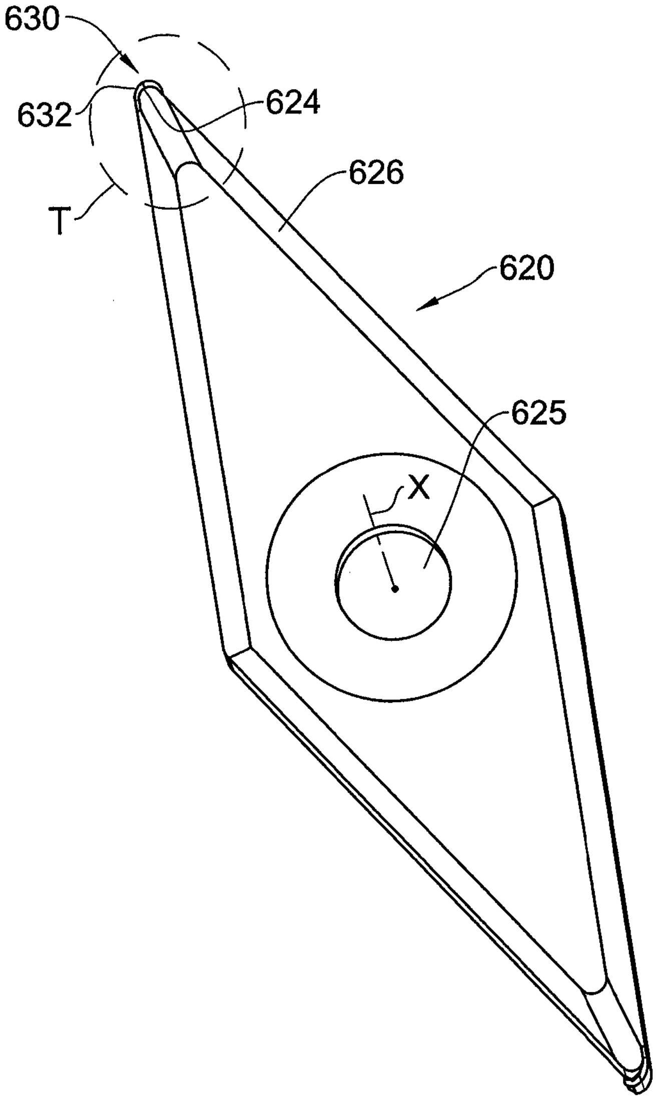


Fig. 22F

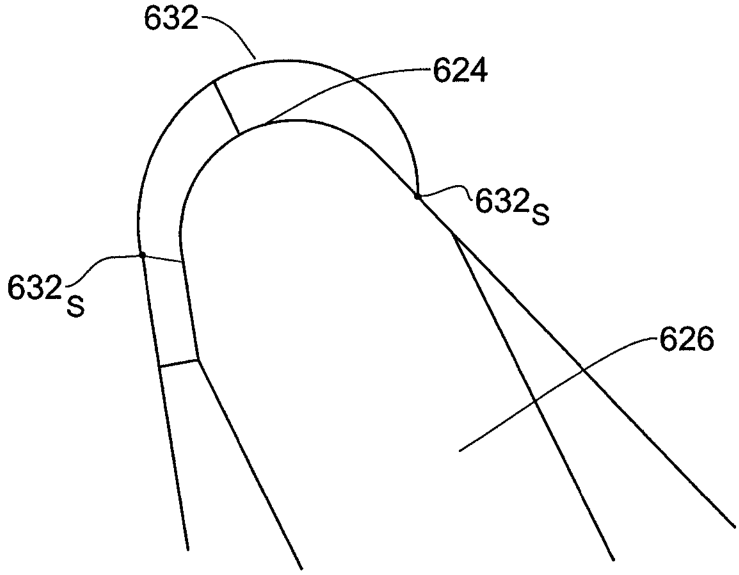


Fig. 22G

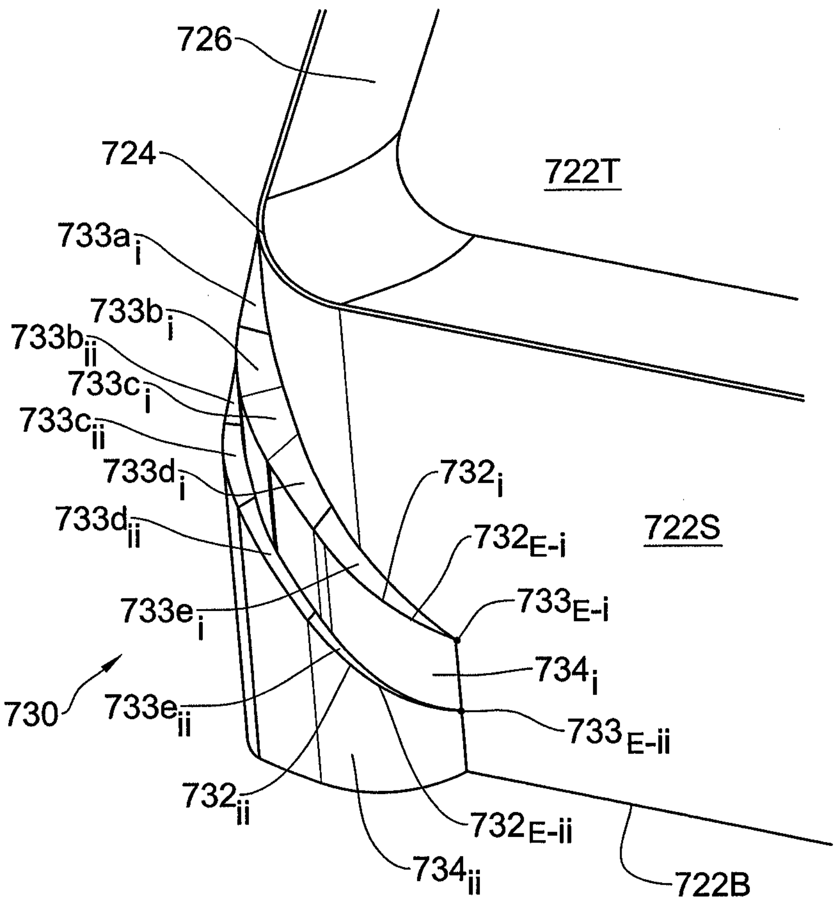


Fig. 23A

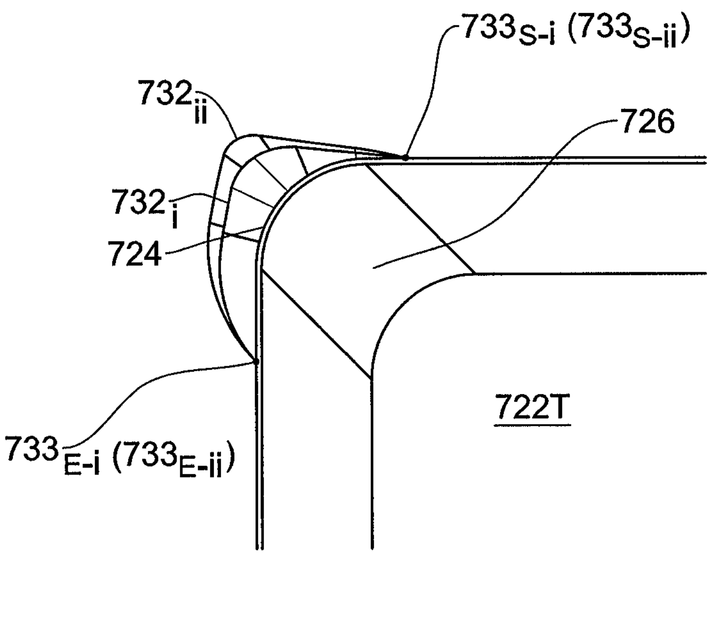


Fig. 23B

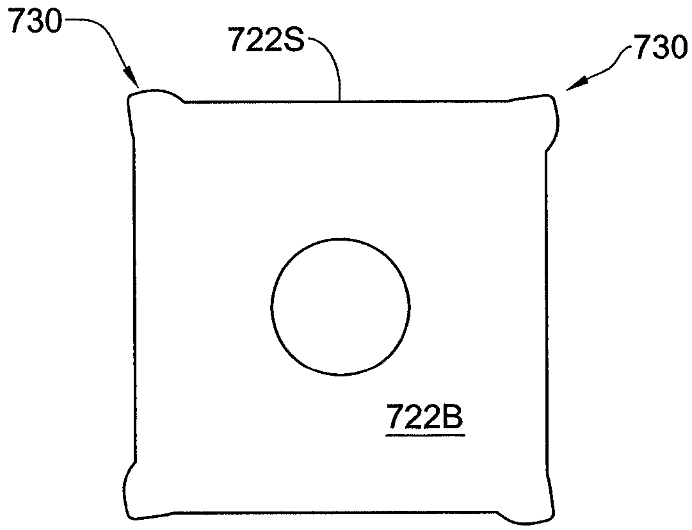


Fig. 23C

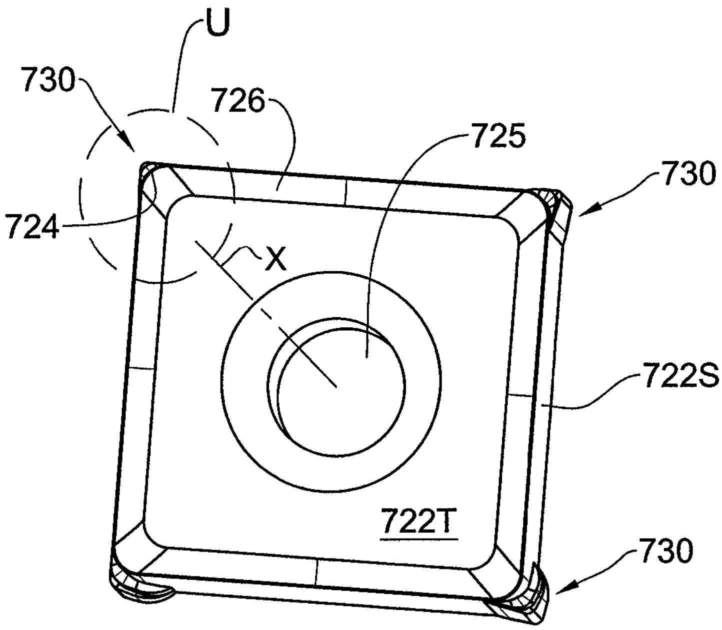


Fig. 23D

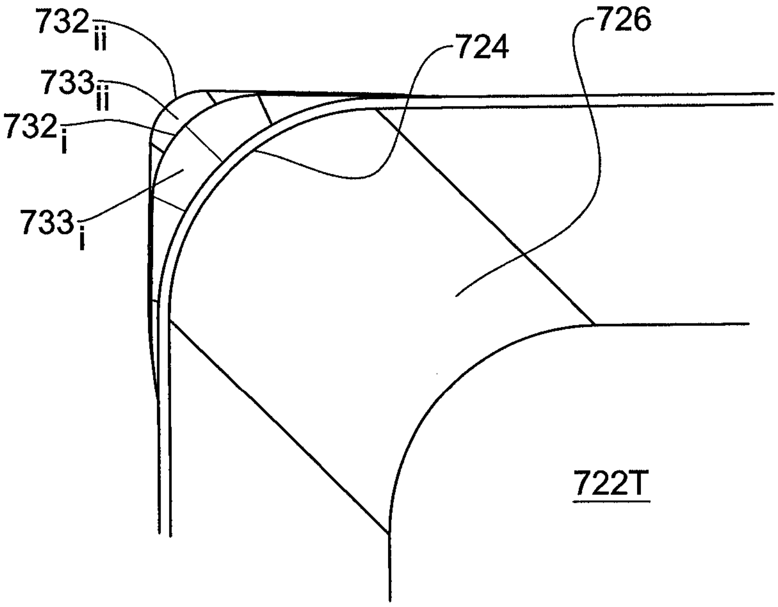


Fig. 23E

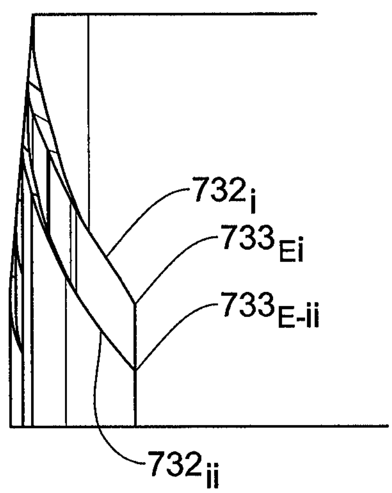


Fig. 23F

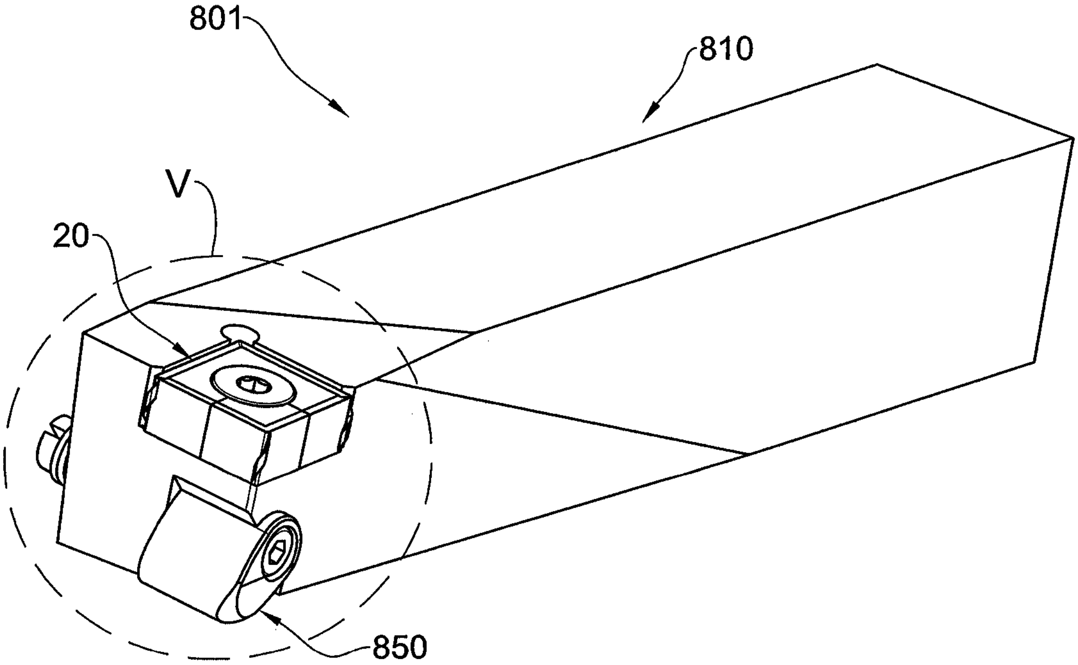


Fig. 24A

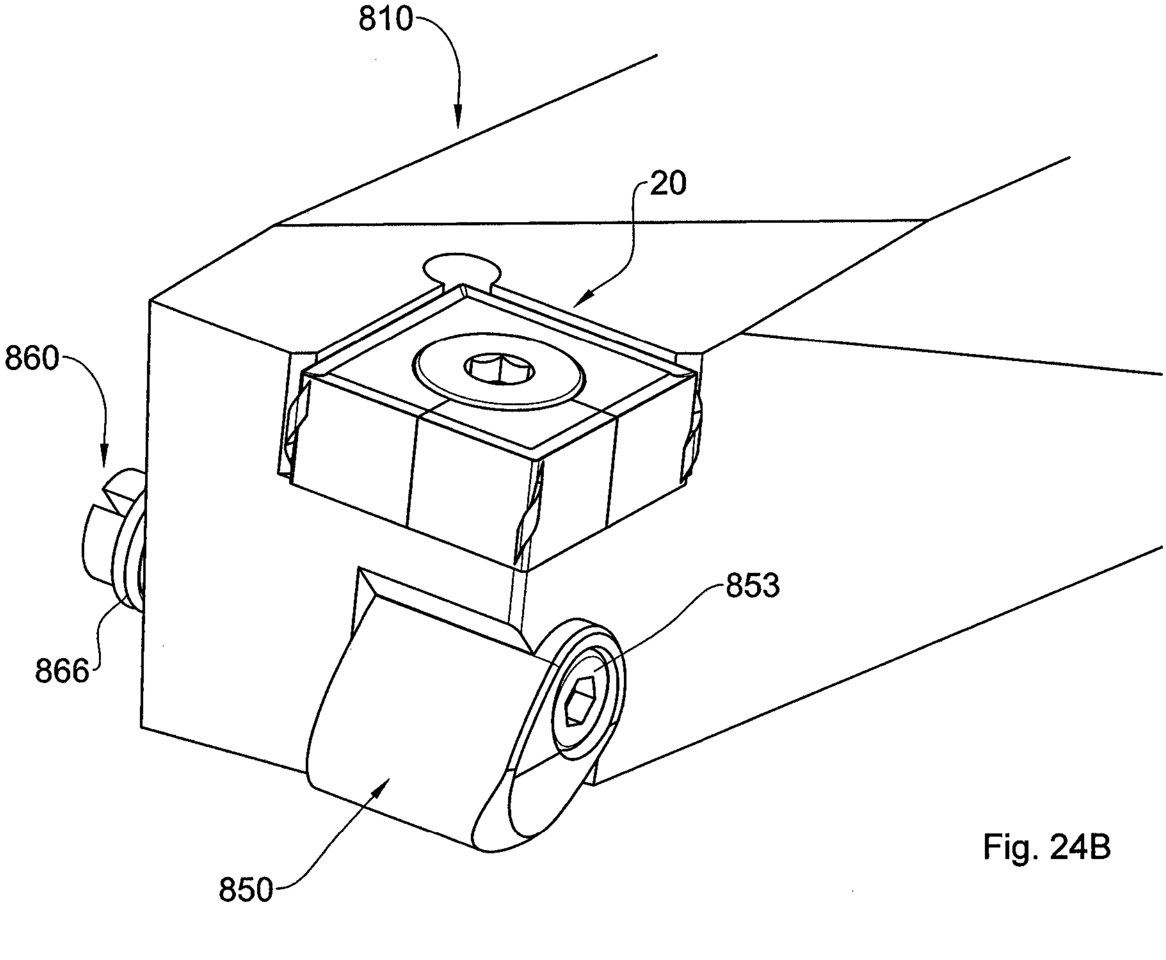


Fig. 24B

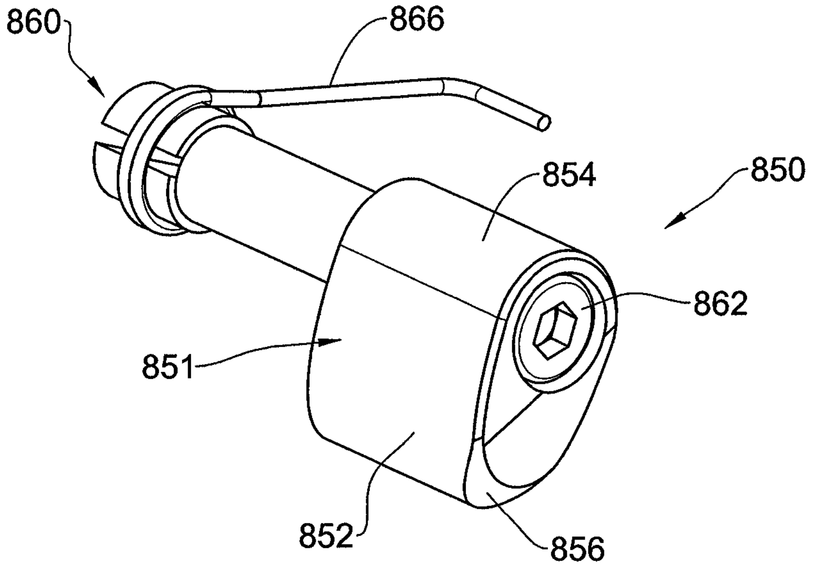


Fig. 24C

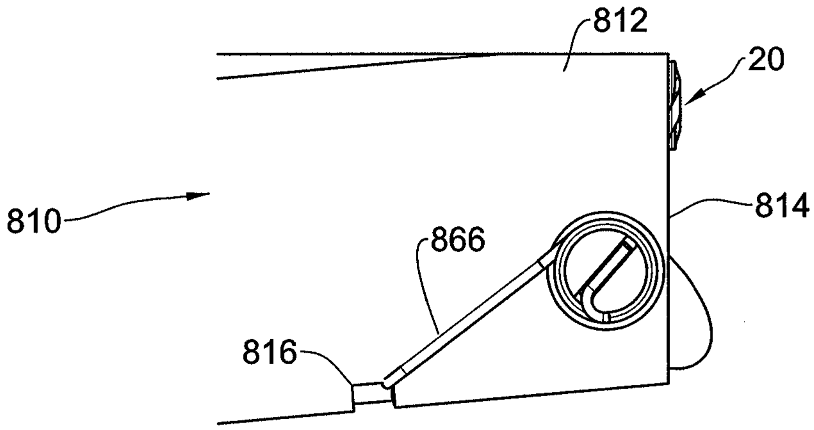


Fig. 24D

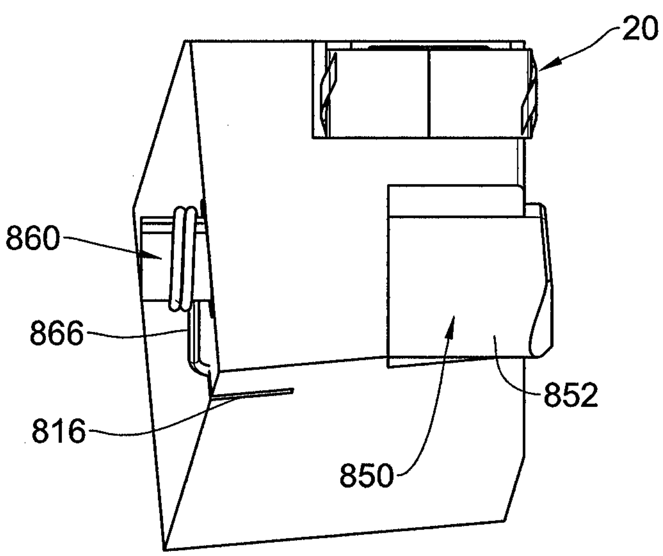


Fig. 24E

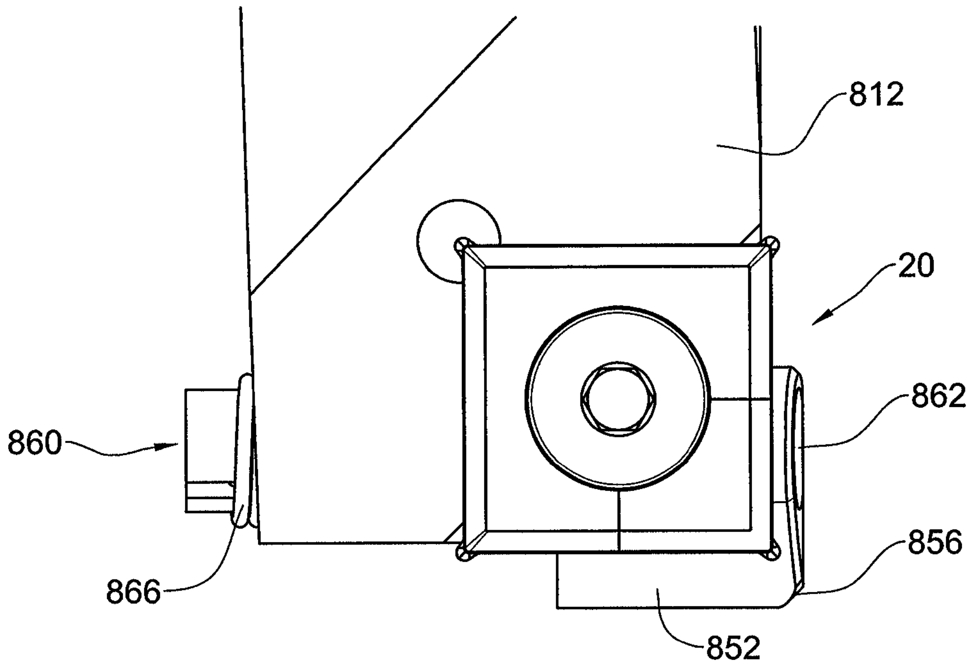


Fig. 24F

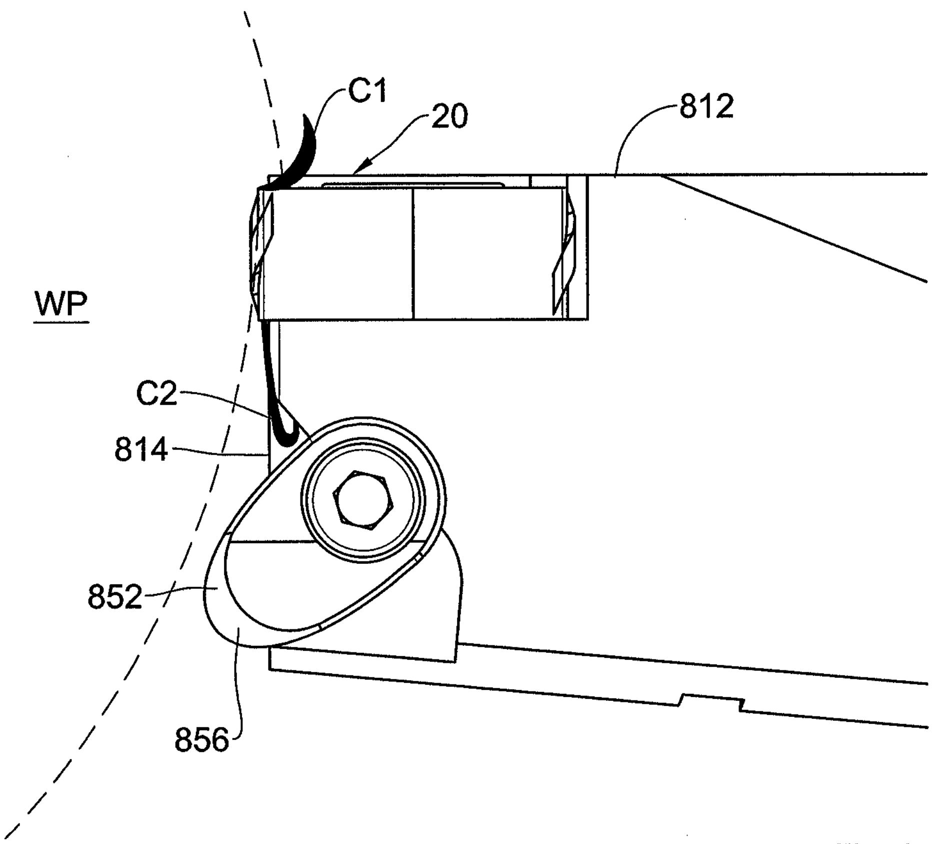


Fig. 24G

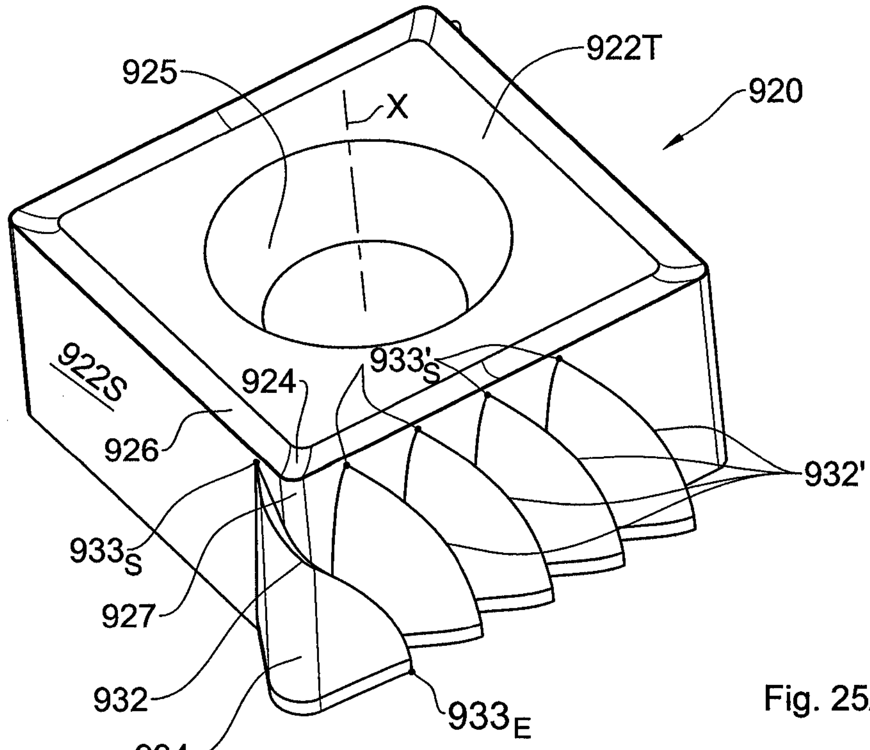


Fig. 25A

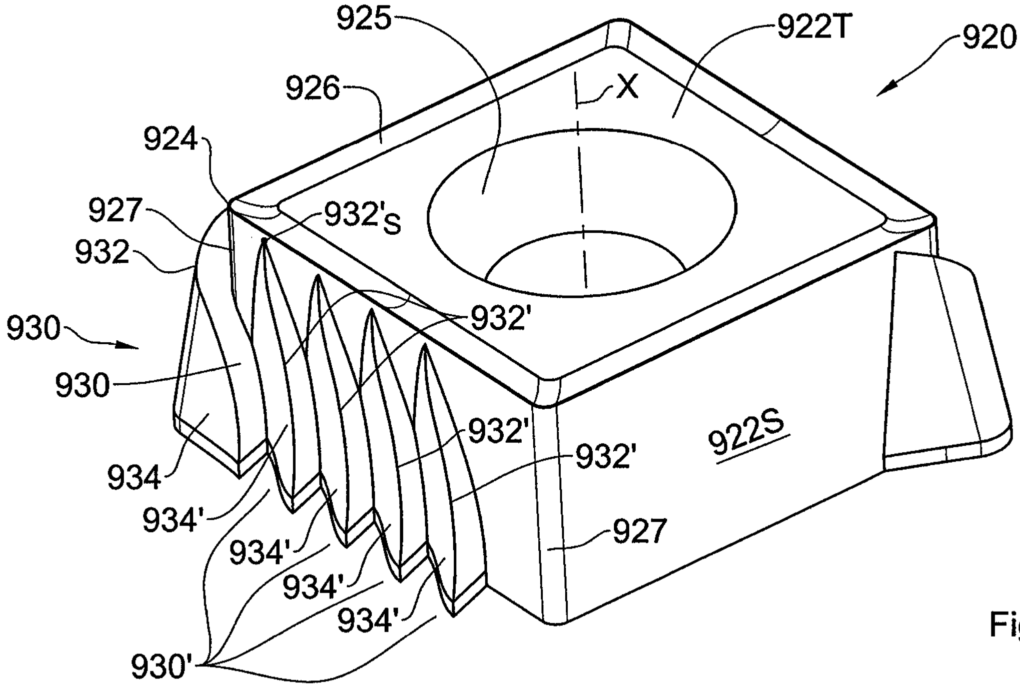


Fig. 25B

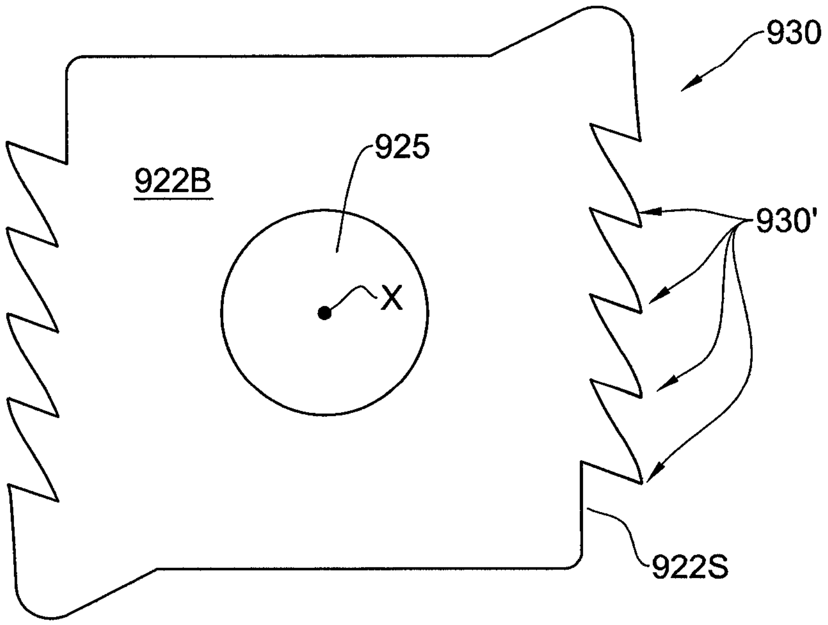


Fig. 25C

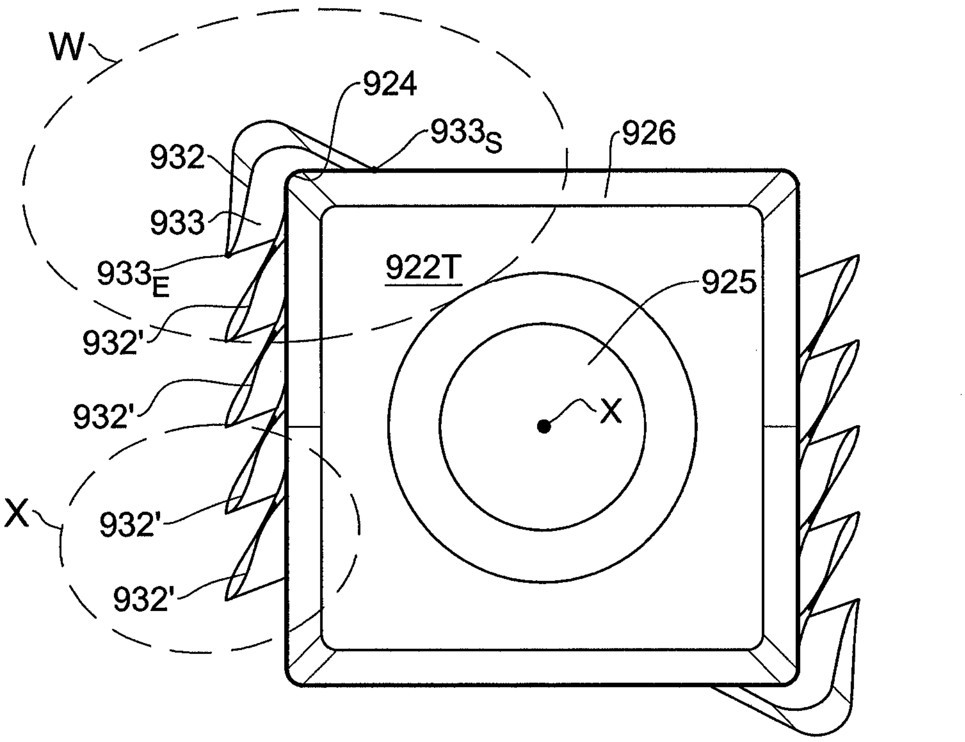


Fig. 25D

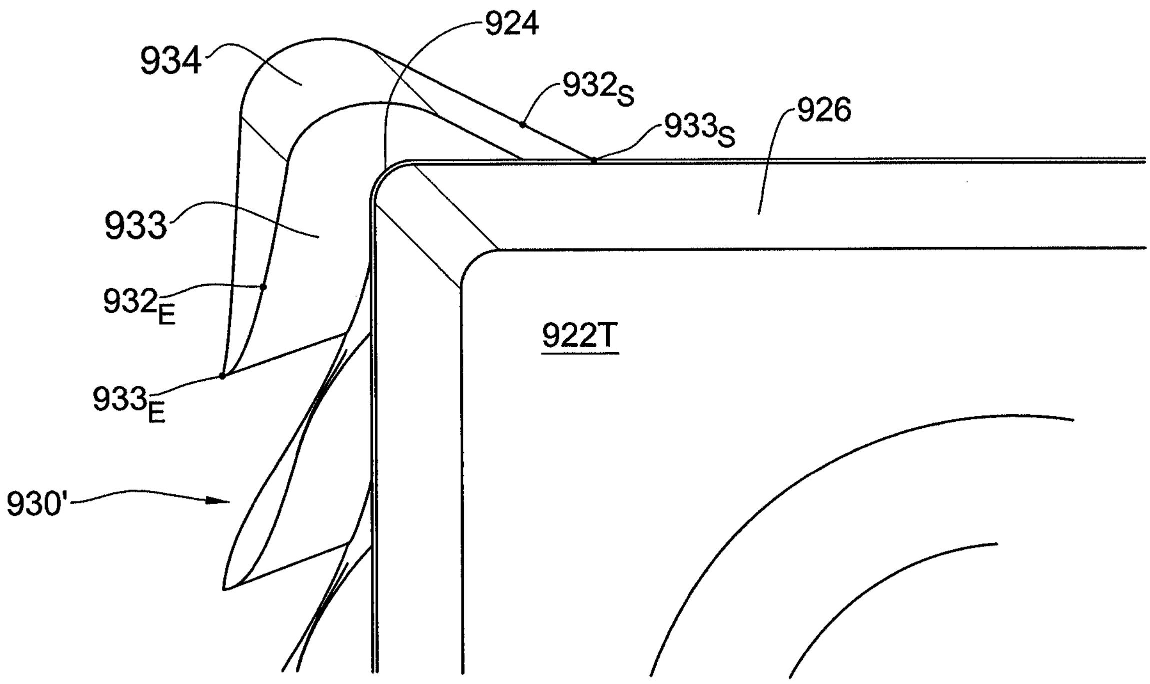


Fig. 25E

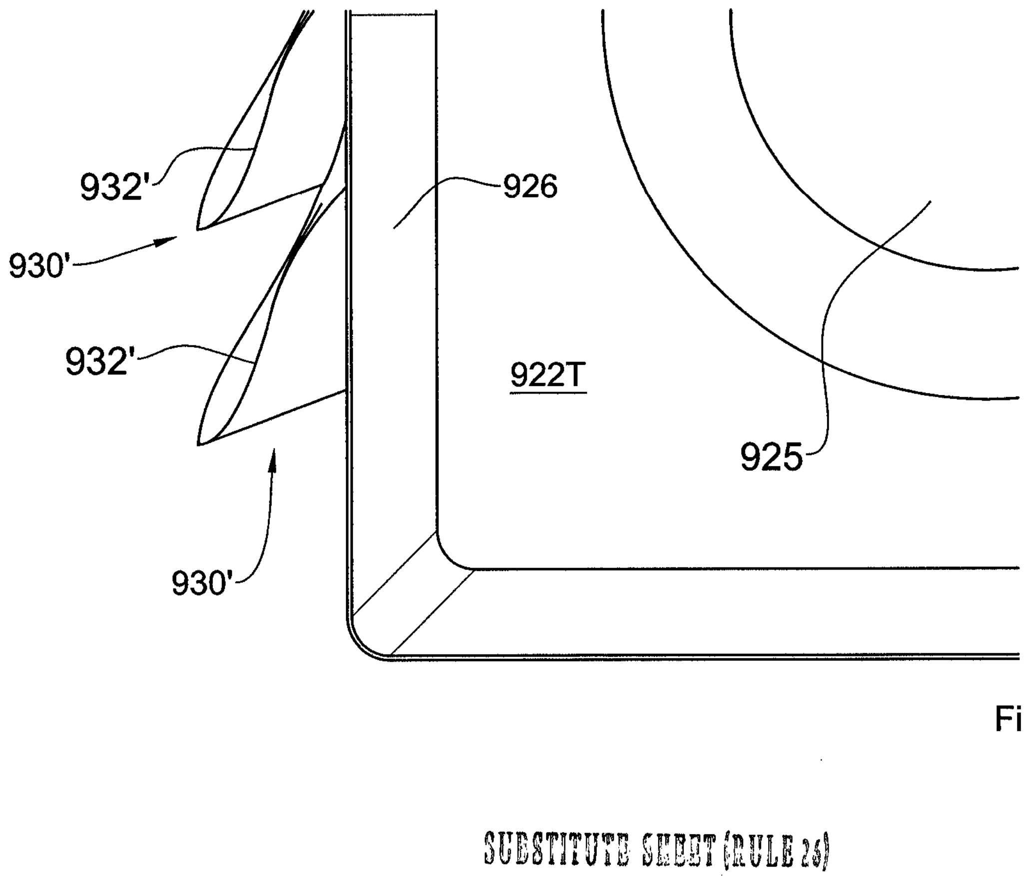


Fig. 25F

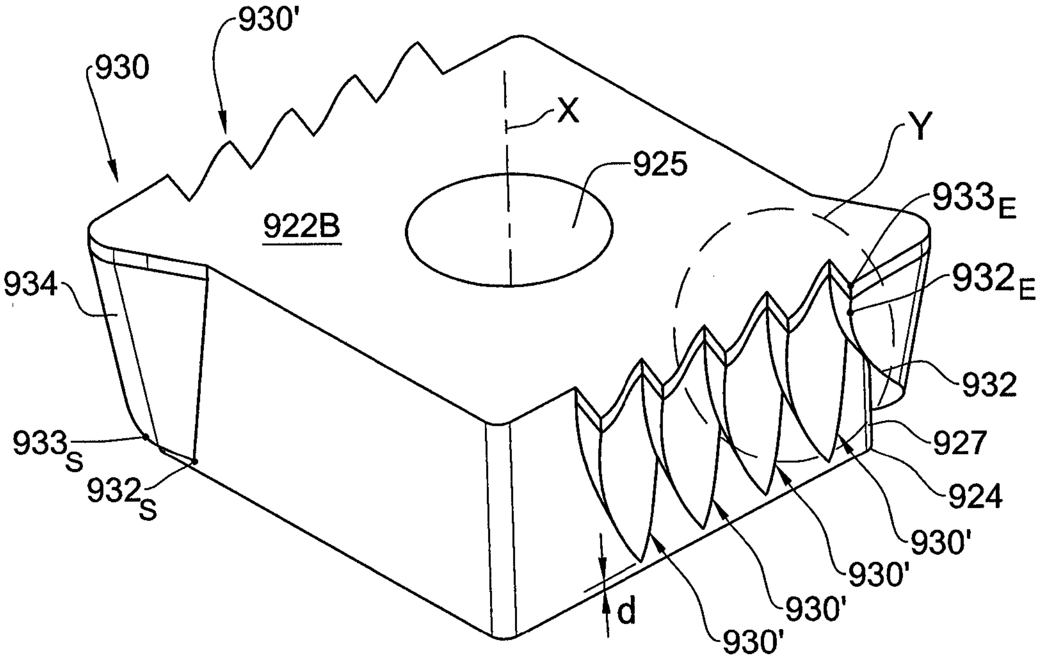


Fig. 25G

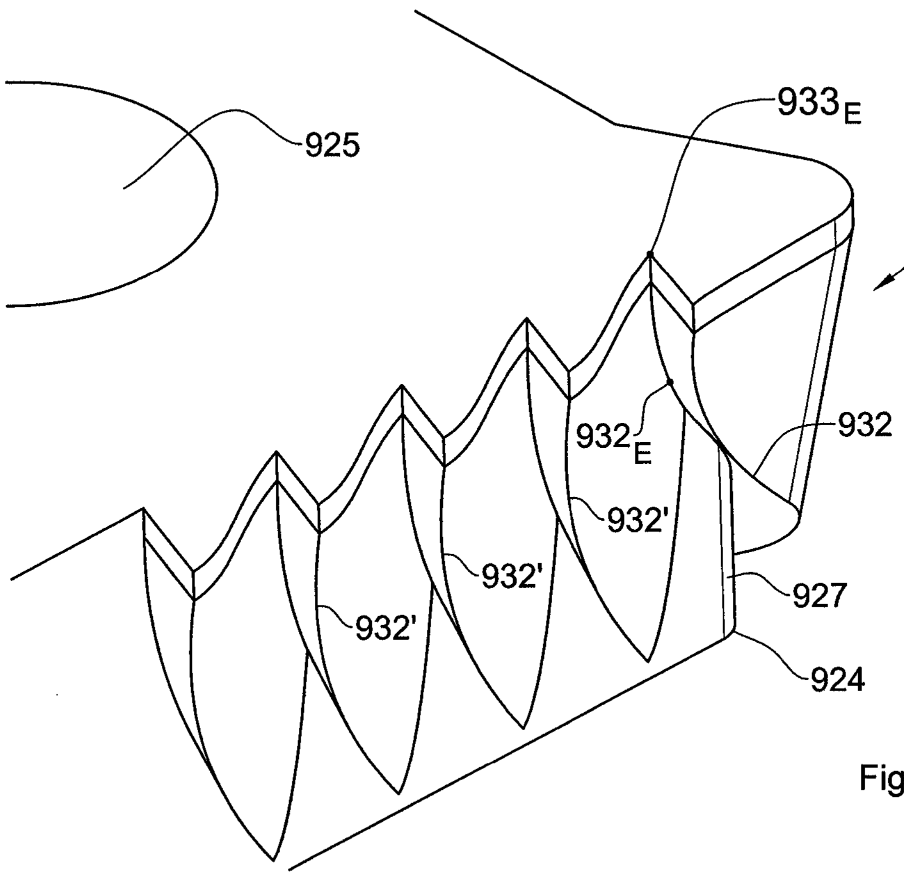


Fig. 25H

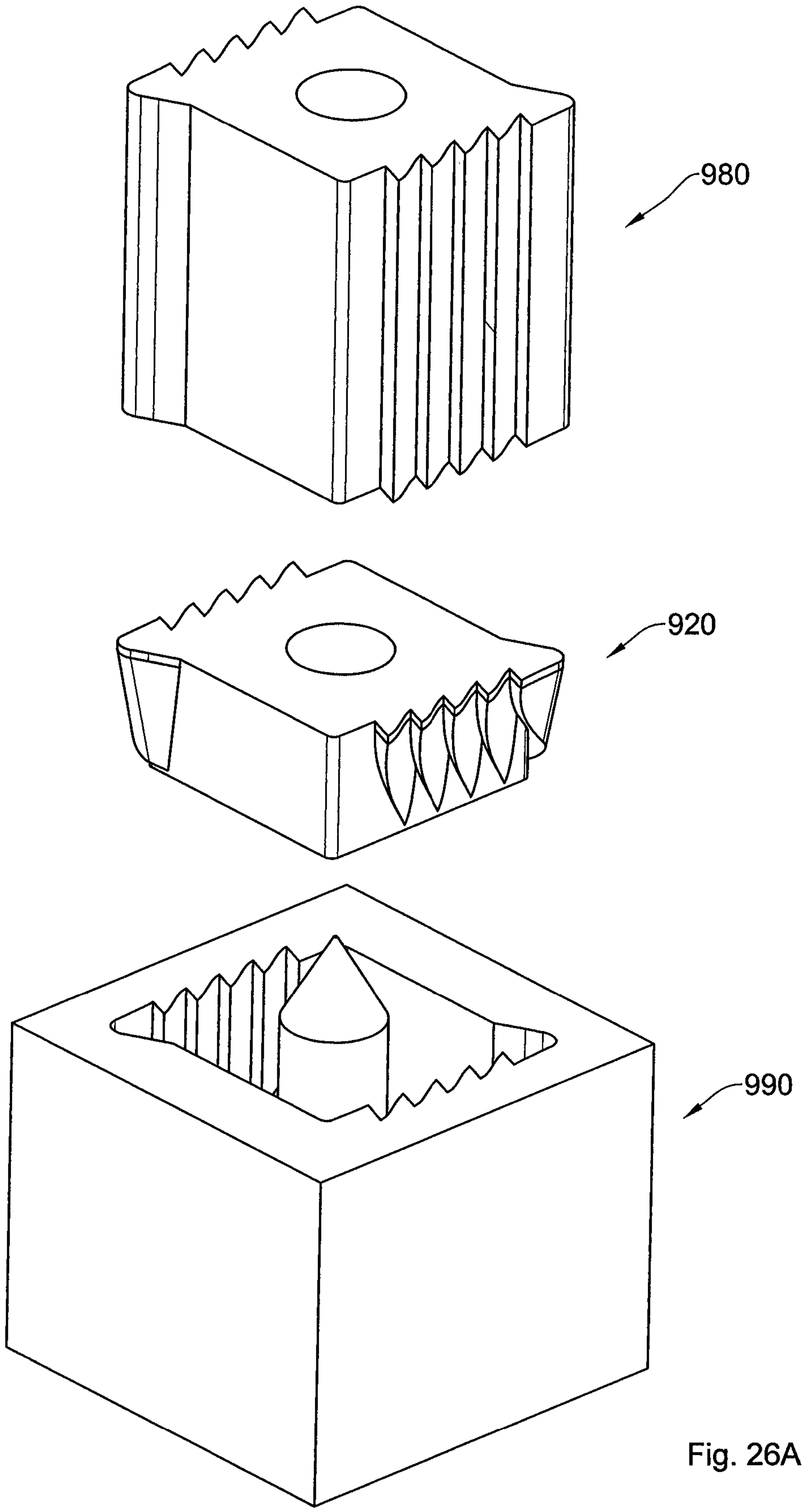


Fig. 26A

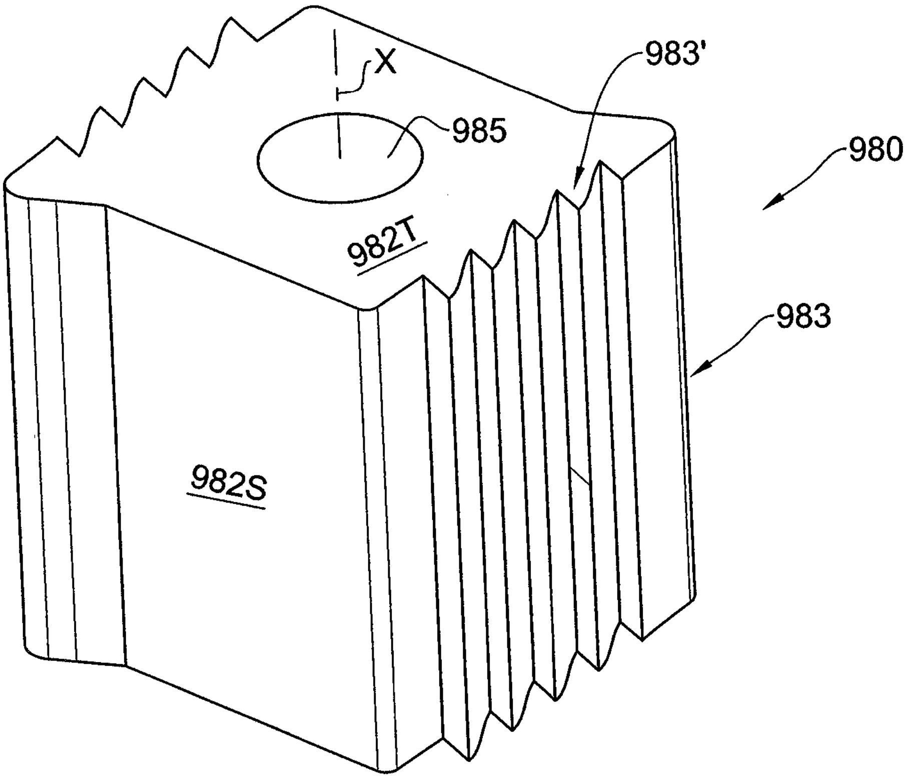


Fig. 26B

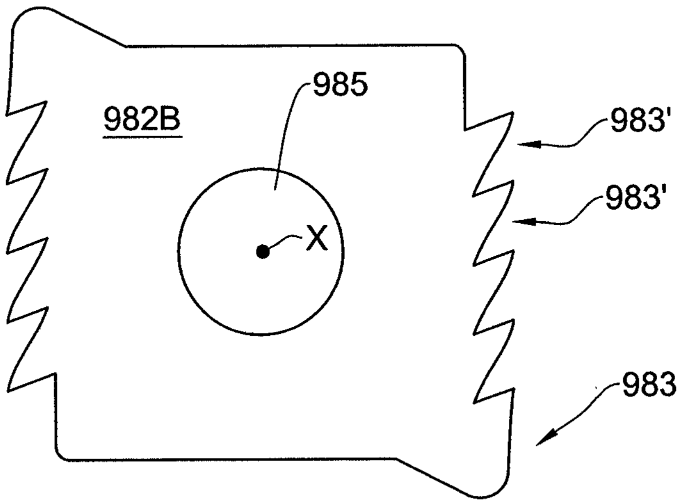


Fig. 26C

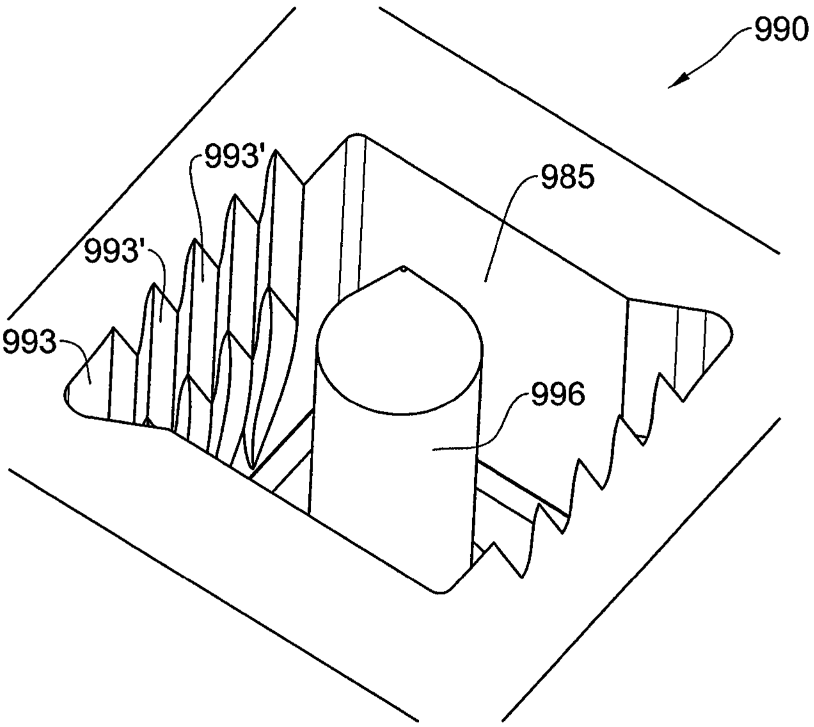


Fig. 26D

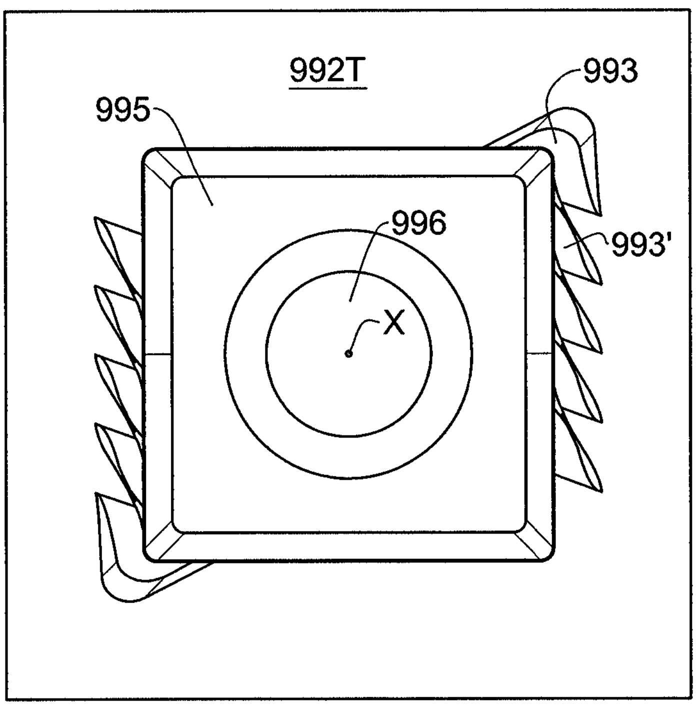


Fig. 26E

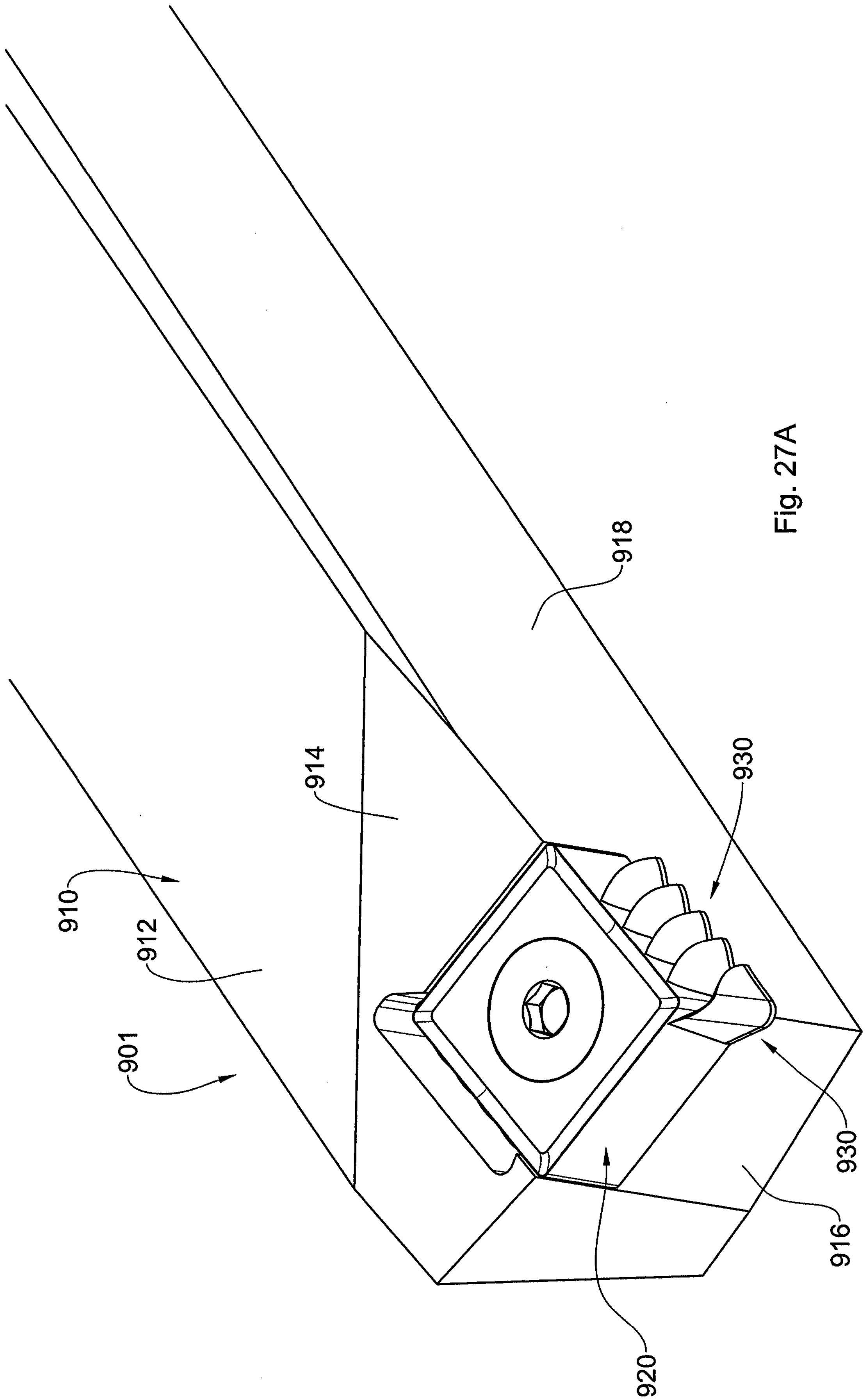


Fig. 27A

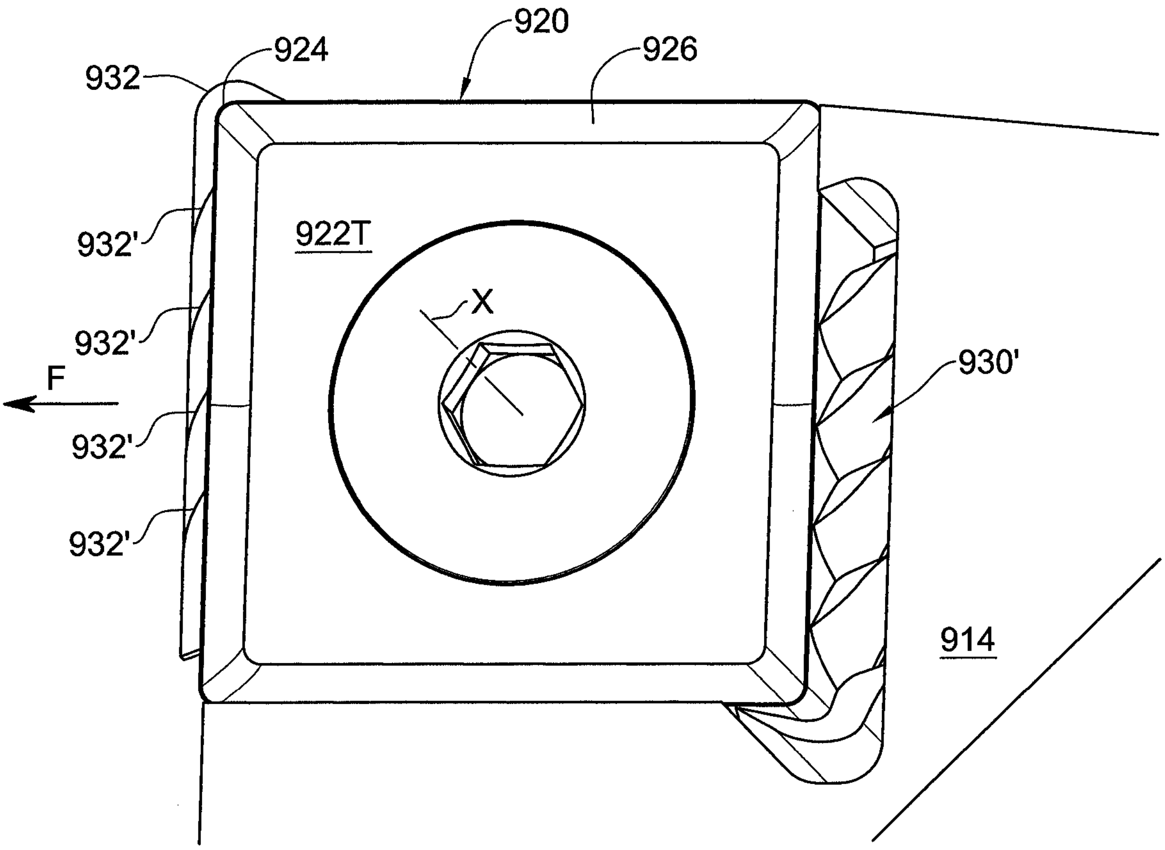


Fig. 27B

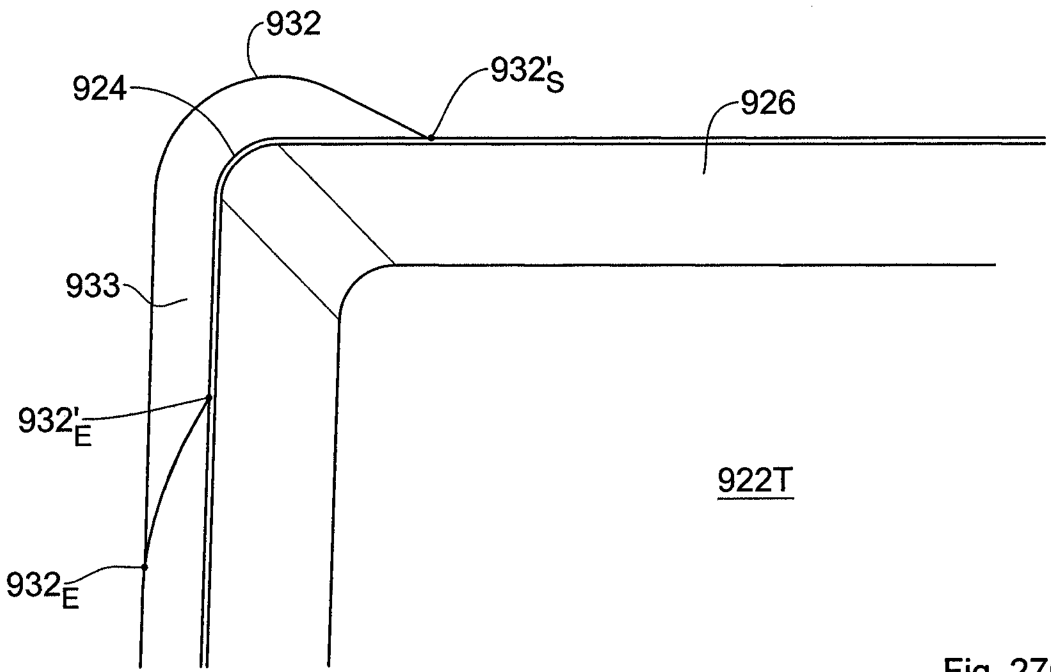


Fig. 27C

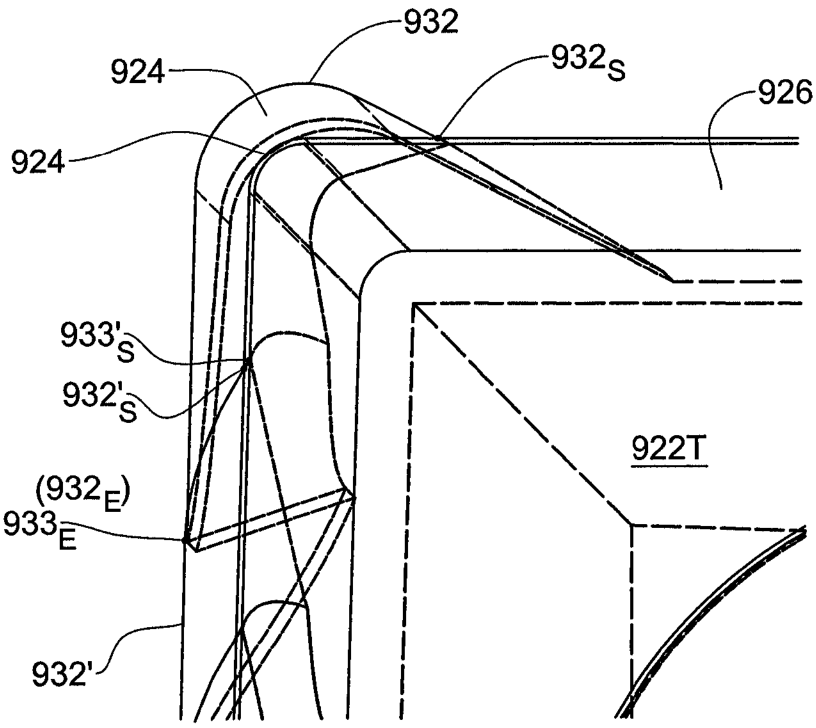


Fig. 27D

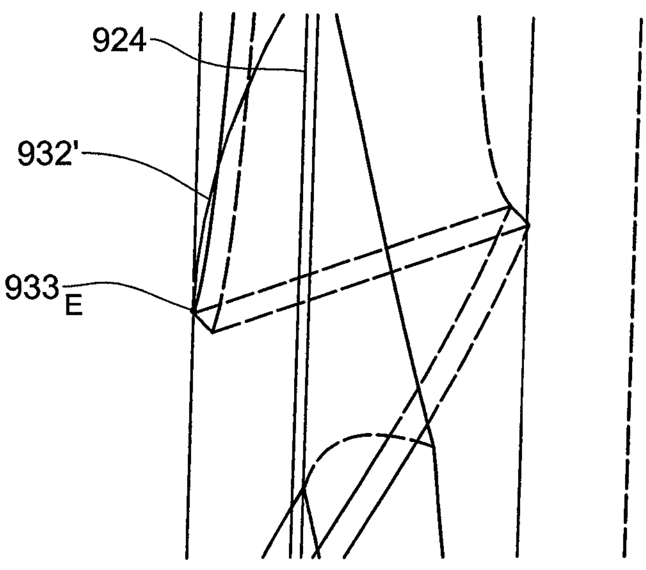


Fig. 27E

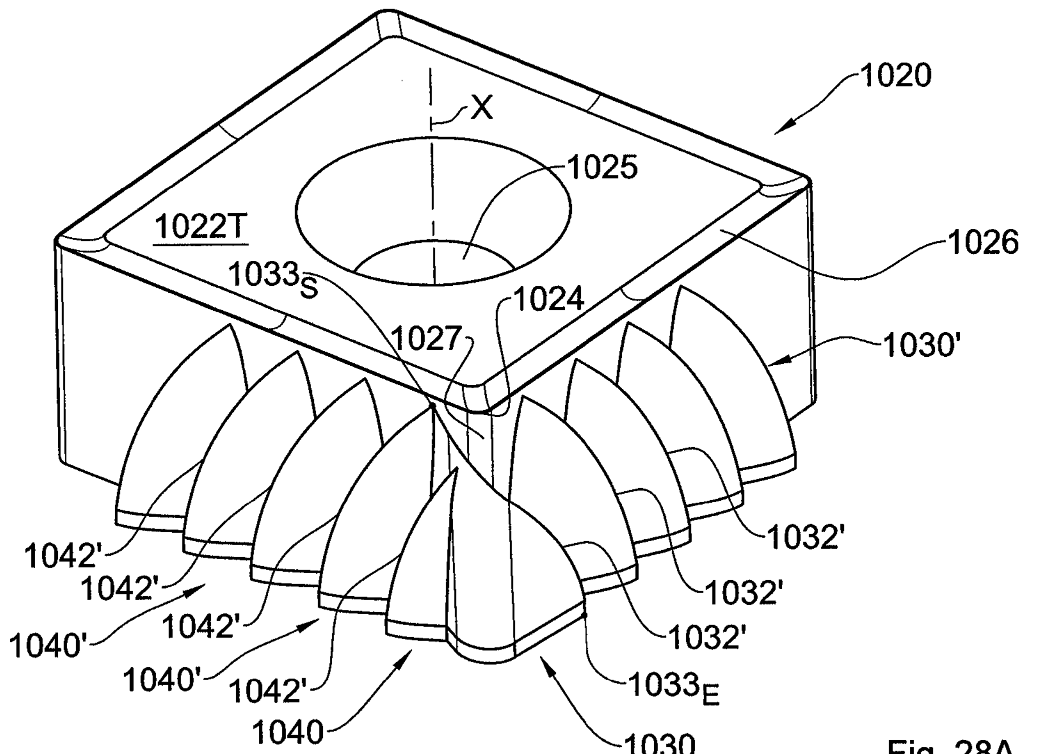


Fig. 28A

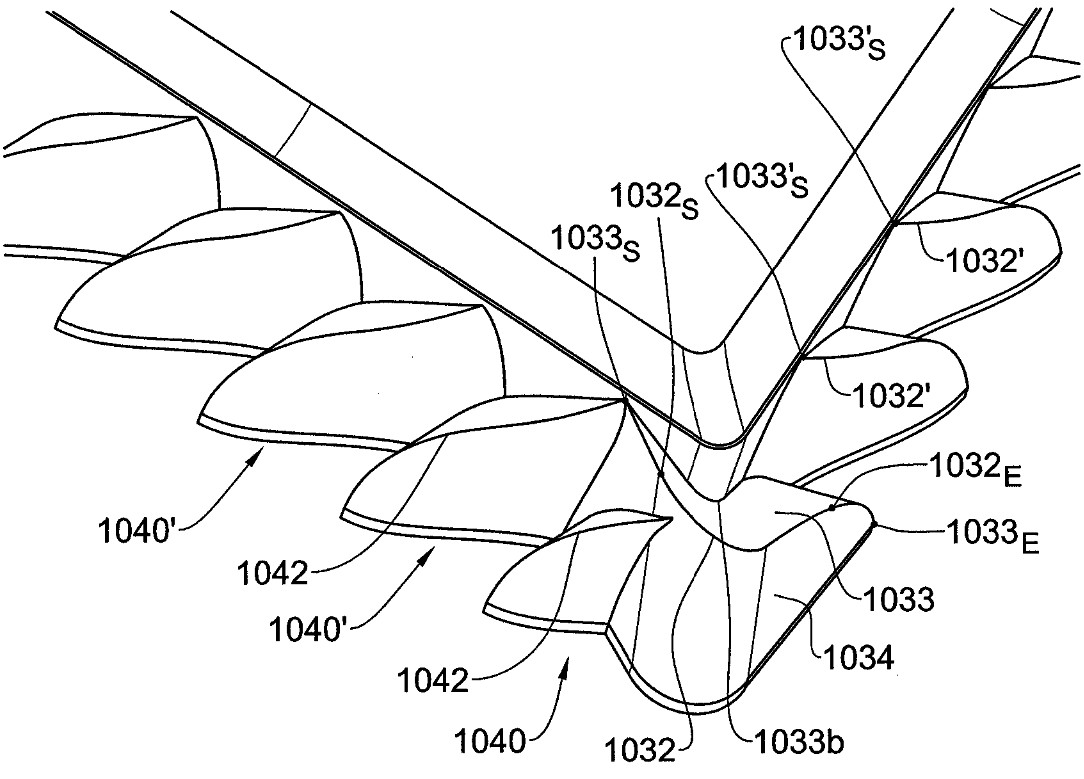


Fig. 28B

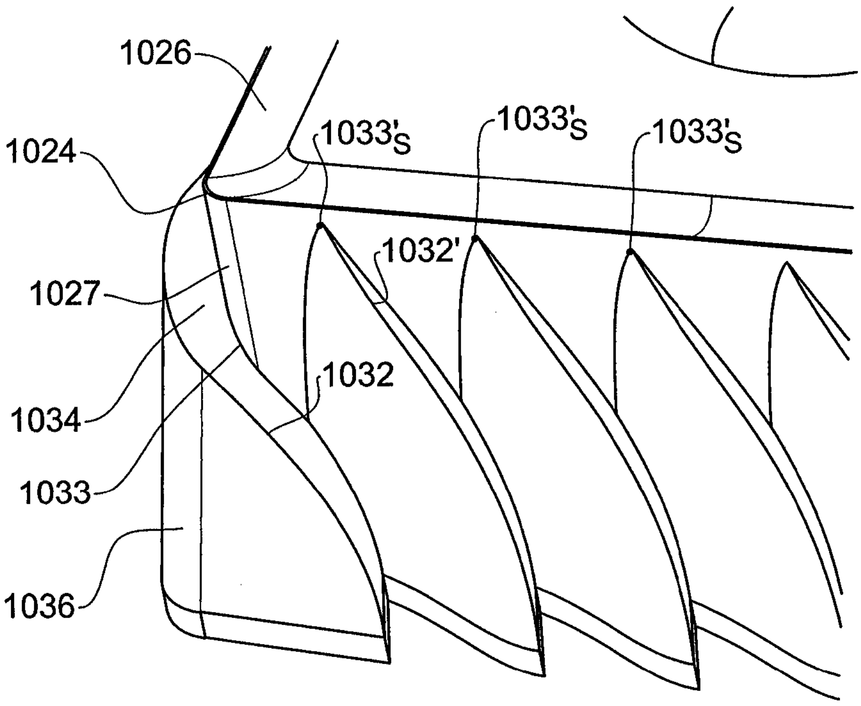


Fig. 28C

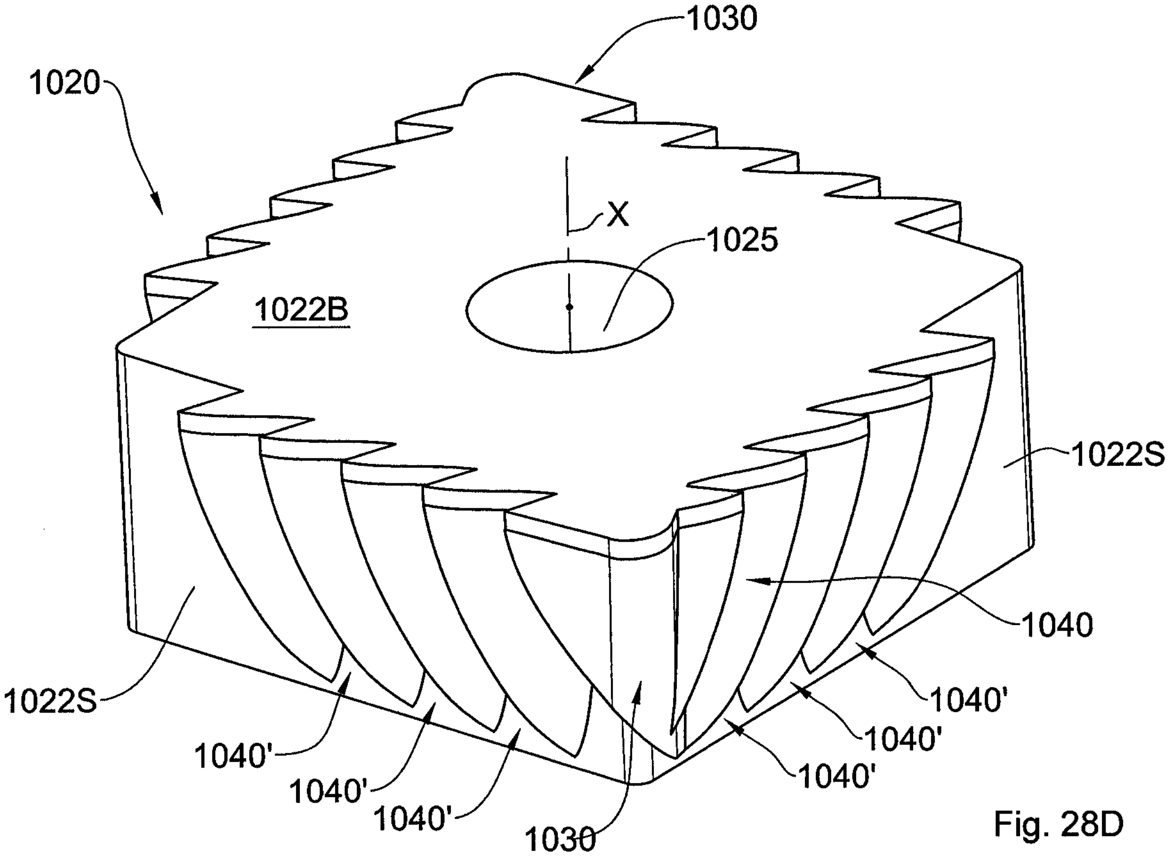


Fig. 28D

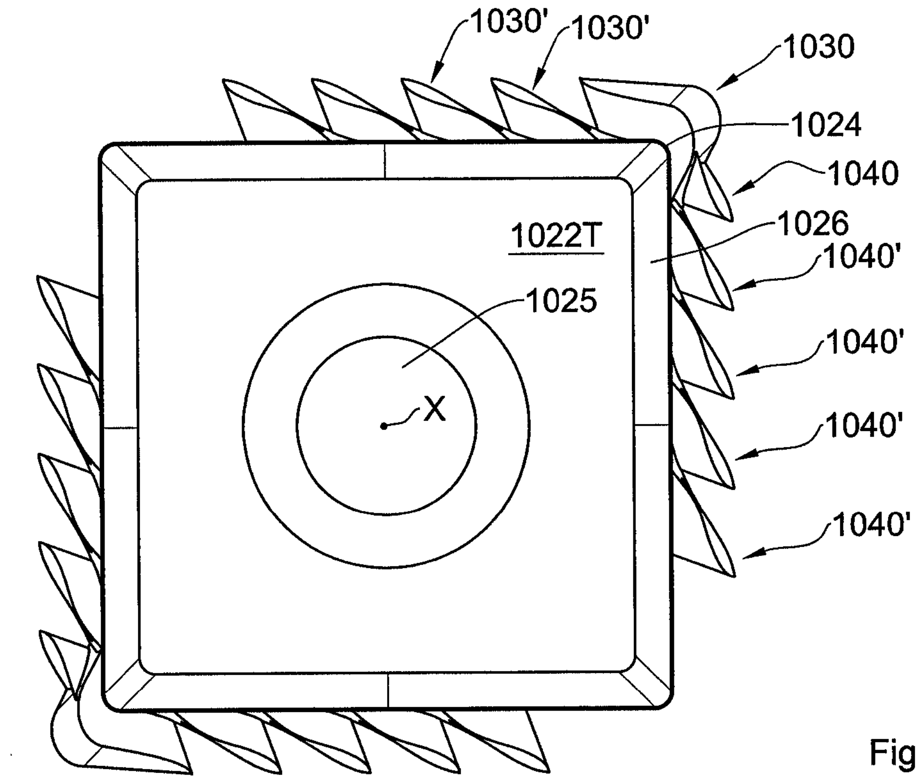


Fig. 28E

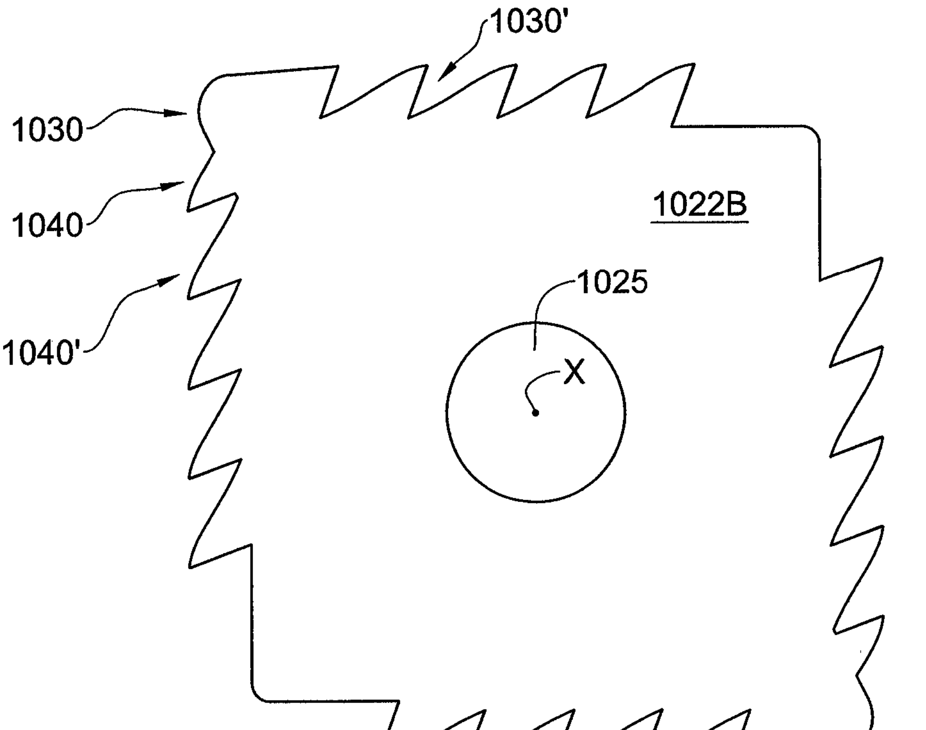


Fig. 28F

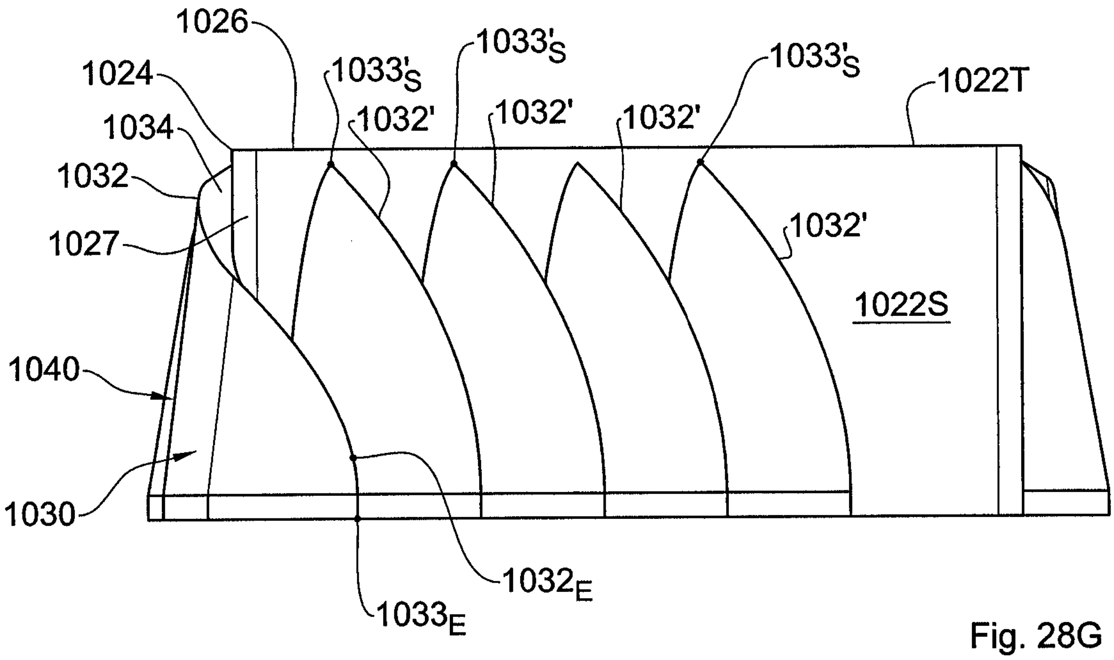


Fig. 28G

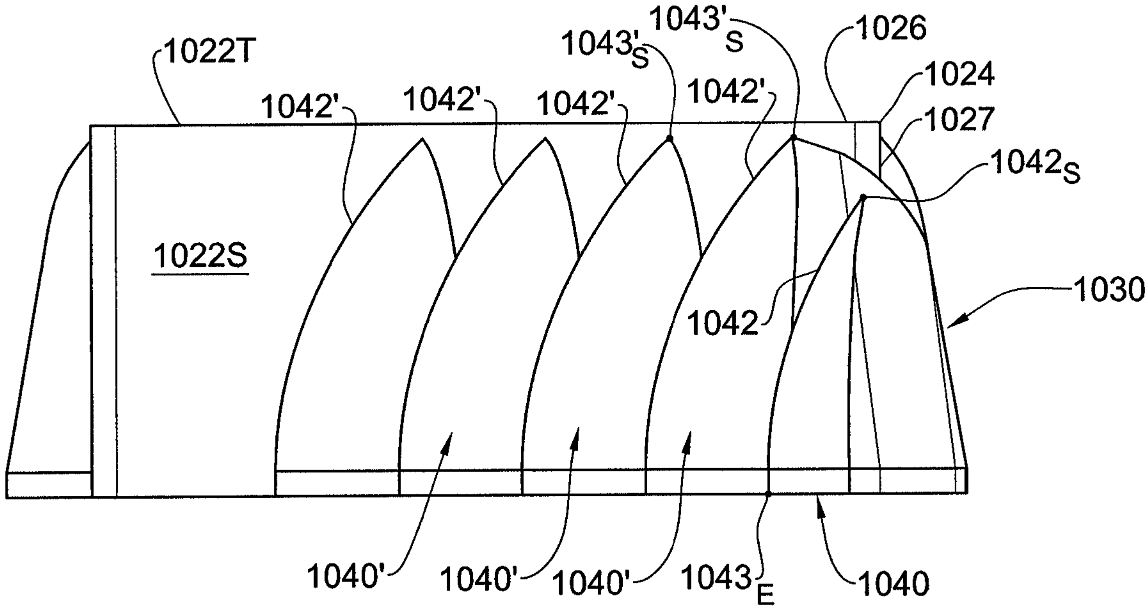


Fig. 28H

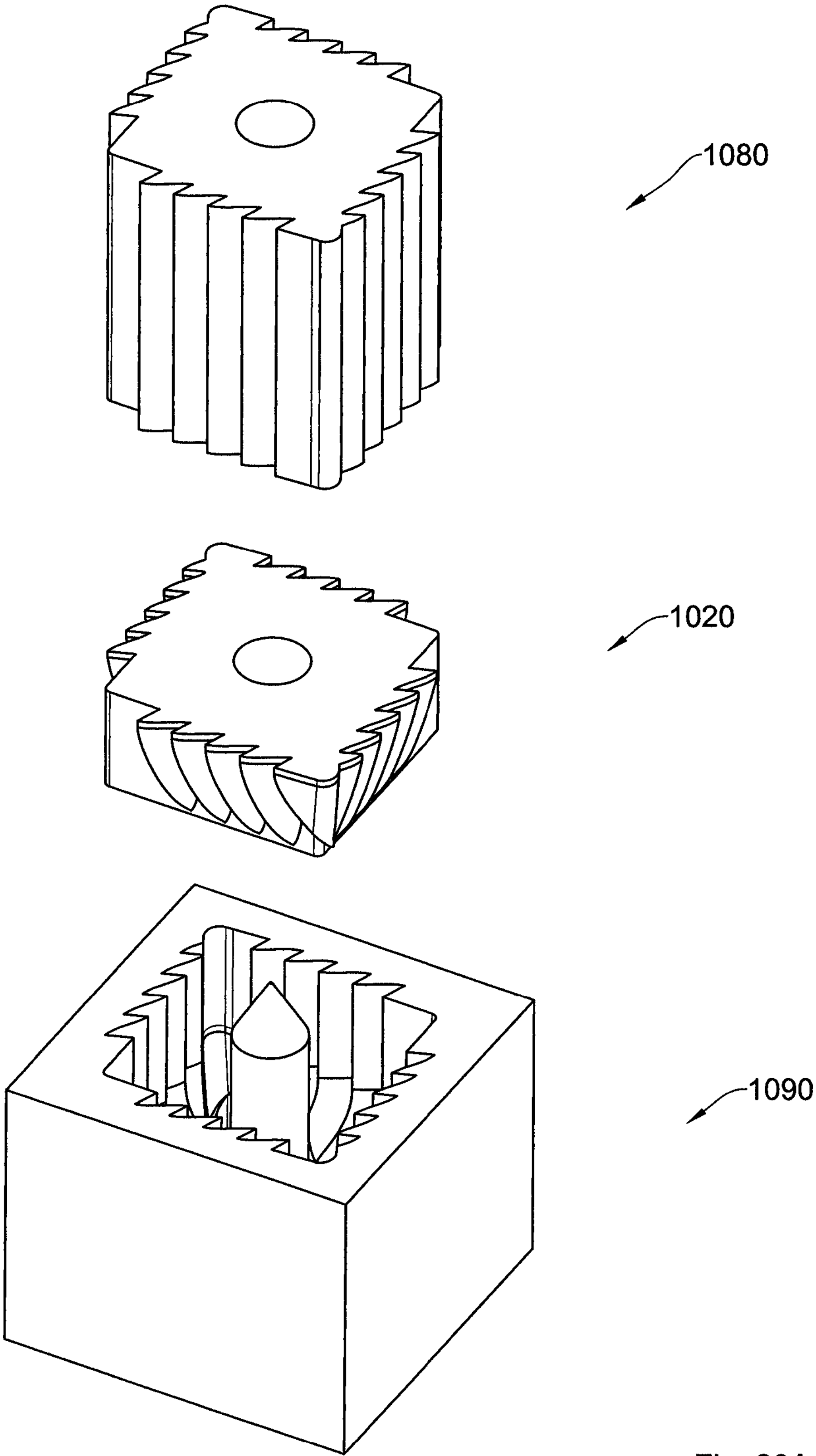


Fig. 29A

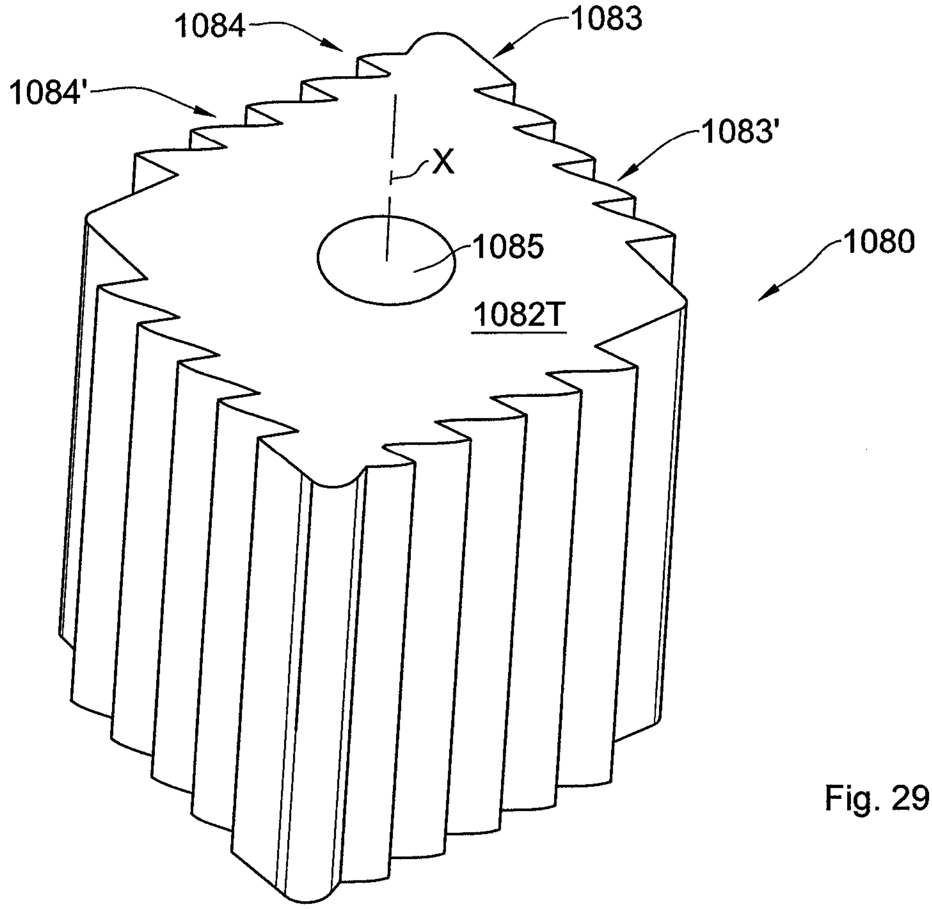


Fig. 29B

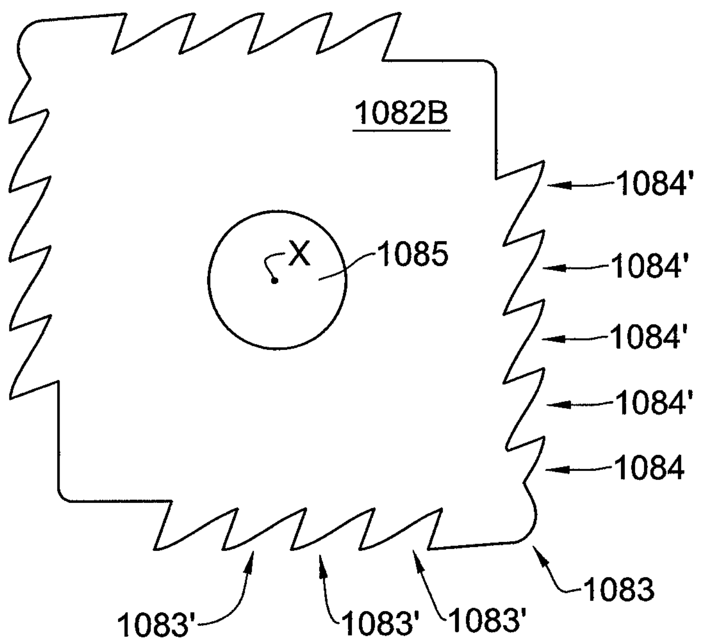


Fig. 29C

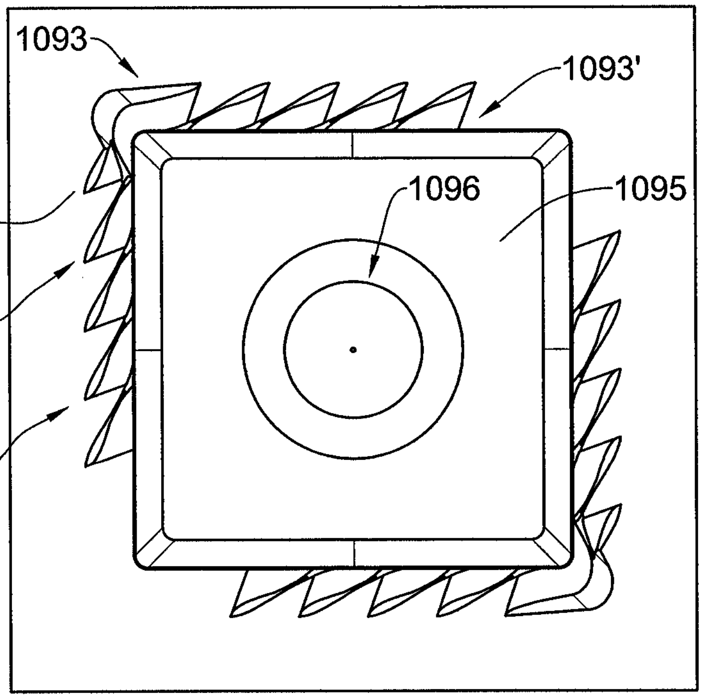


Fig. 29D

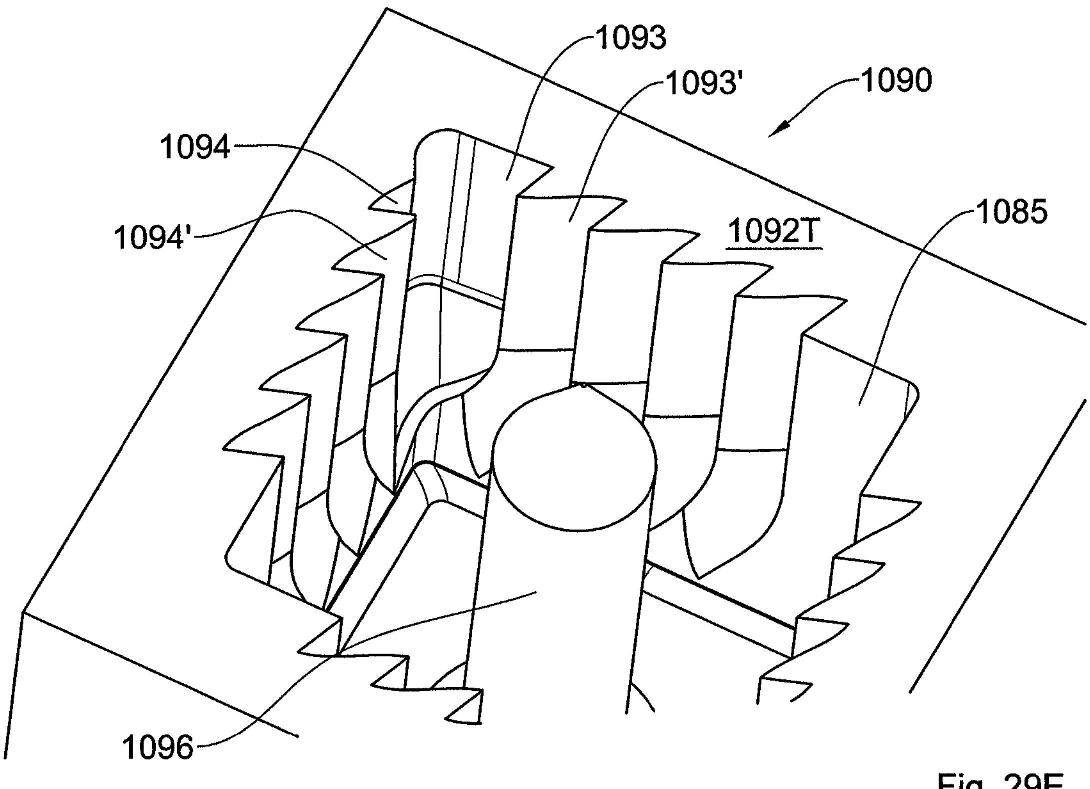


Fig. 29E

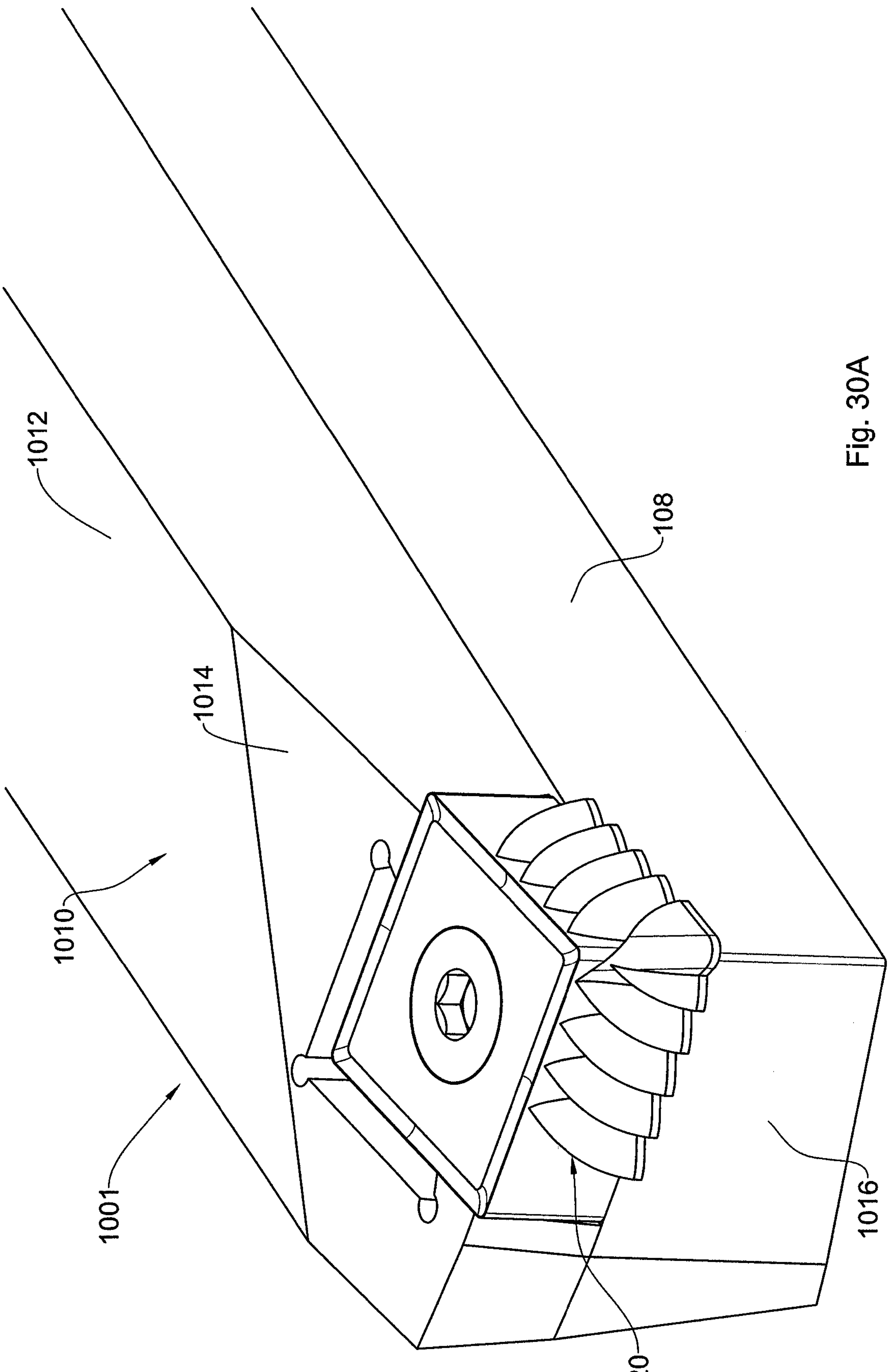


Fig. 30A

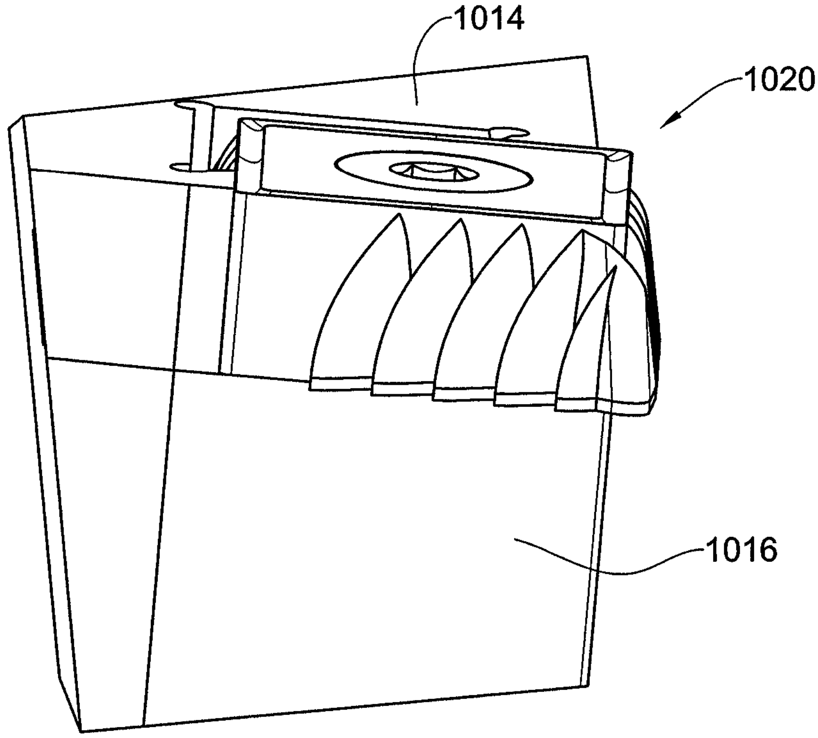


Fig. 30B

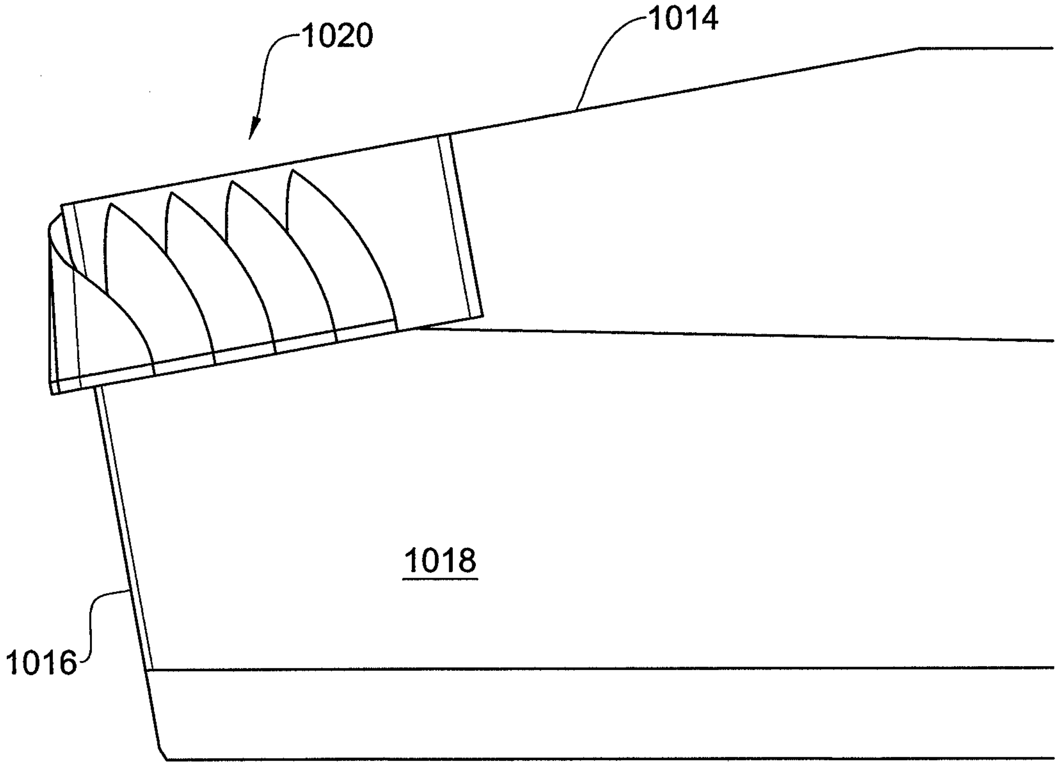


Fig. 30C

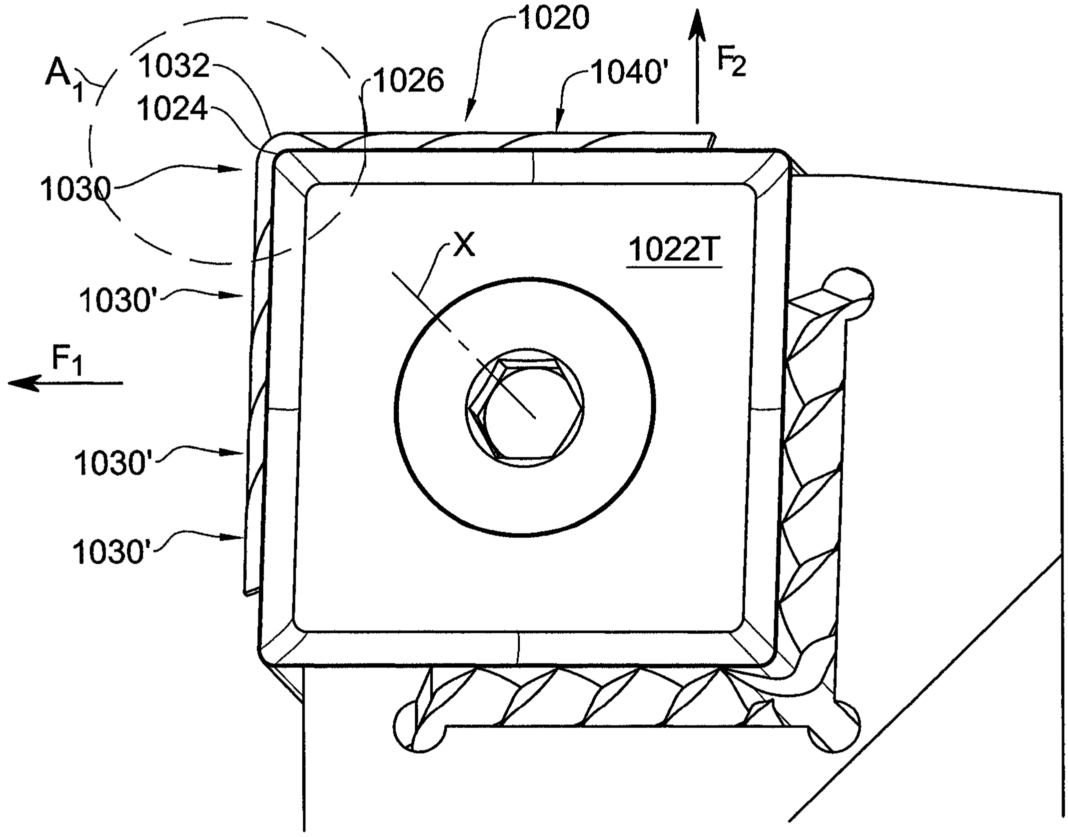


Fig. 30D

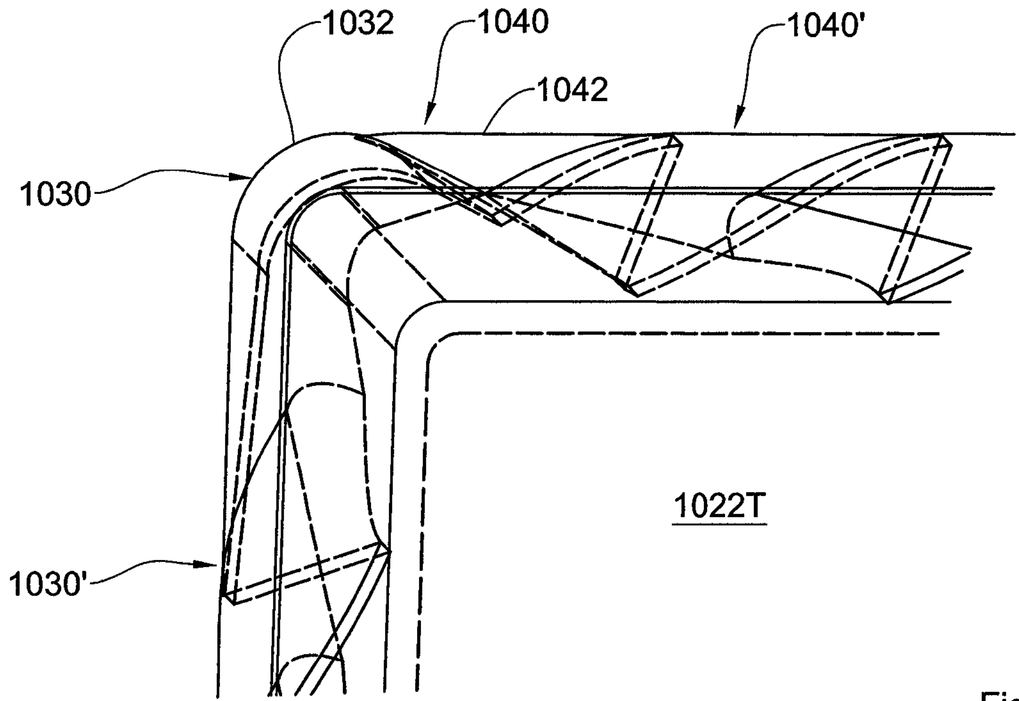


Fig. 30E

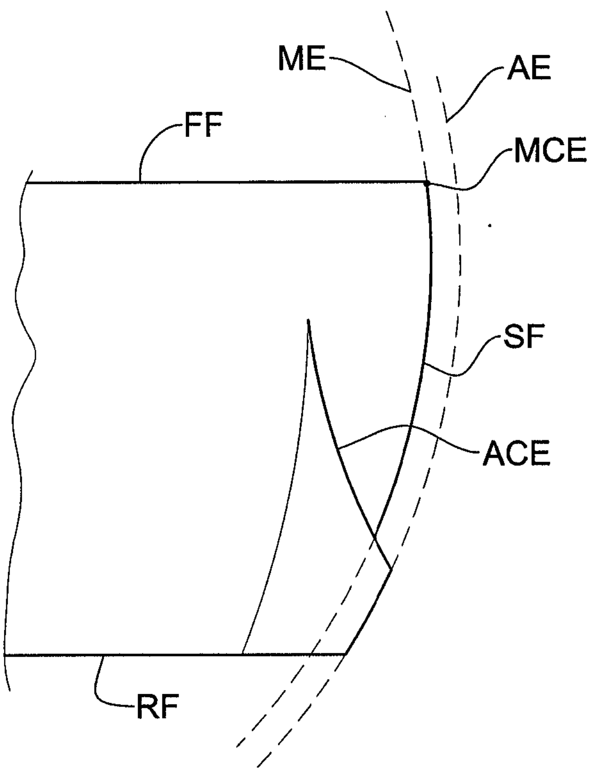


Fig. 31

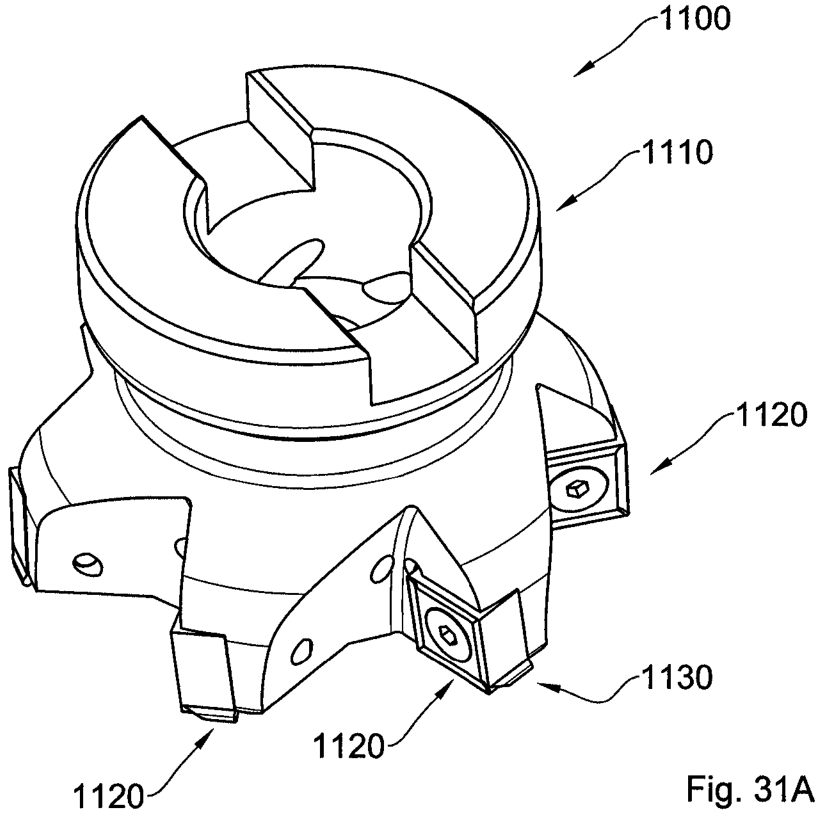


Fig. 31A

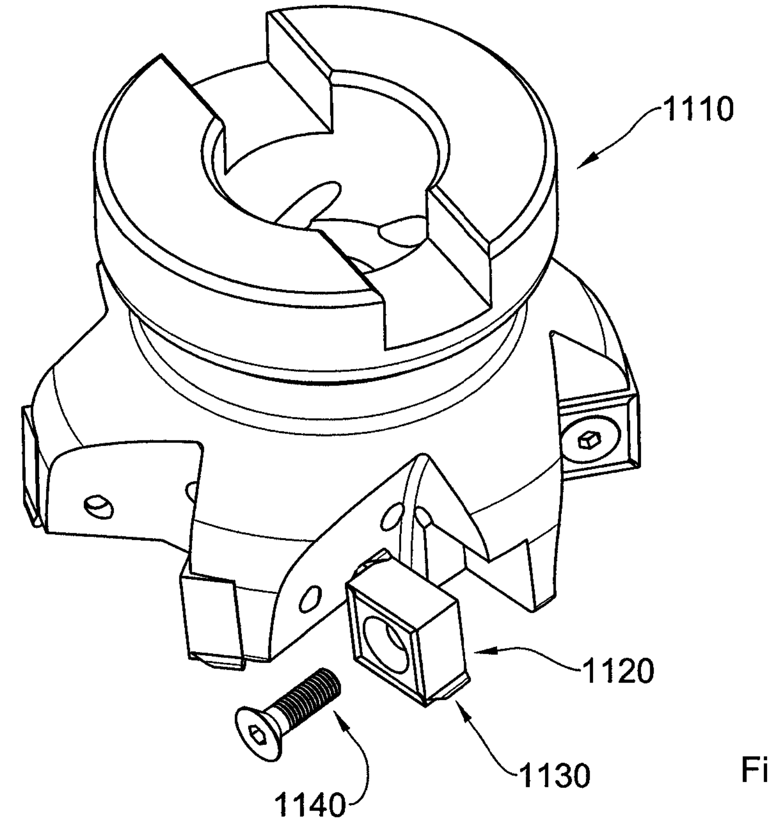


Fig. 31B

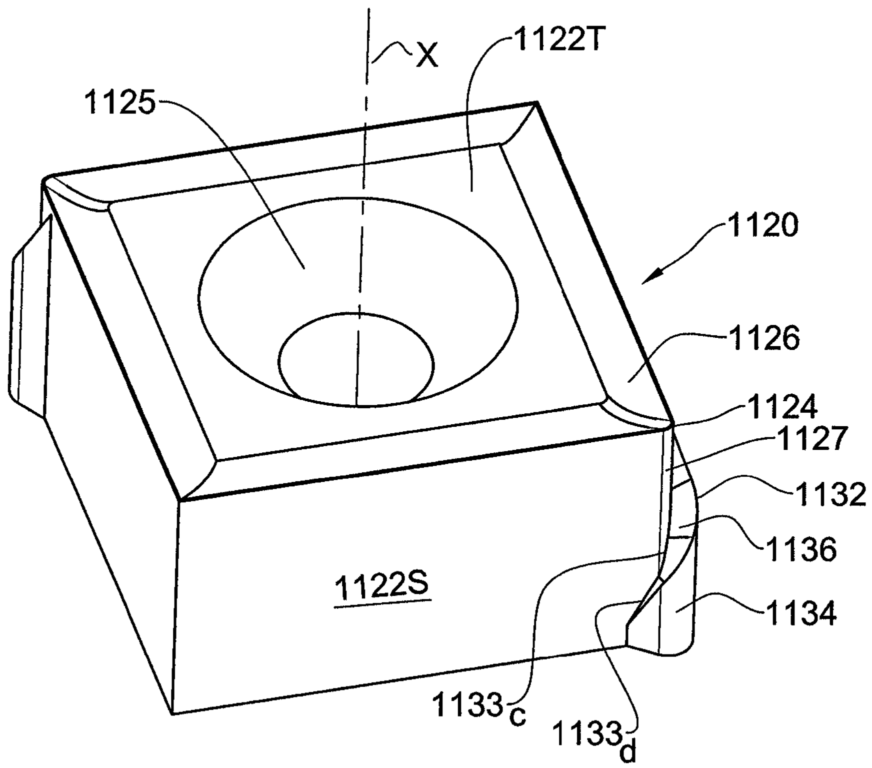


Fig. 31C

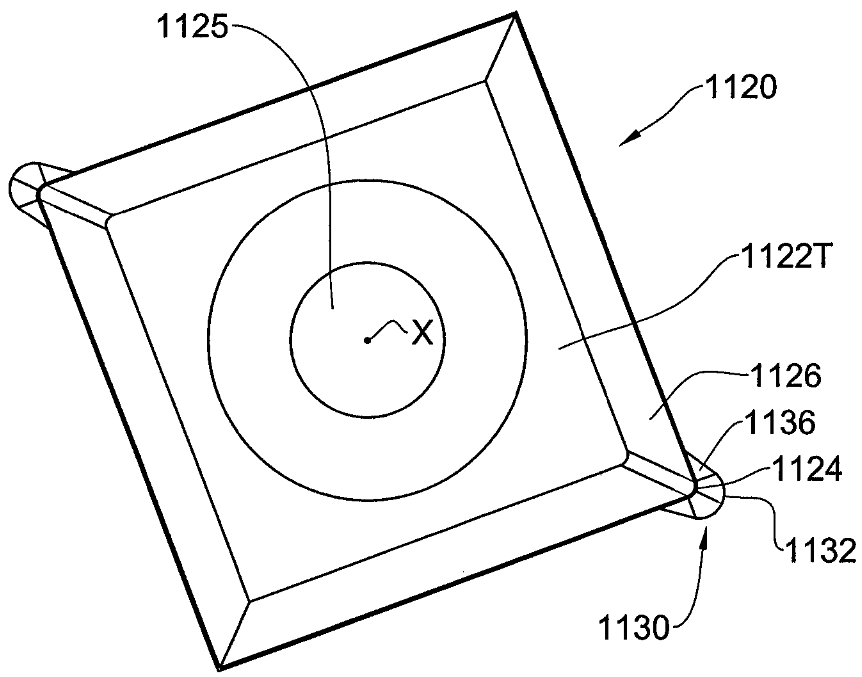


Fig. 31D

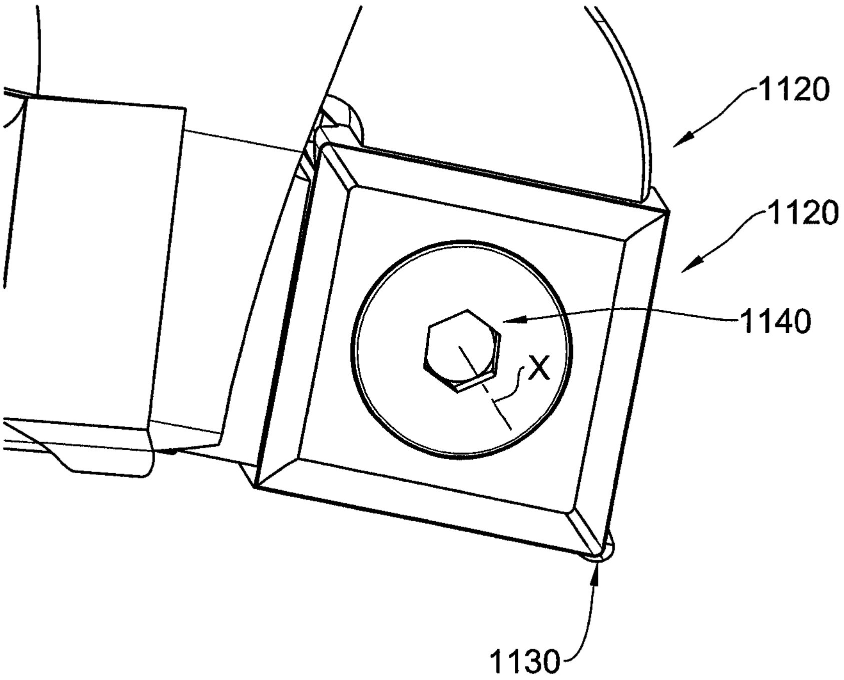


Fig. 31E

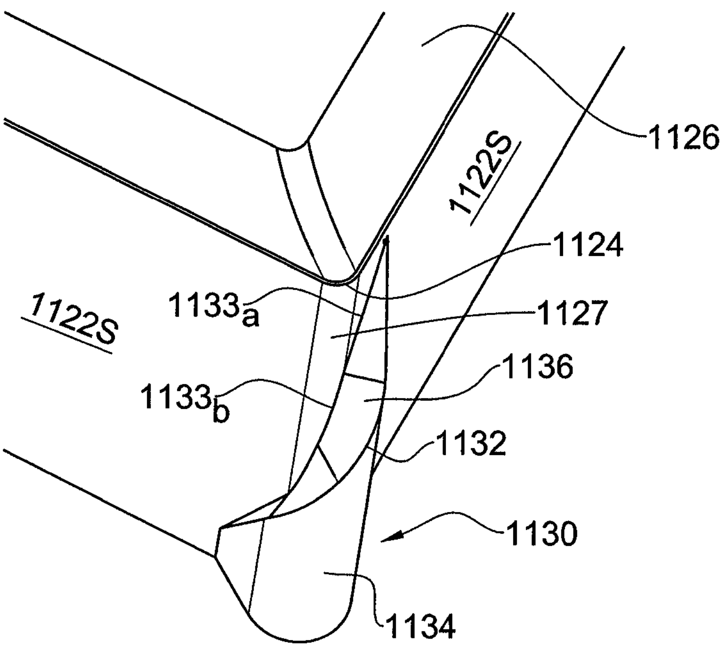


Fig. 31F

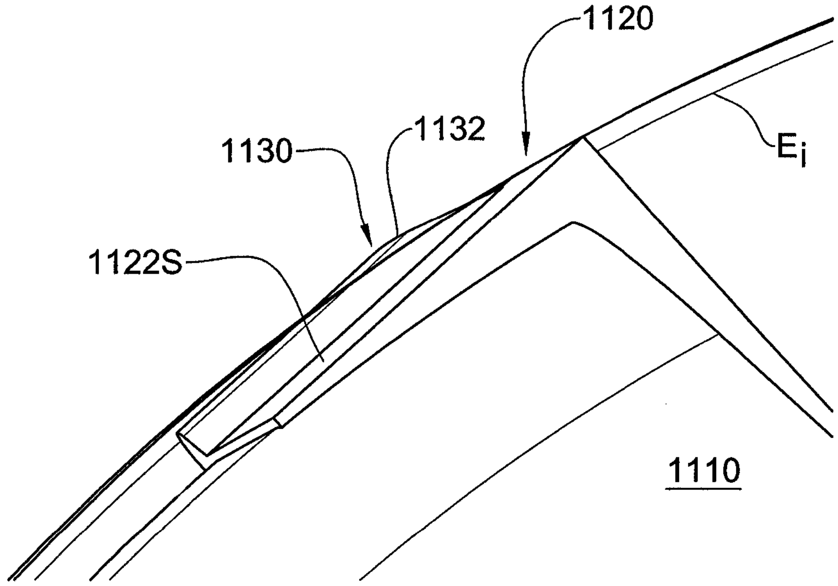
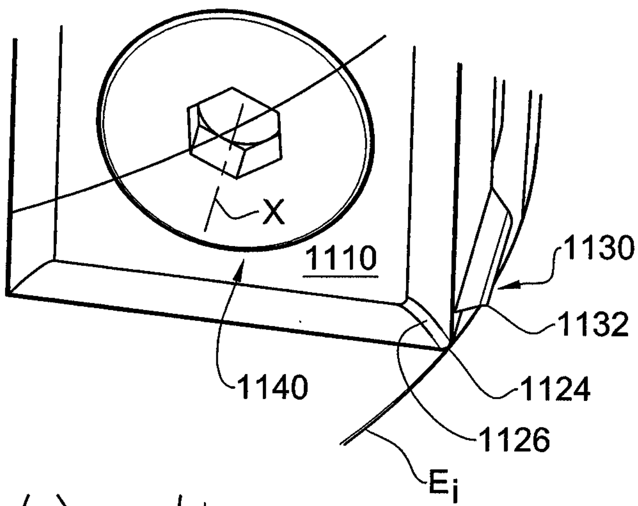


Fig. 31G

Fig. 31H



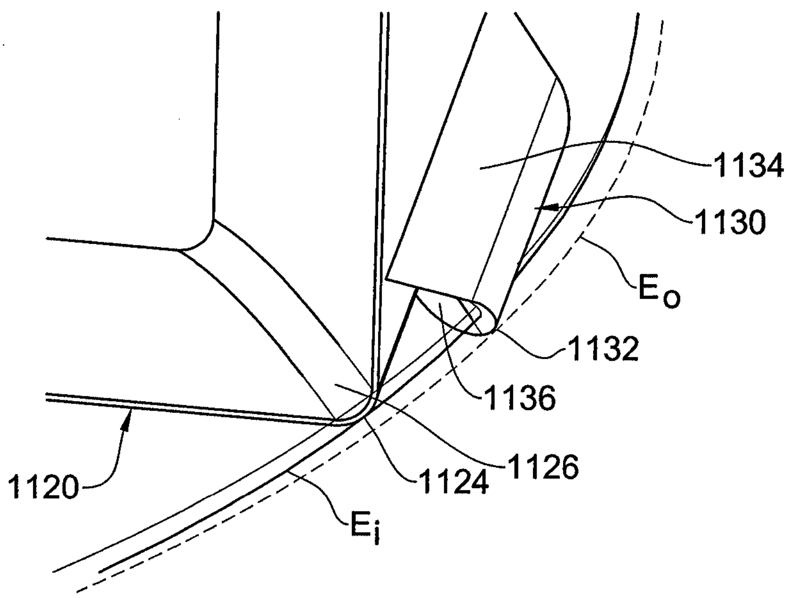


Fig. 31I

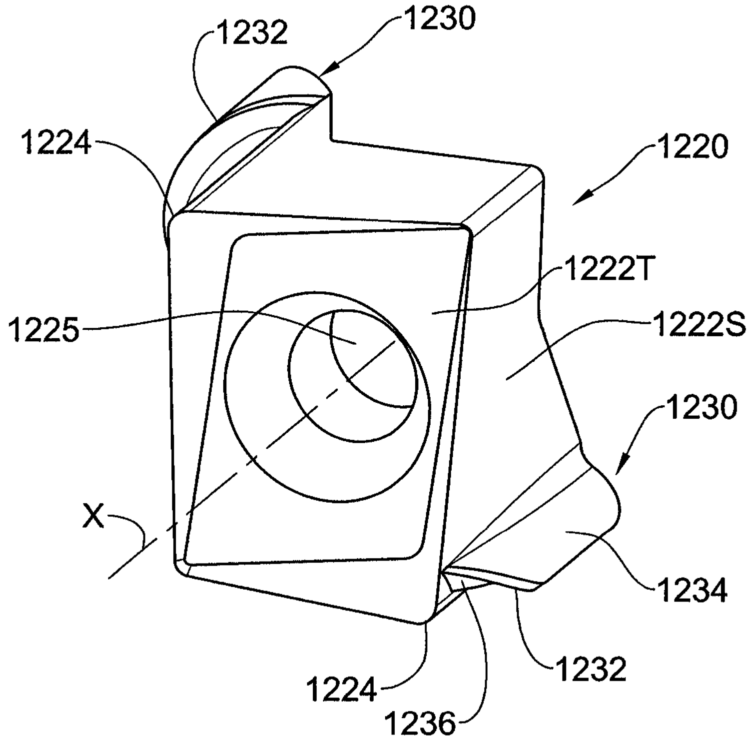


Fig. 32A

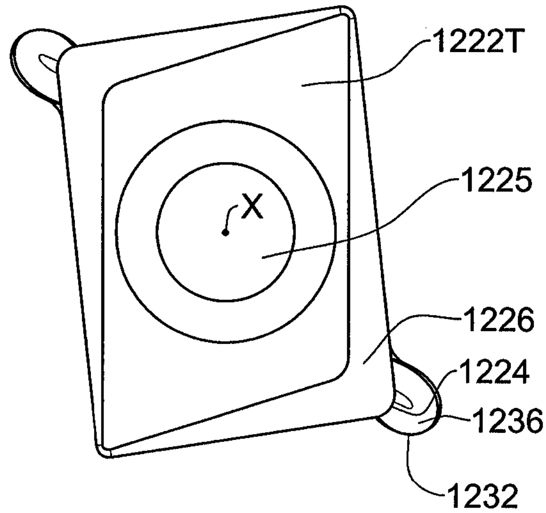


Fig. 32B

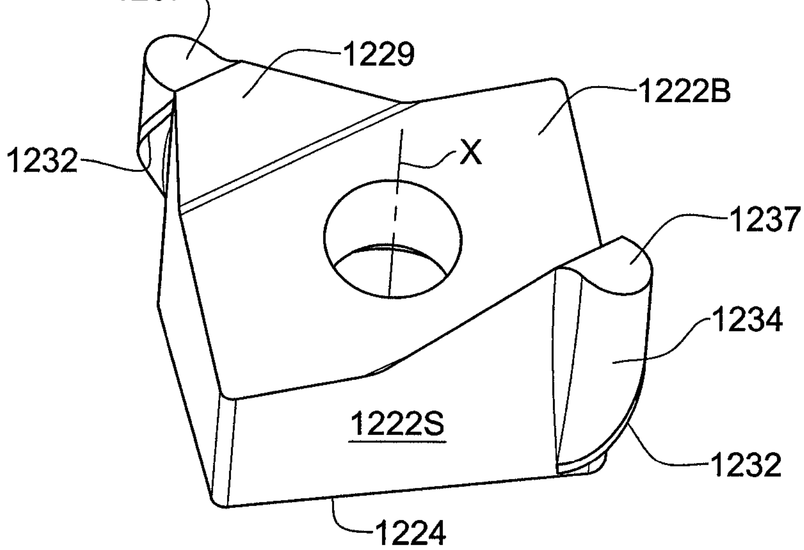


Fig. 32C

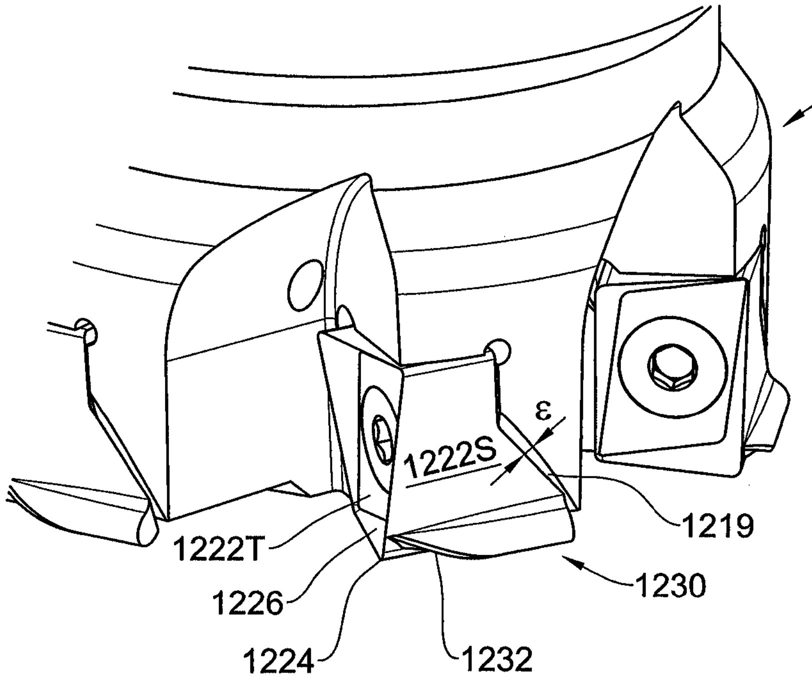


Fig. 32D

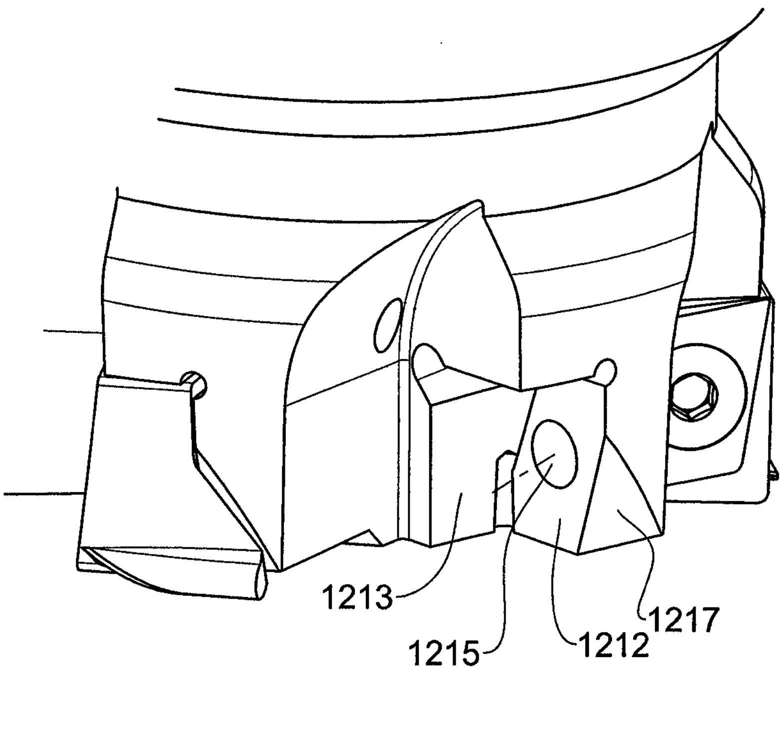


Fig. 32E

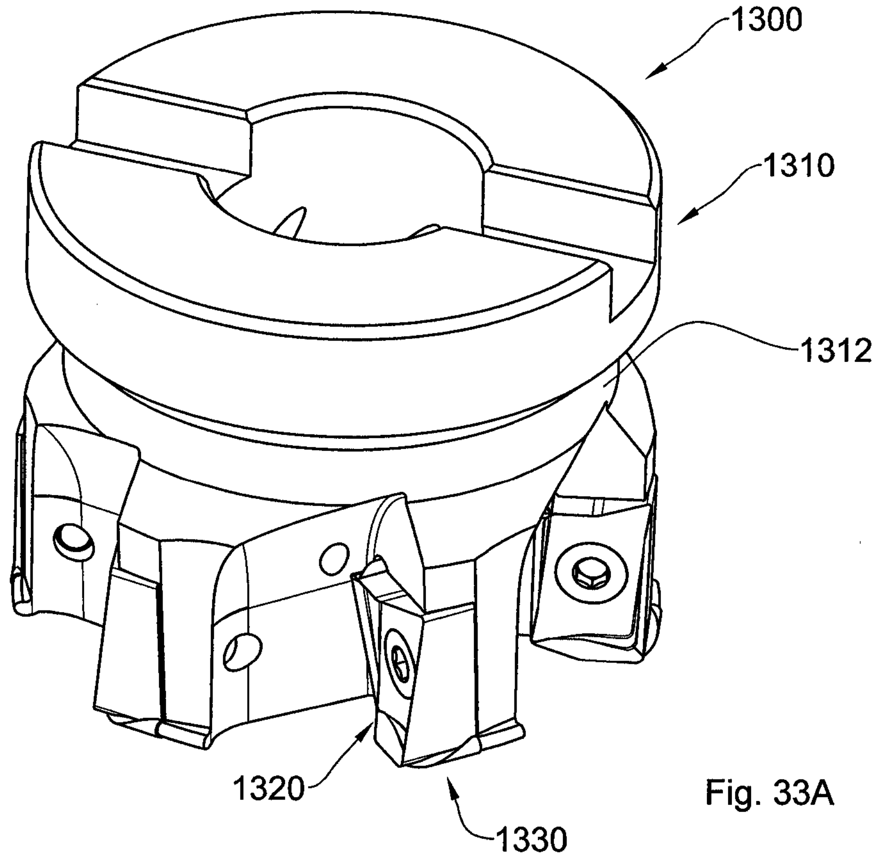


Fig. 33A

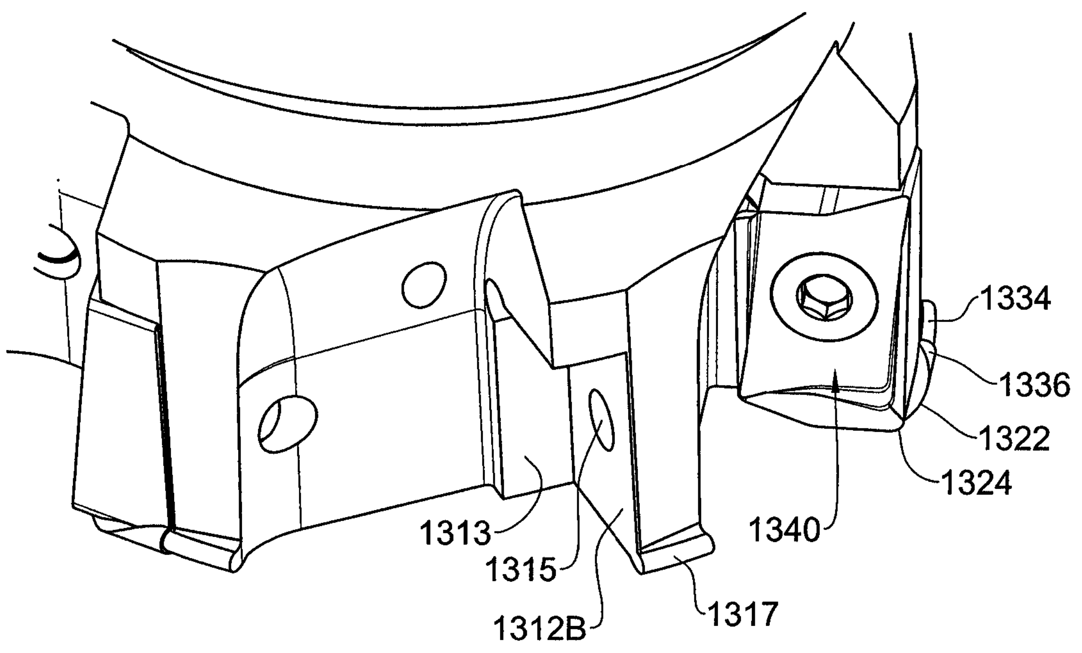


Fig. 33B

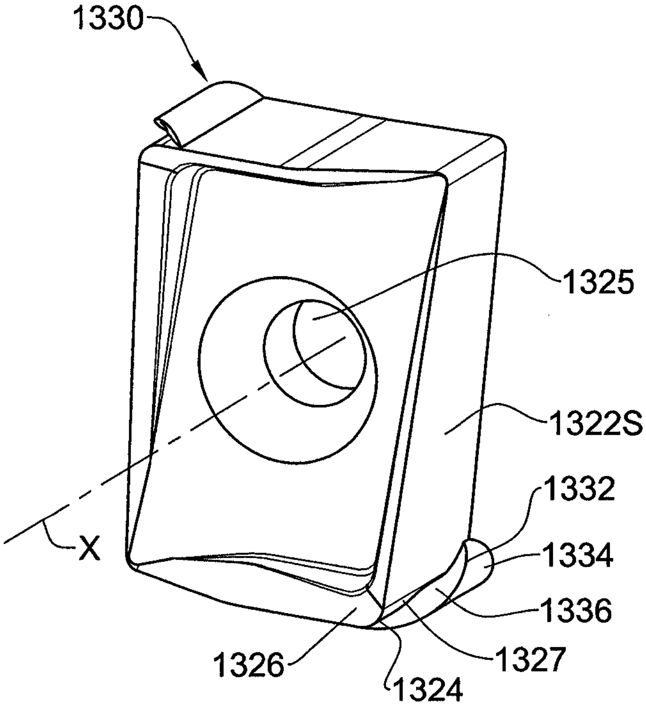


Fig. 33C

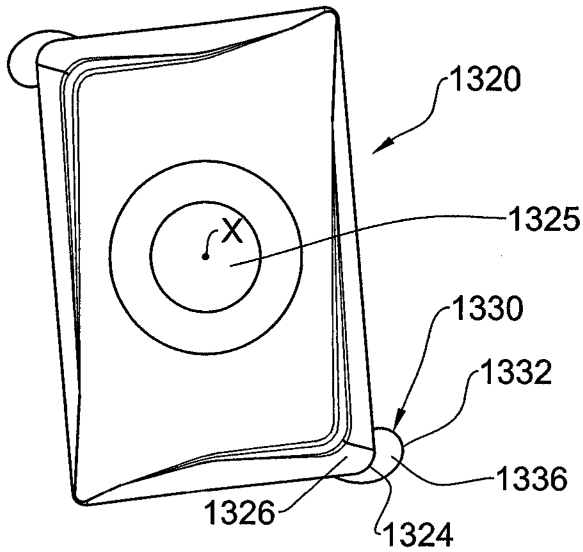


Fig. 33D

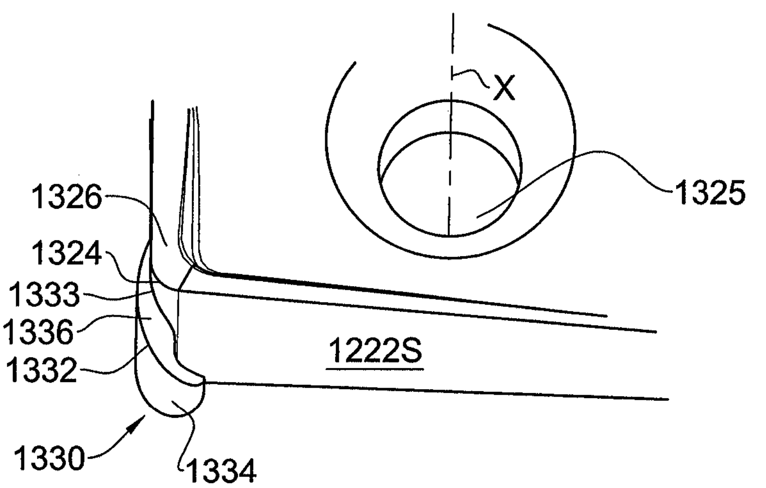


Fig. 33E

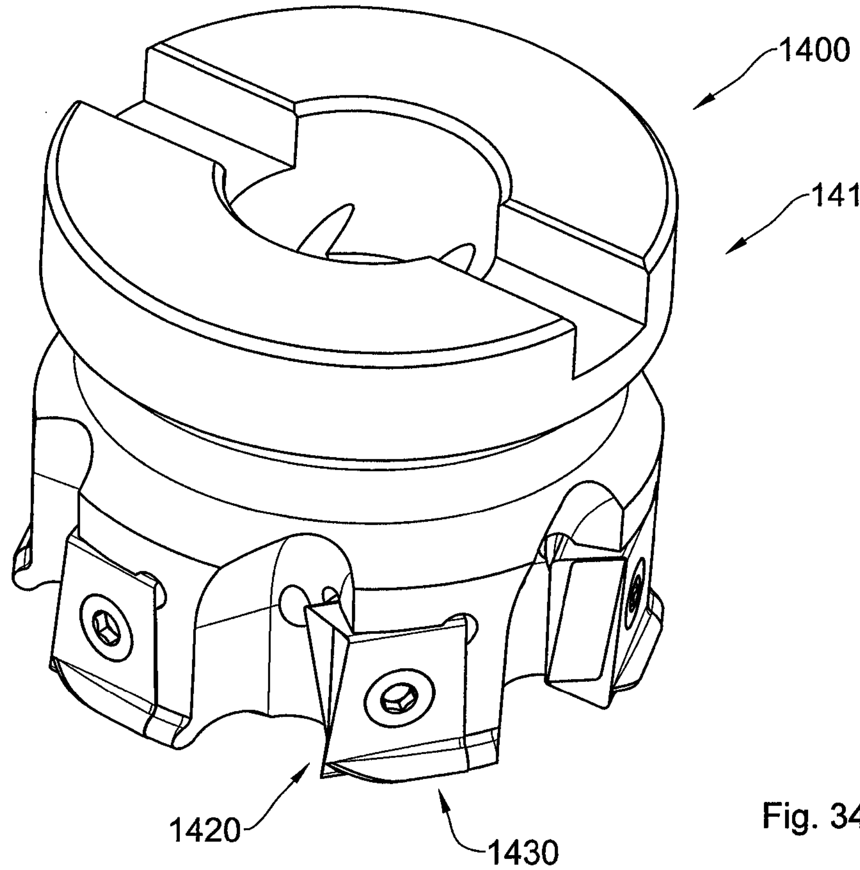


Fig. 34A

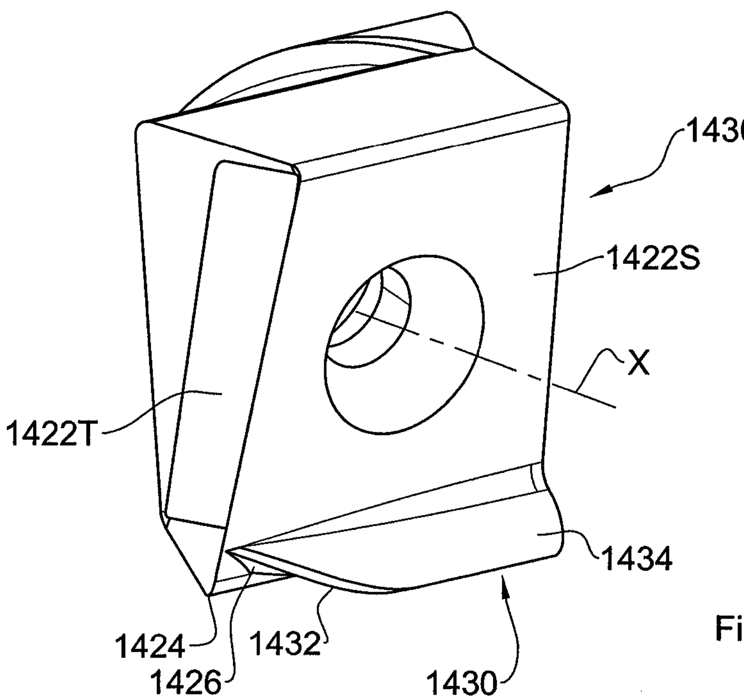


Fig. 34B

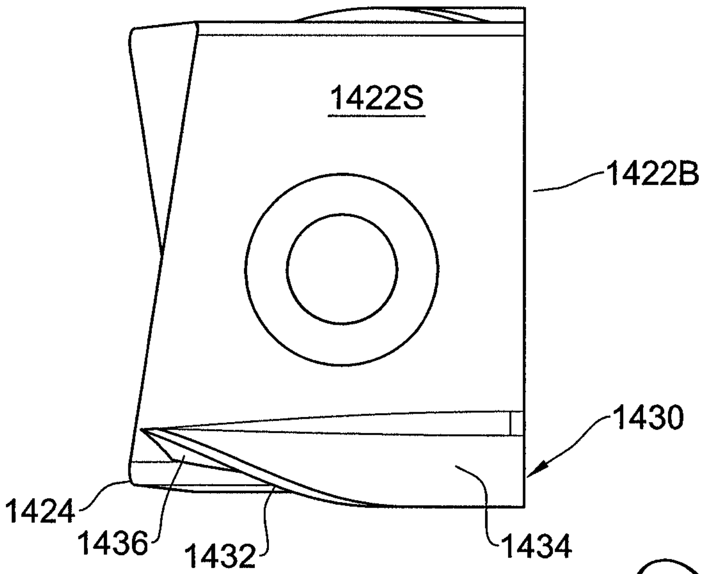


Fig. 34C

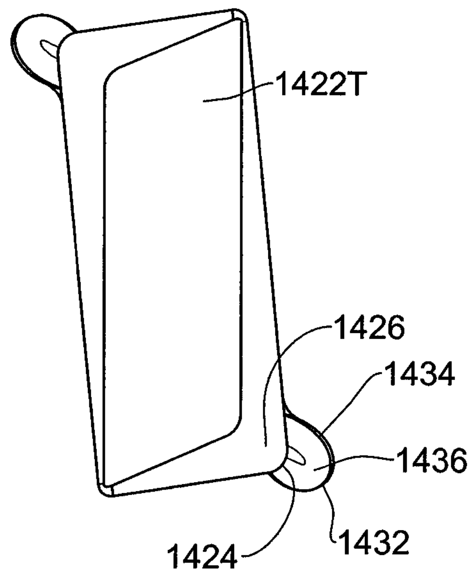


Fig. 34D

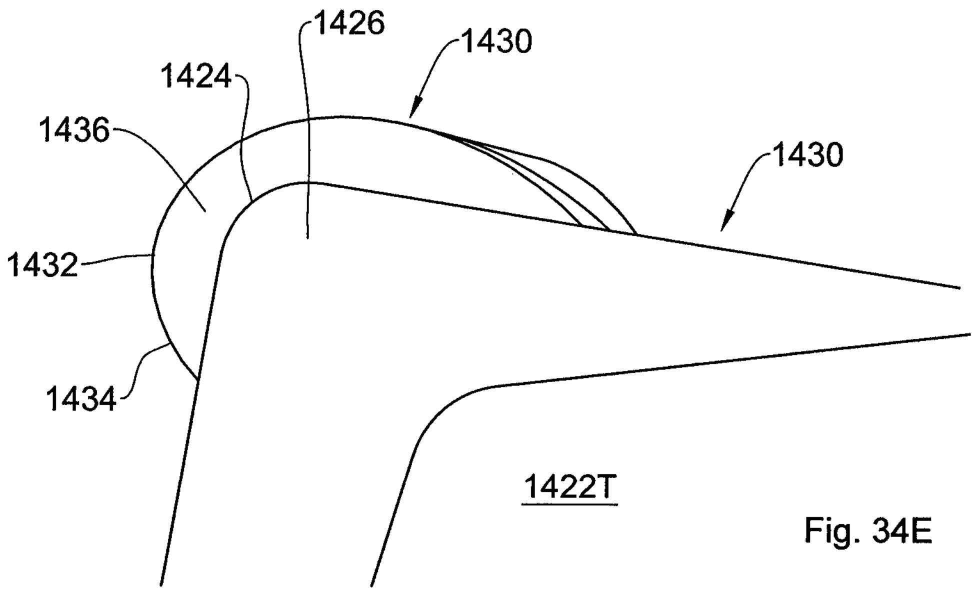


Fig. 34E

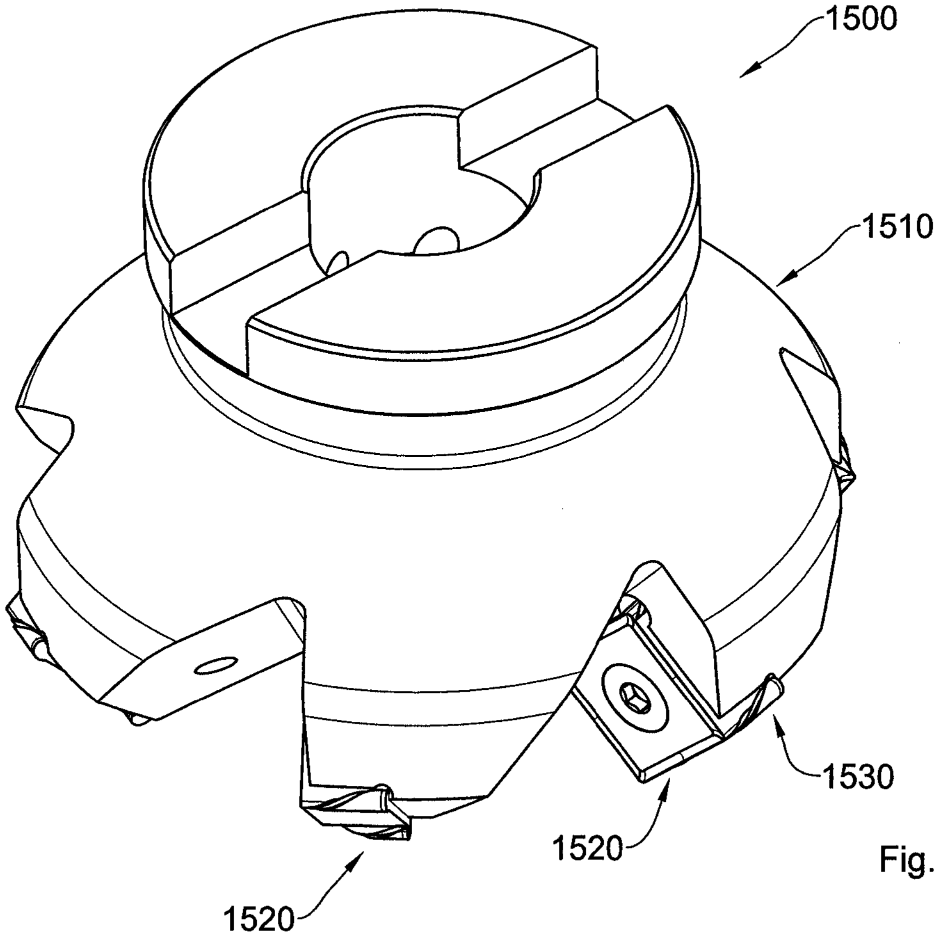


Fig. 35A

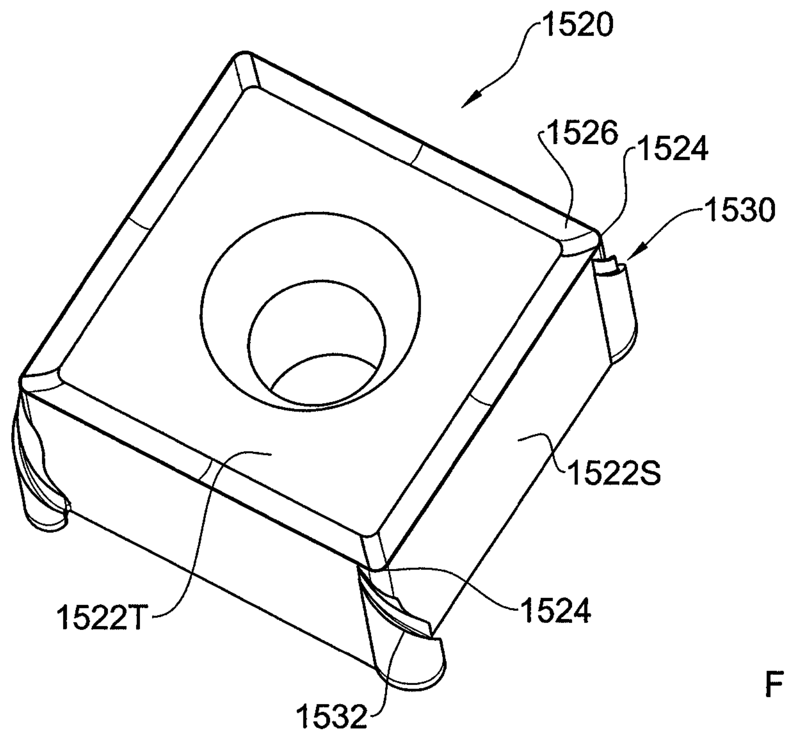


Fig. 35B

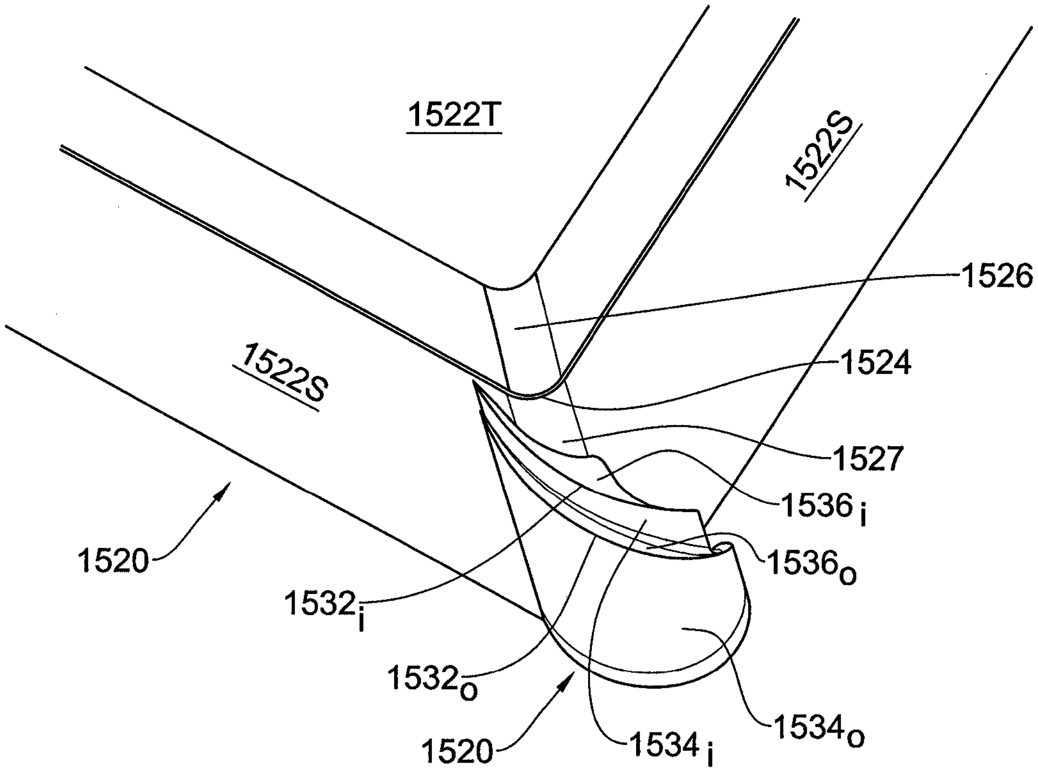


Fig. 35C

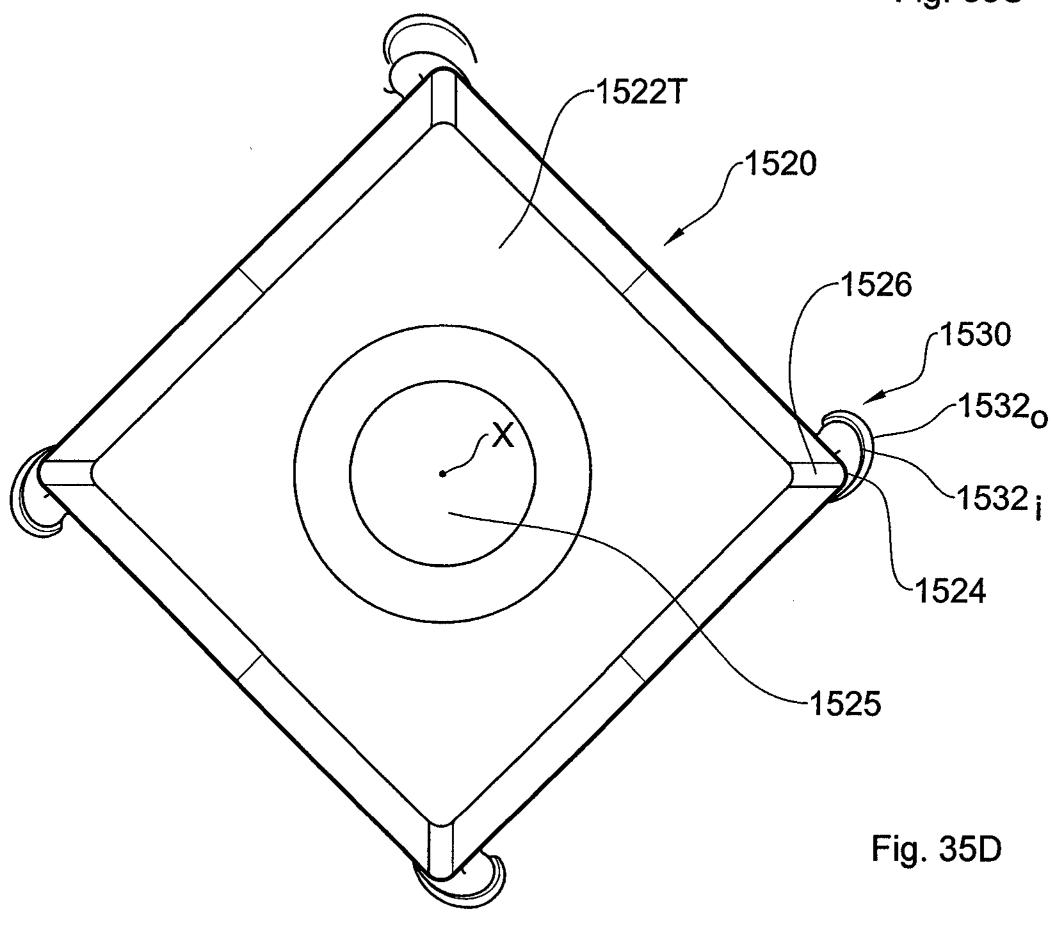


Fig. 35D

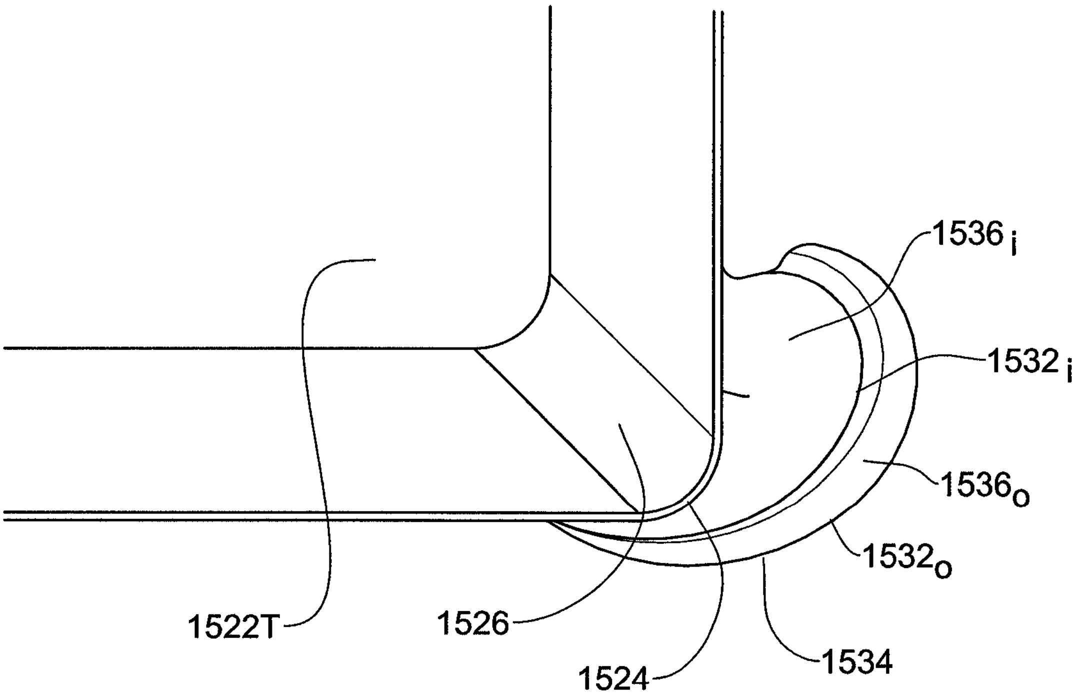


Fig. 35E

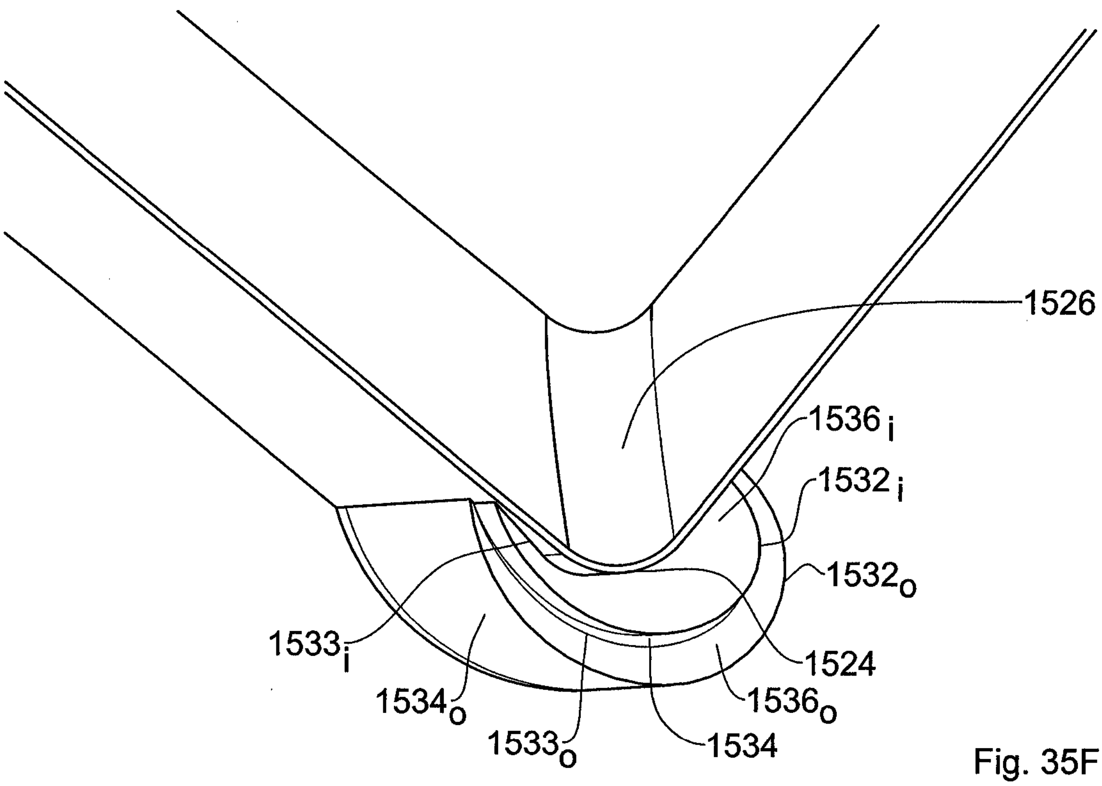


Fig. 35F

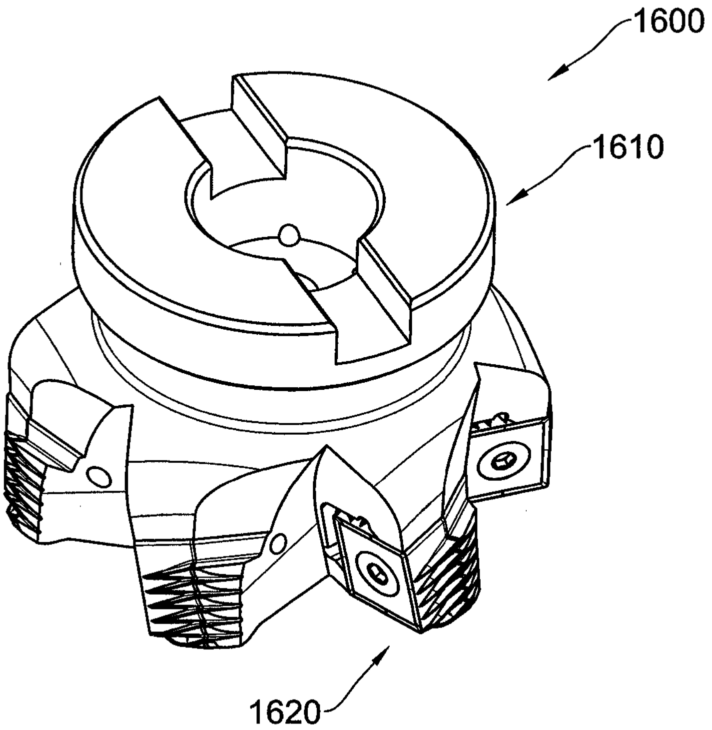


Fig. 36A

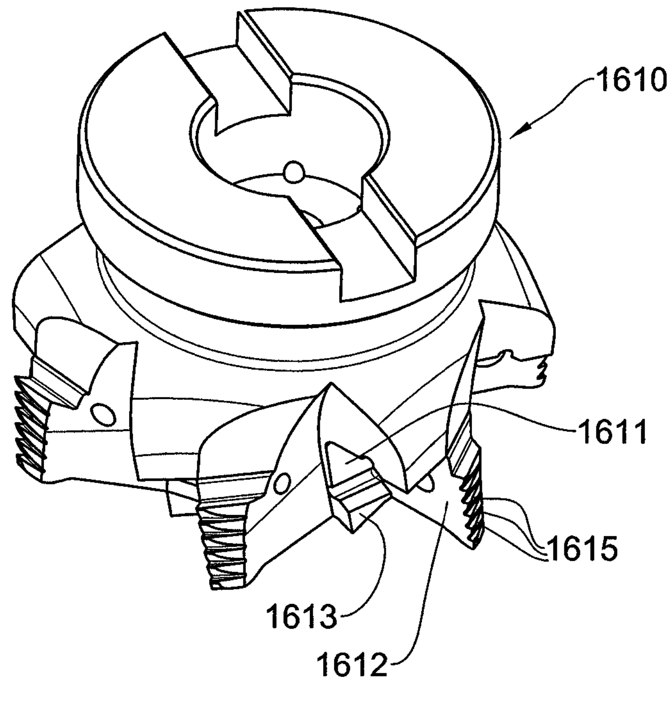


Fig. 36B

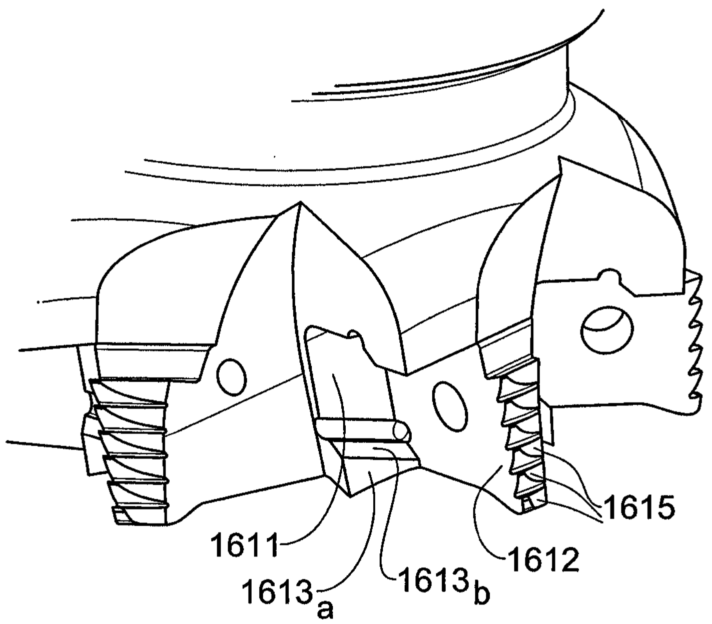


Fig. 36C

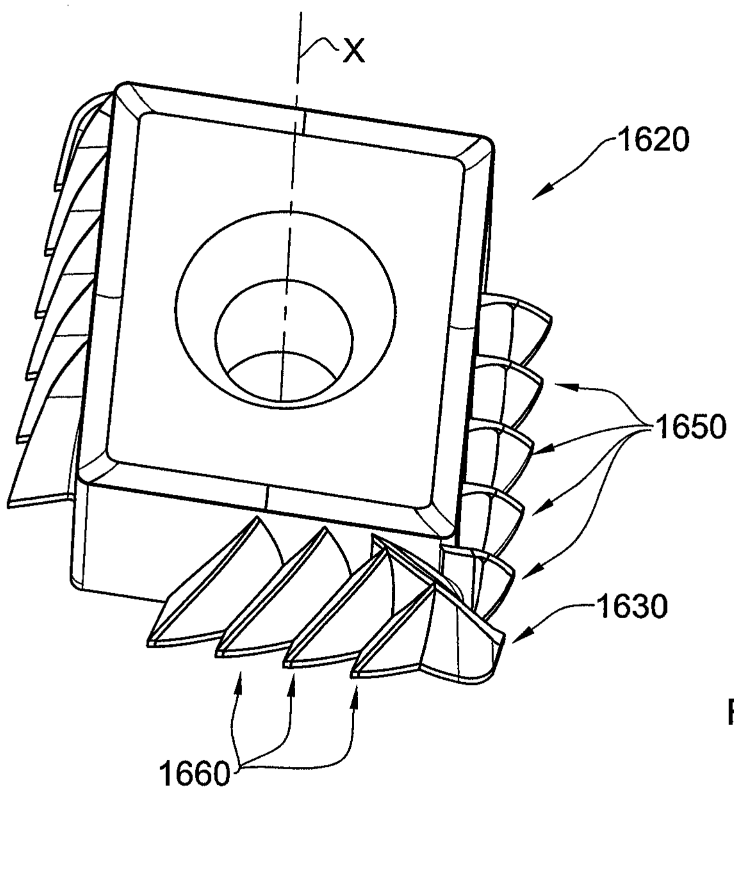


Fig. 36D

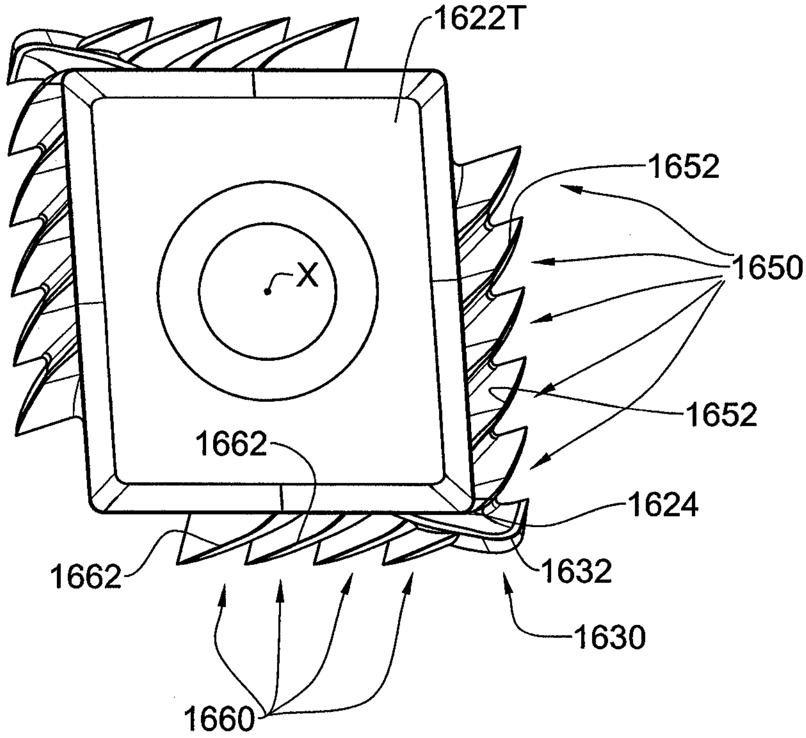


Fig. 36E

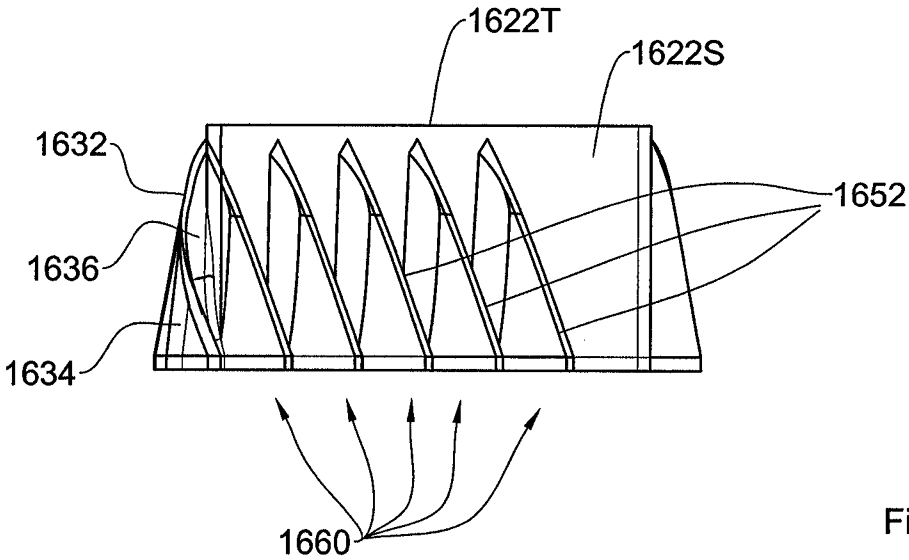


Fig. 36F

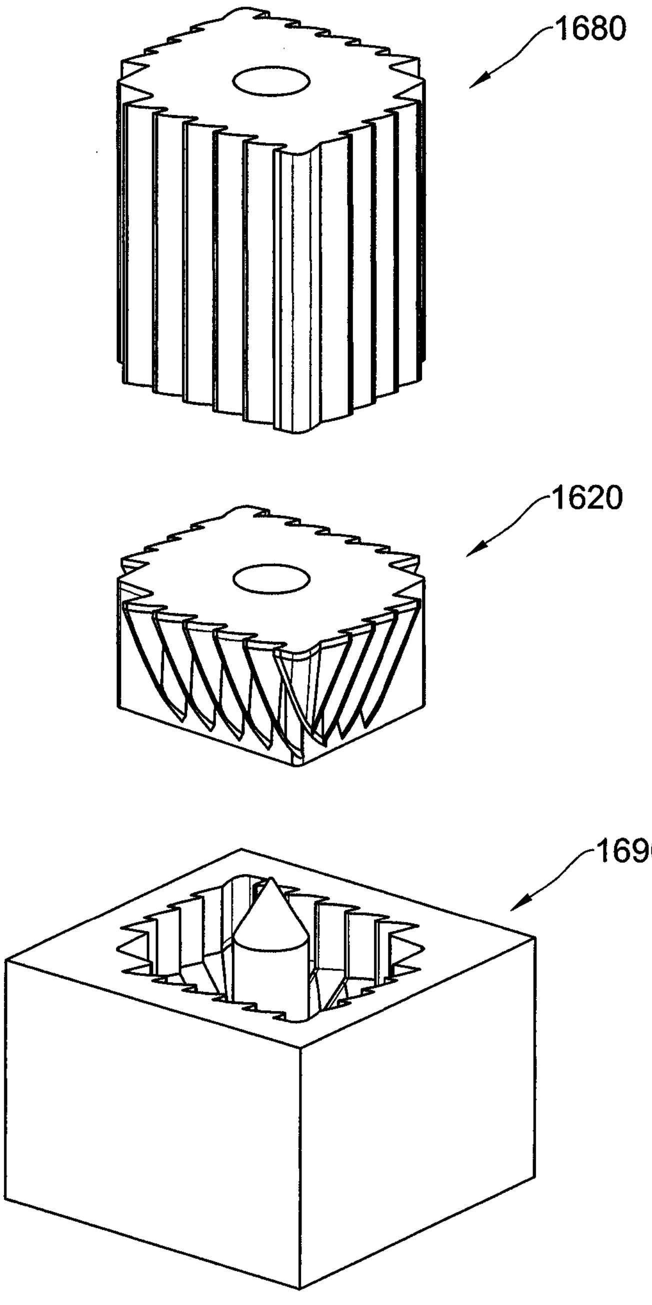


Fig. 36G

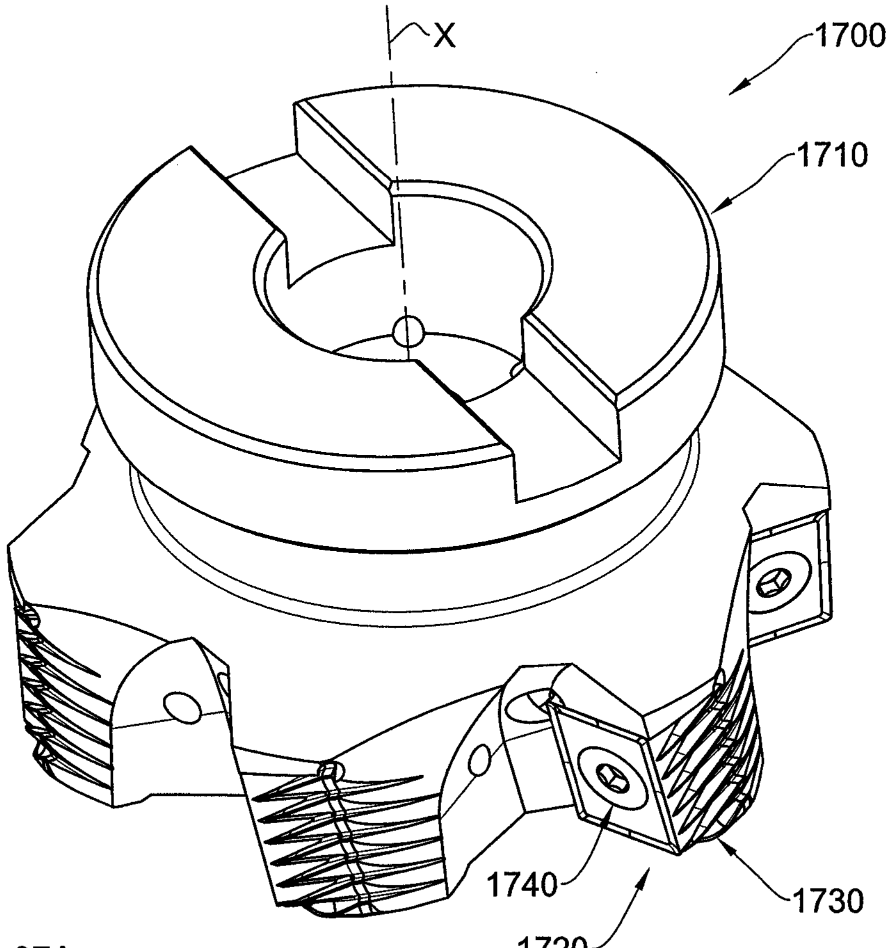


Fig. 37A

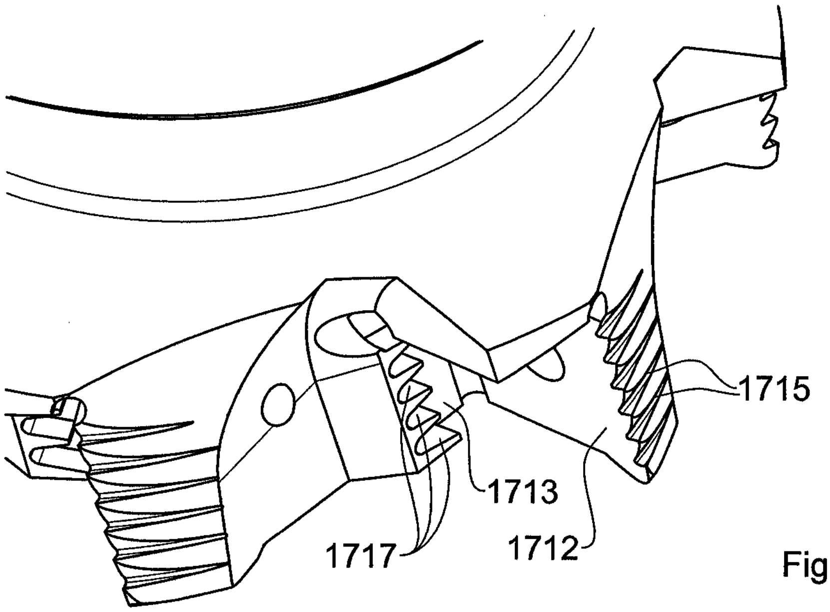


Fig. 37B

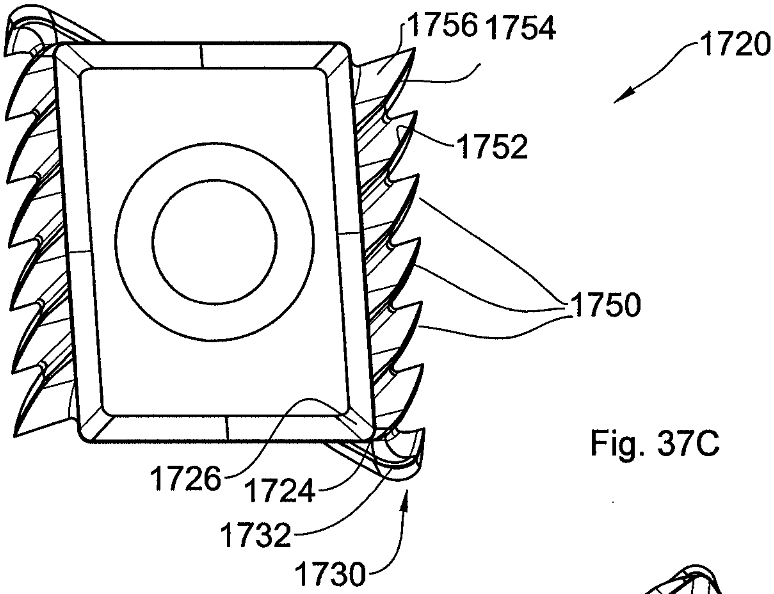


Fig. 37C

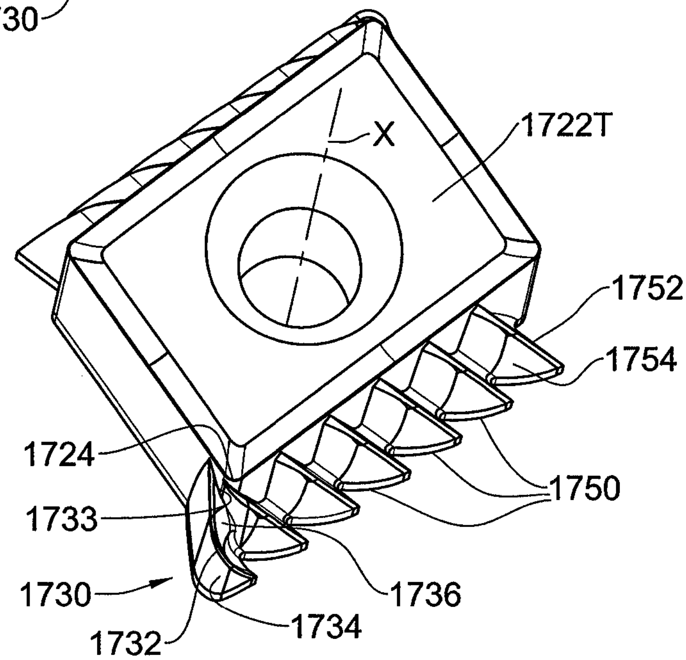


Fig. 37D

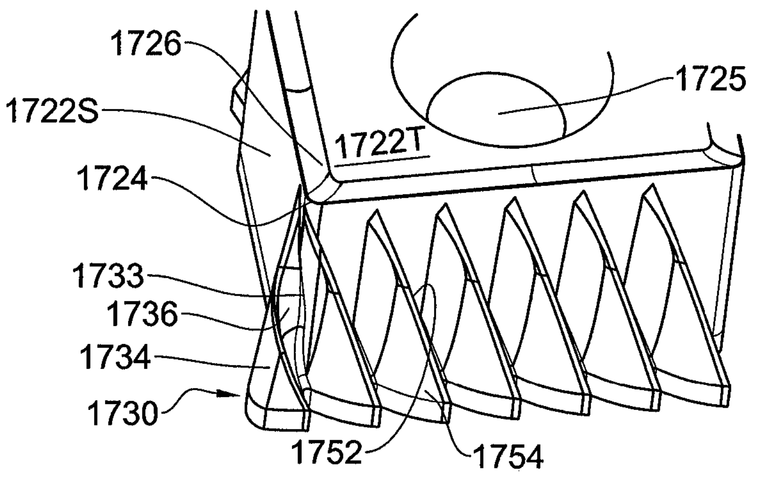


Fig. 37E

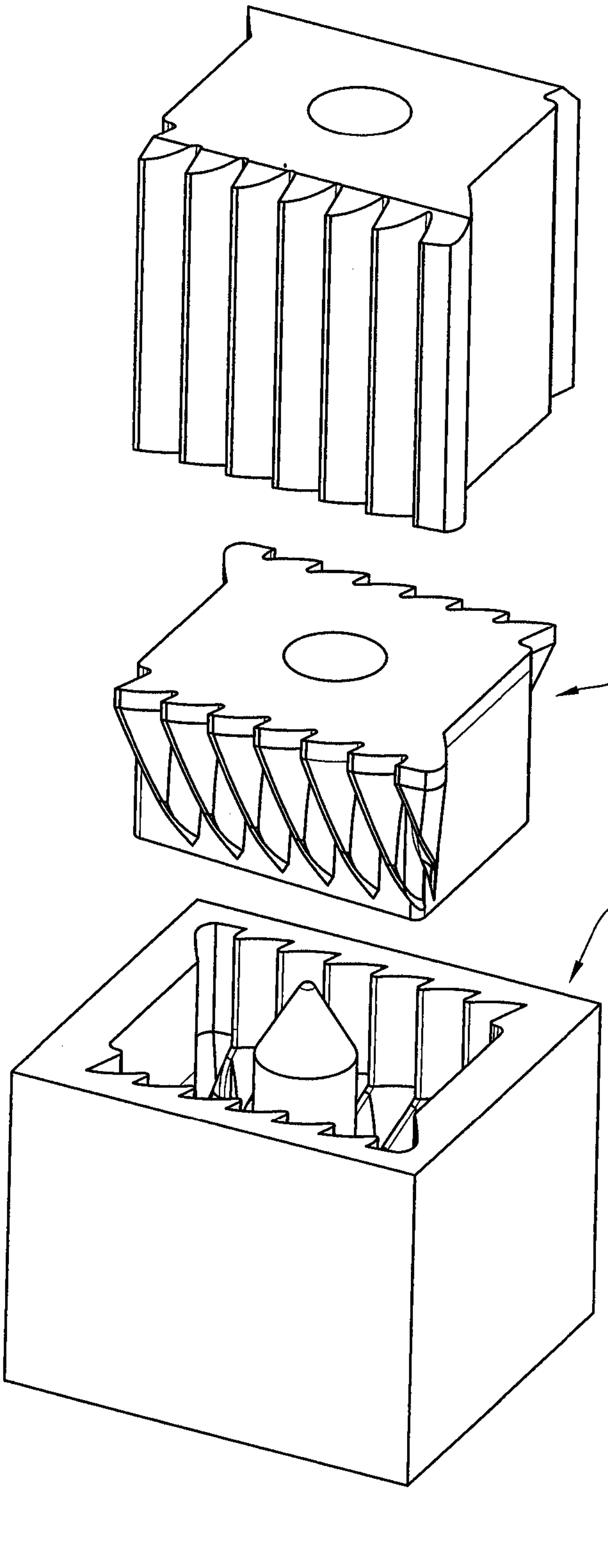


Fig. 37F

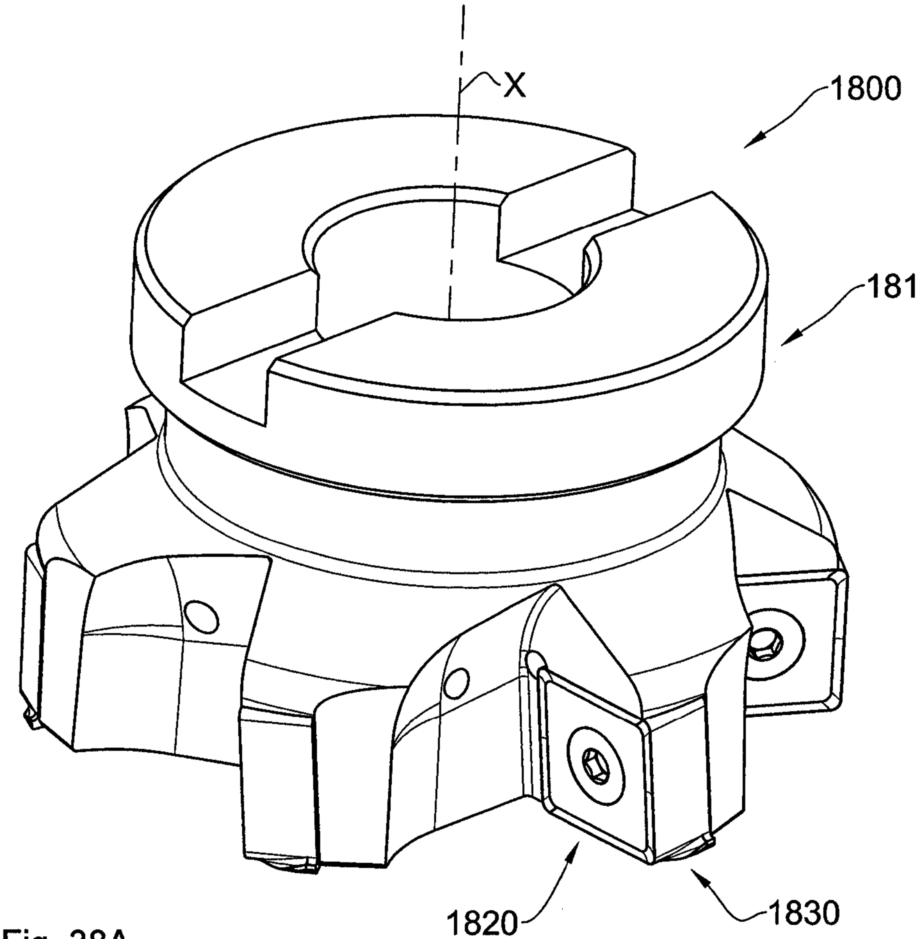


Fig. 38A

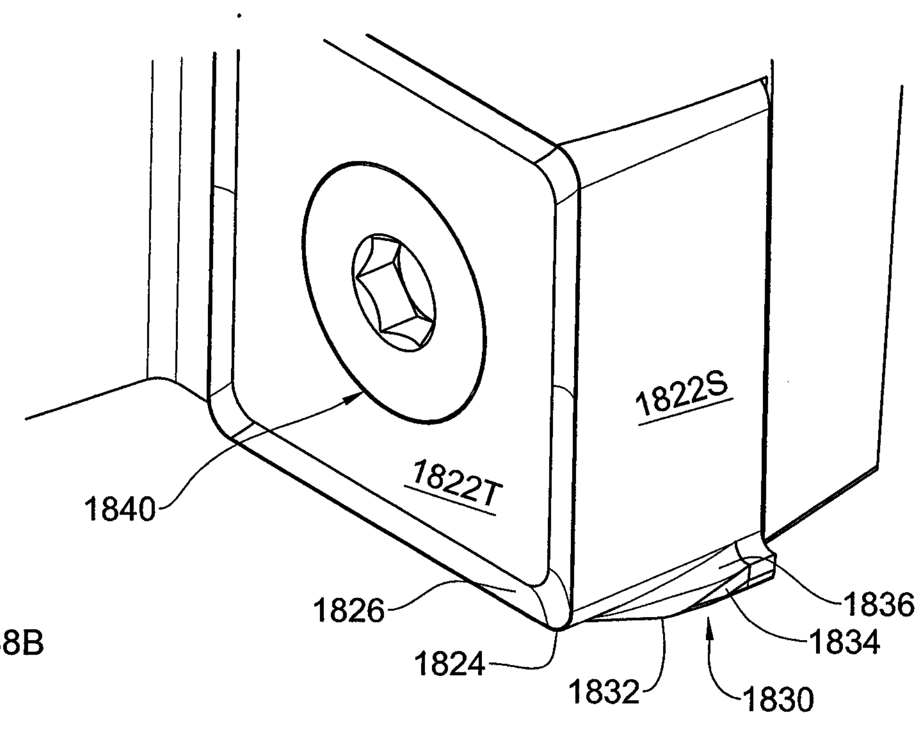


Fig. 38B

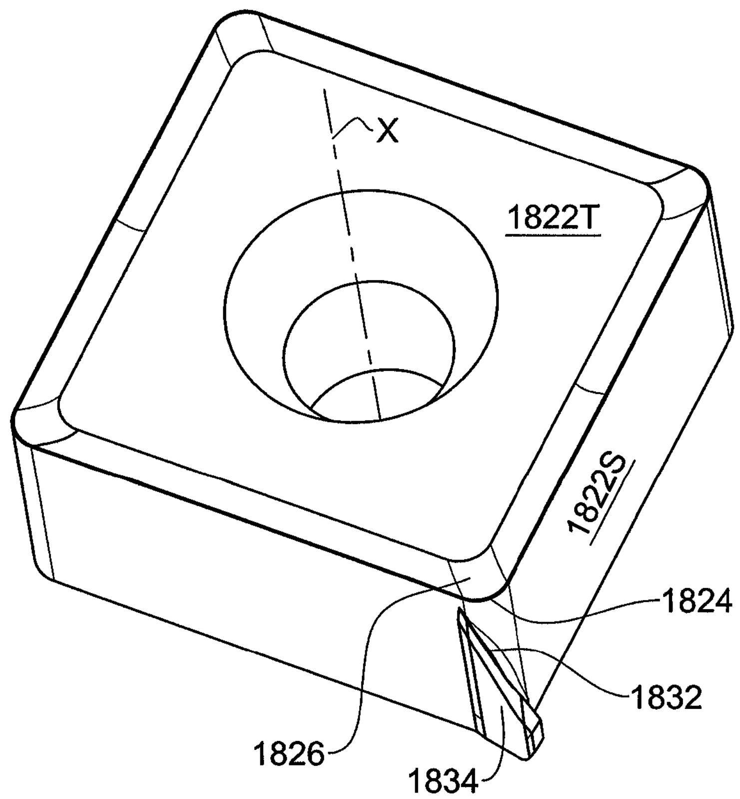


Fig. 38C

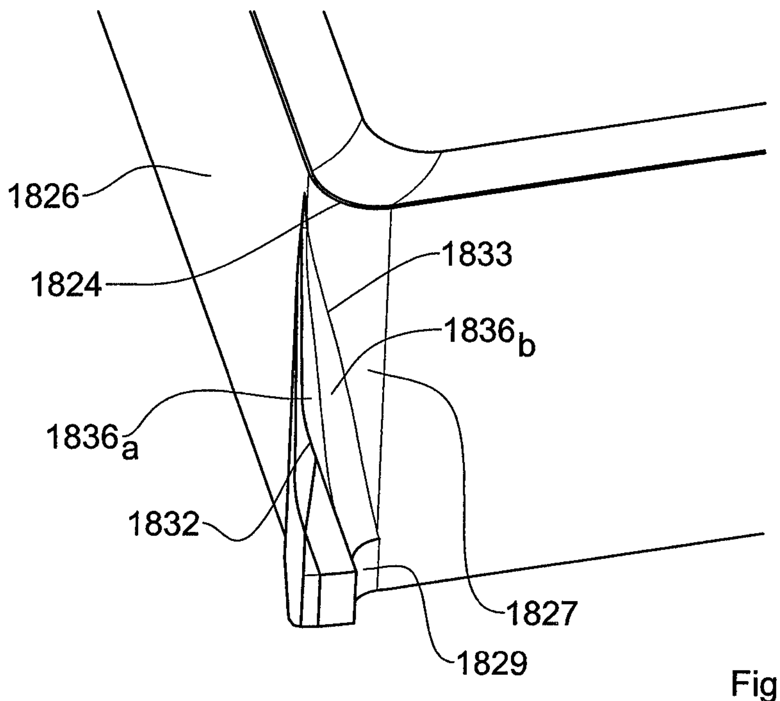


Fig. 38D

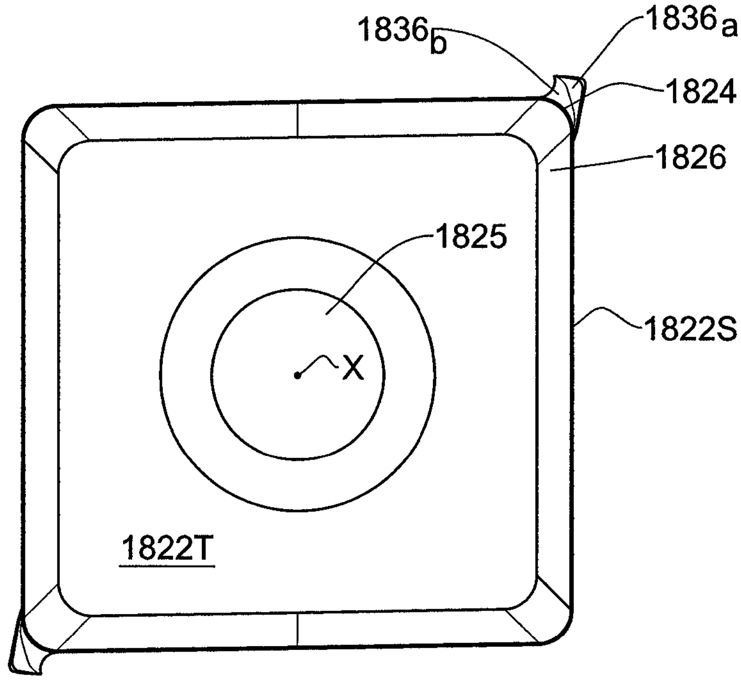


Fig. 38E

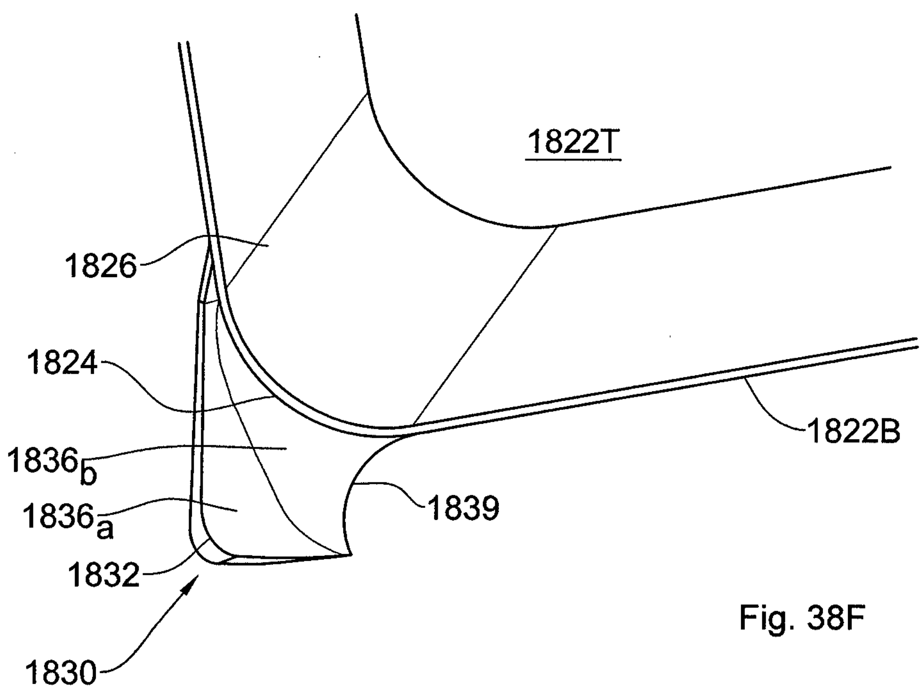


Fig. 38F

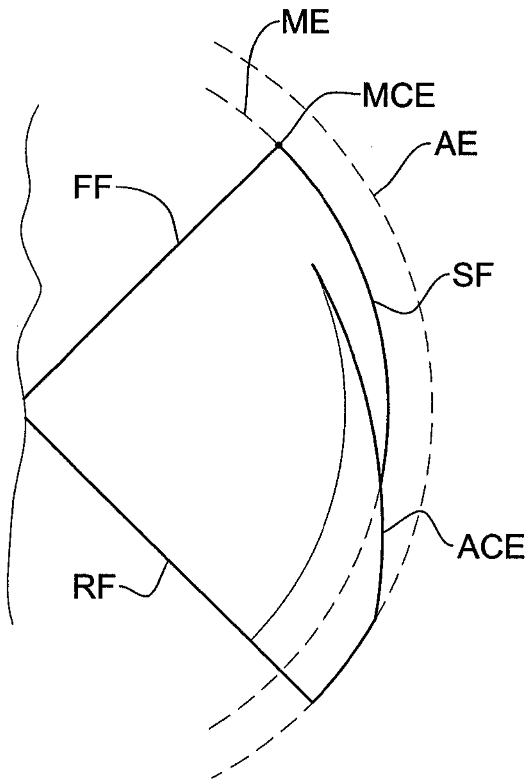


Fig. 39

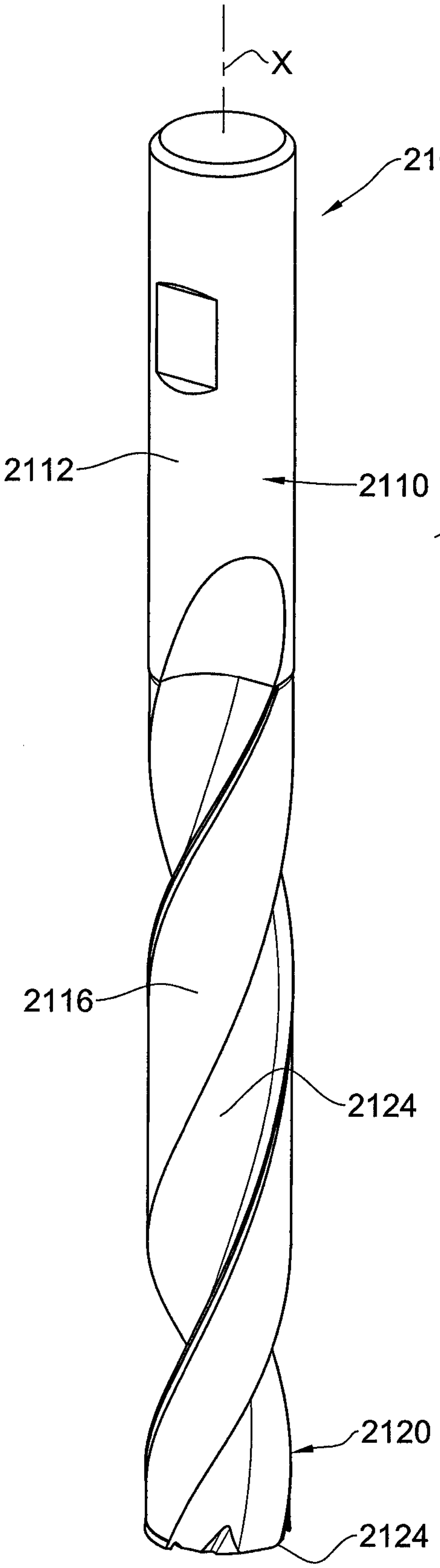


Fig. 39A

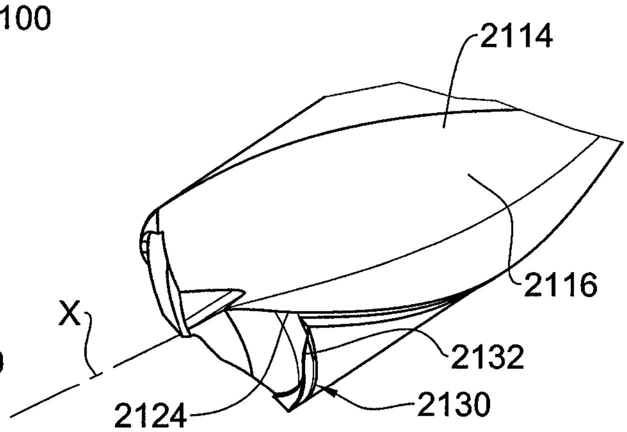


Fig. 39B

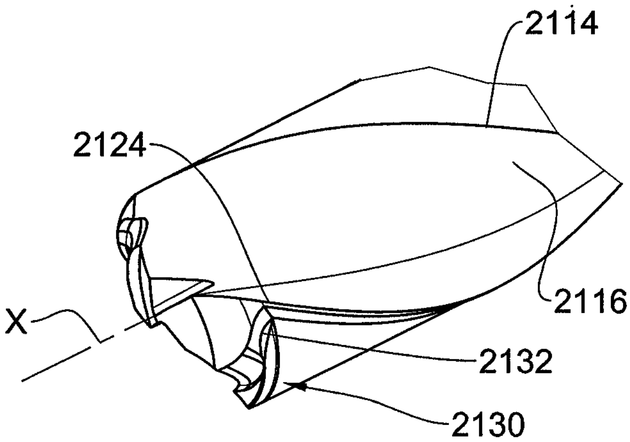


Fig. 39C

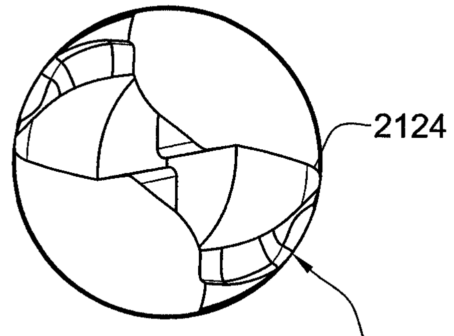


Fig. 39D

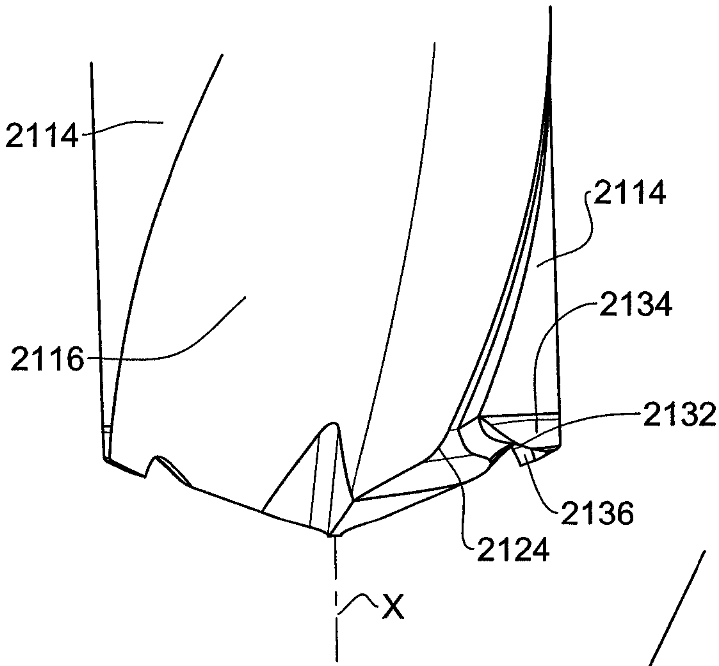


Fig. 39E

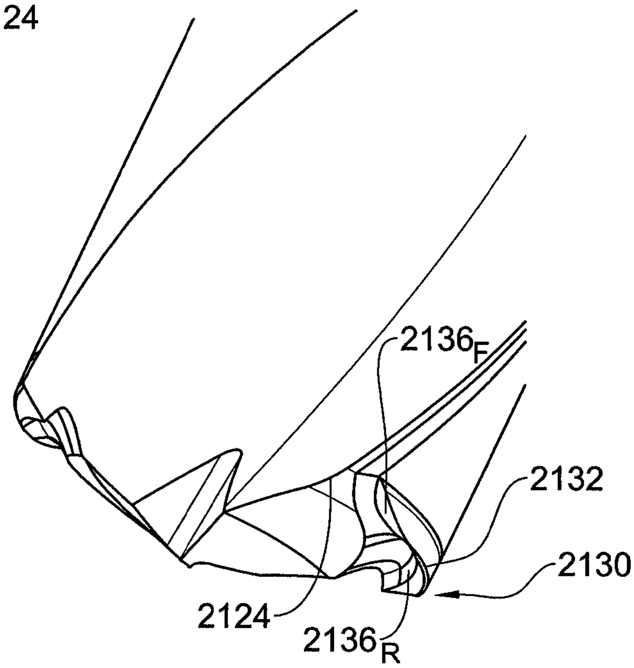


Fig. 39F

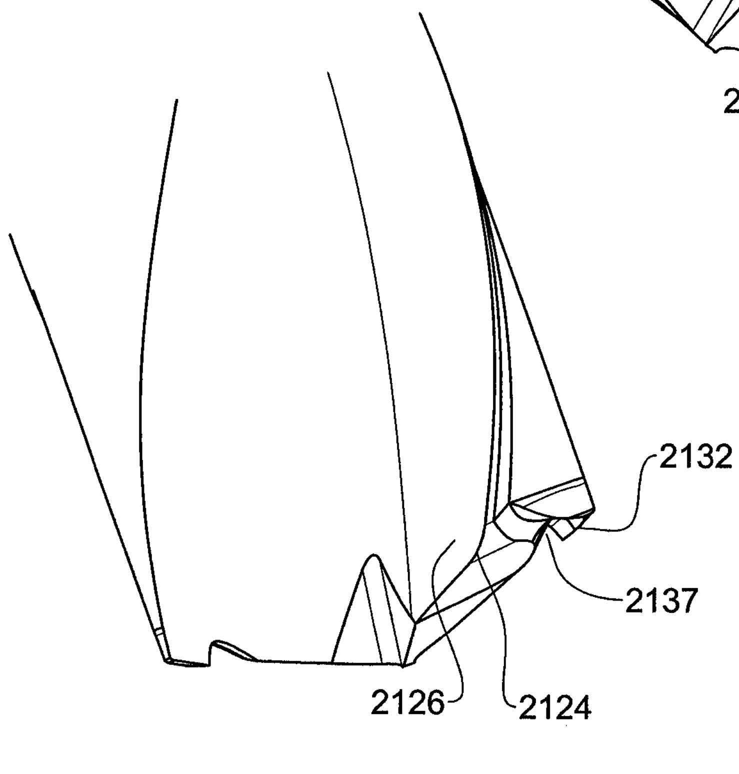


Fig. 39G

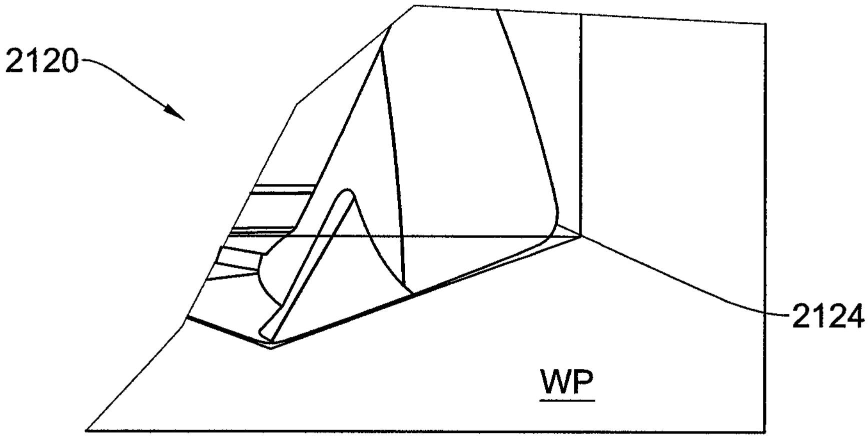


Fig. 40A

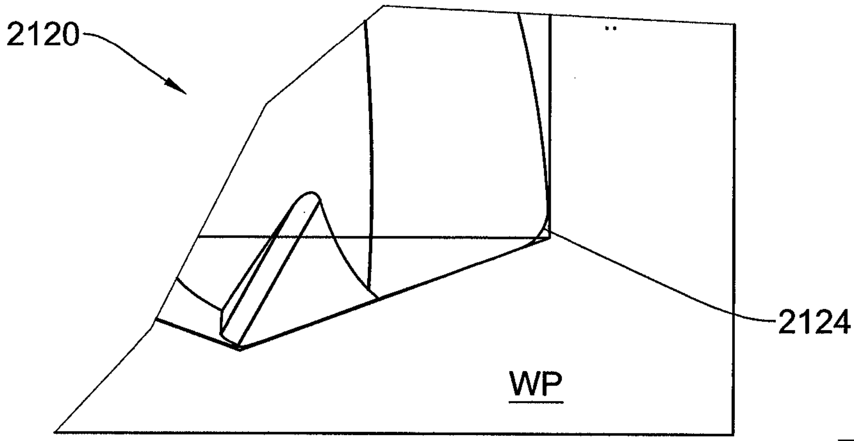


Fig. 40B

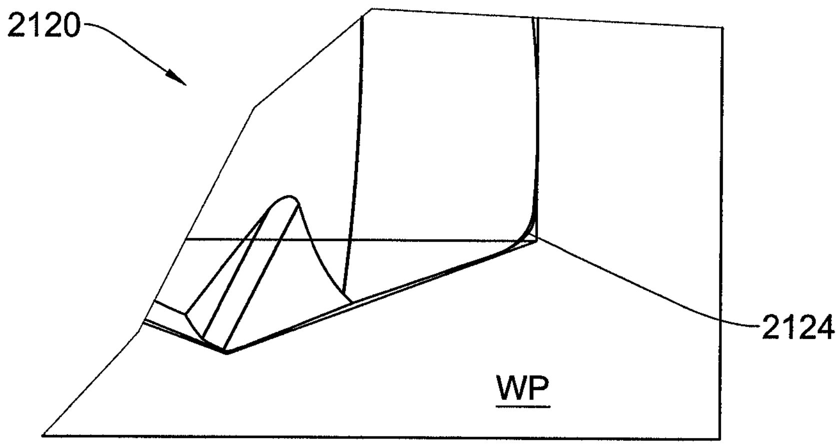


Fig. 40C

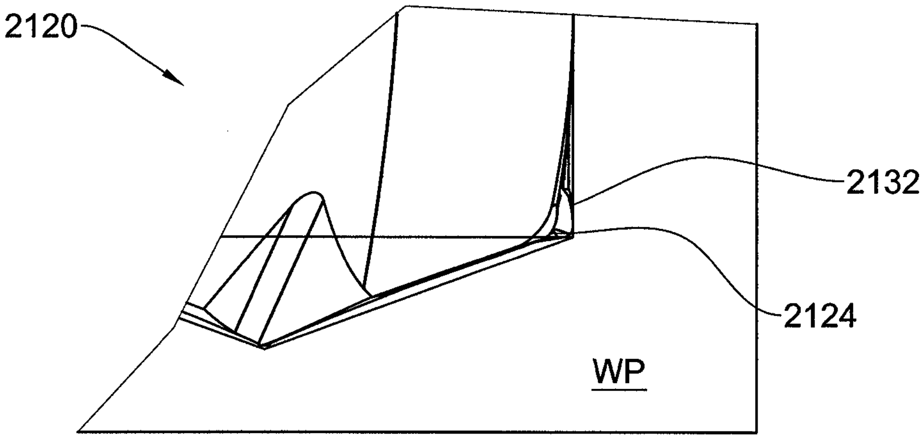


Fig. 40D

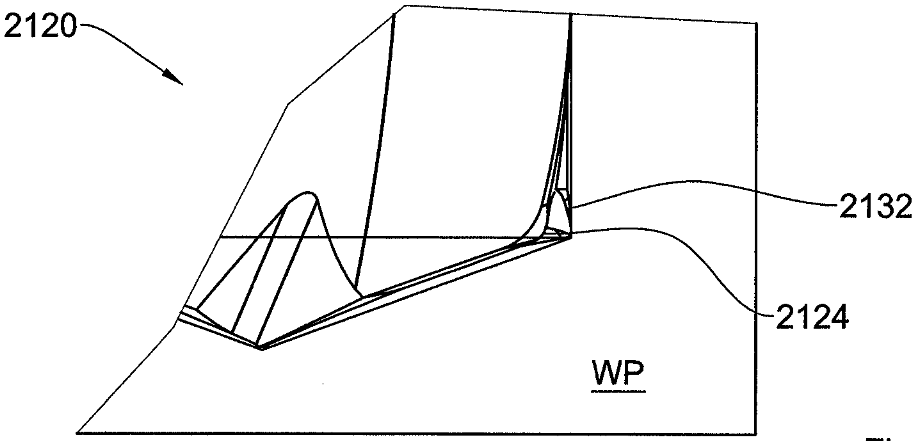


Fig. 40E

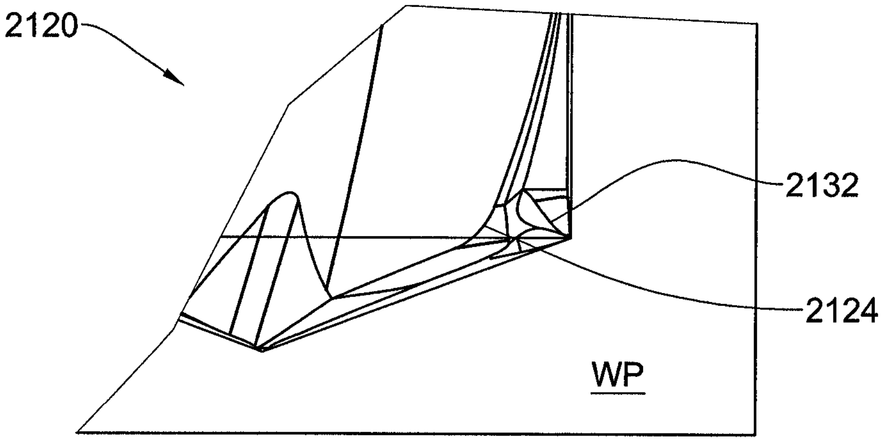


Fig. 40F

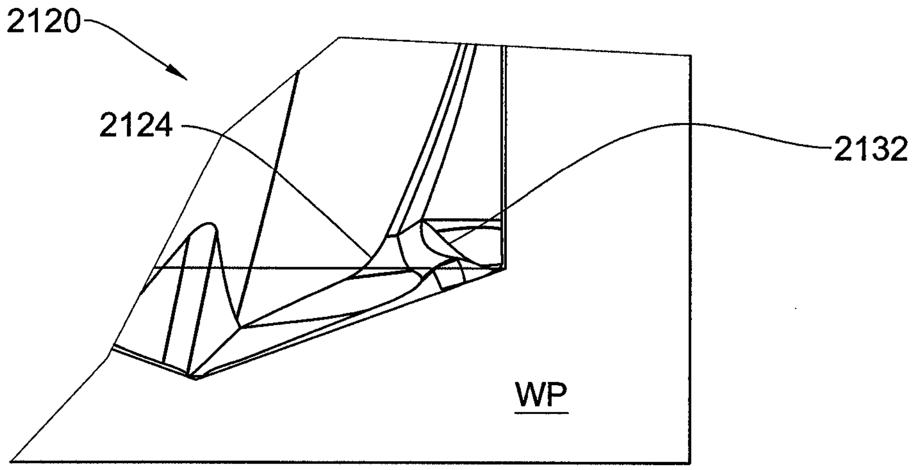


Fig. 40G

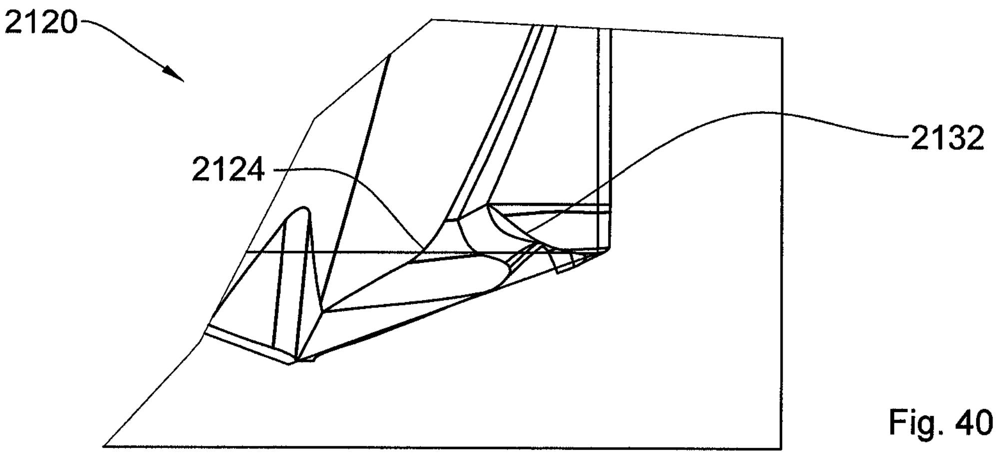


Fig. 40H

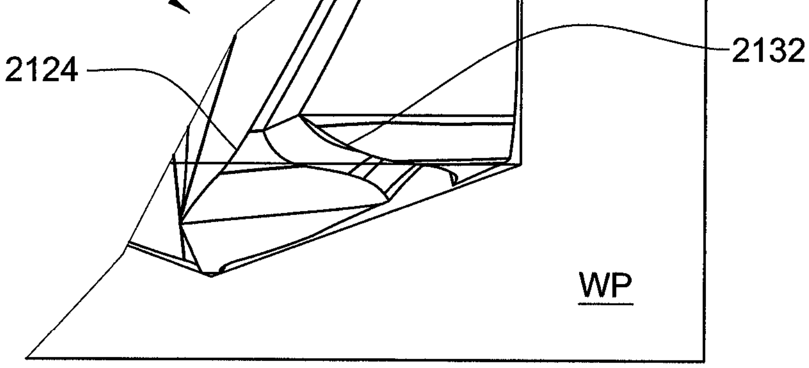


Fig. 40I

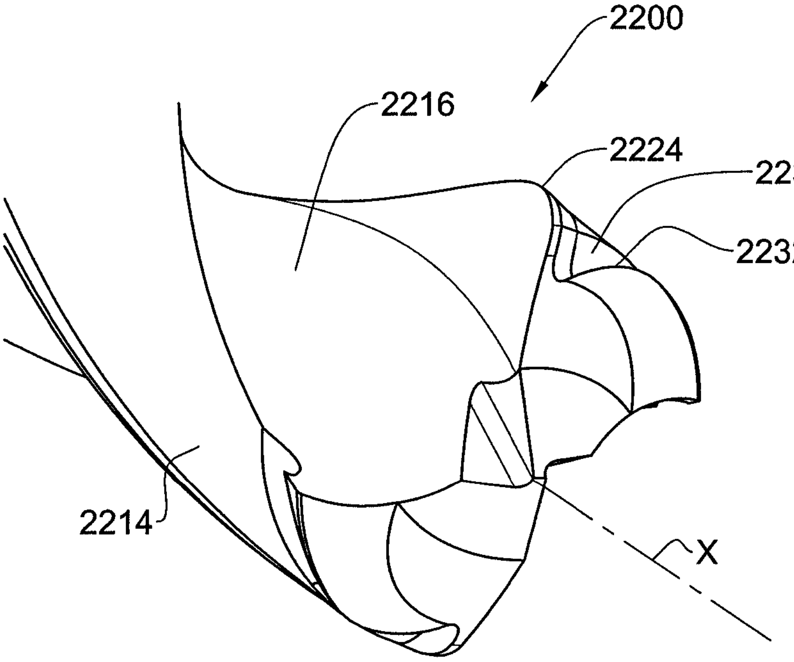


Fig. 41A

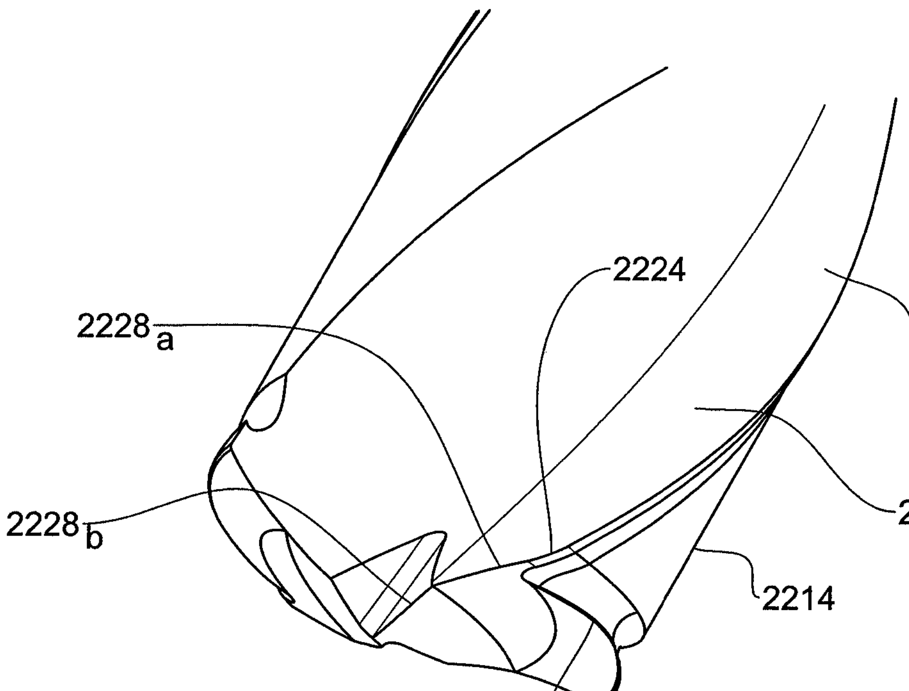


Fig. 41B

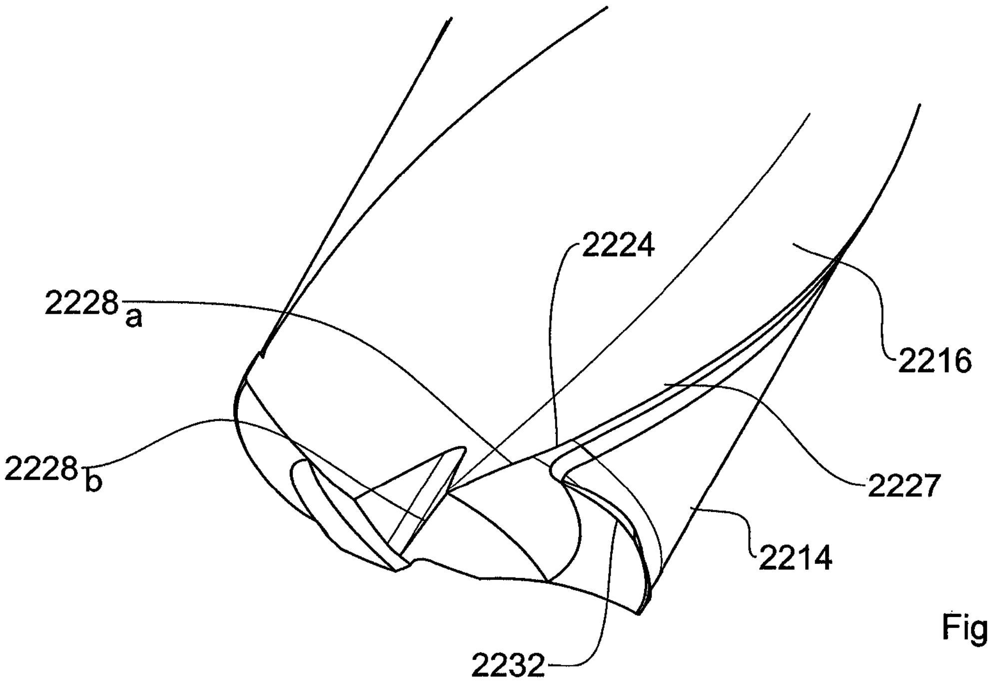


Fig. 41C

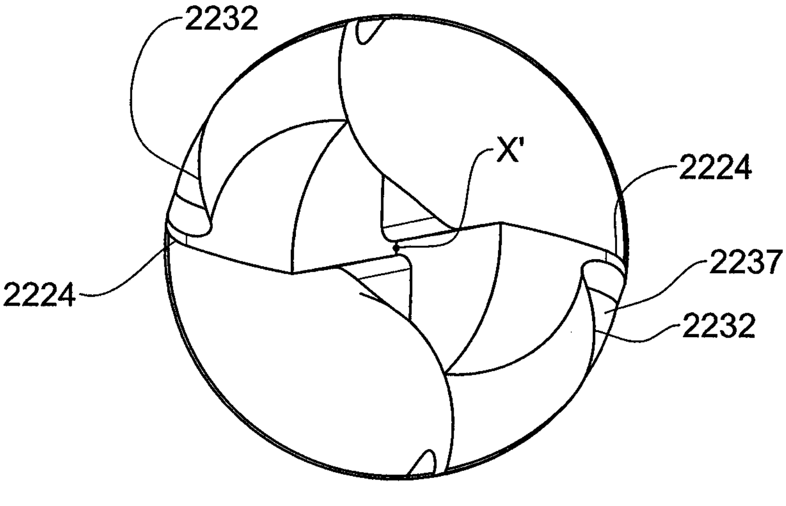


Fig. 41D

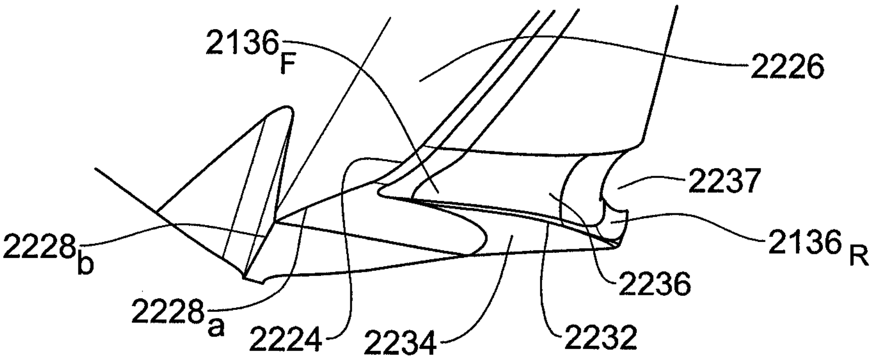


Fig. 41E

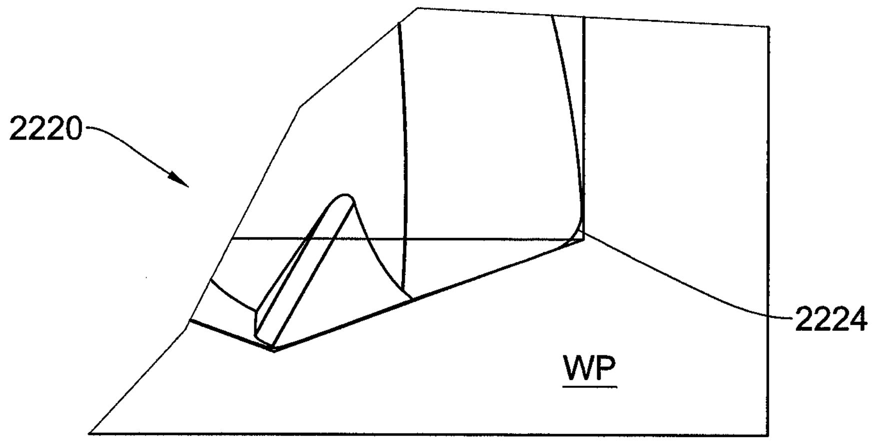


Fig. 42A

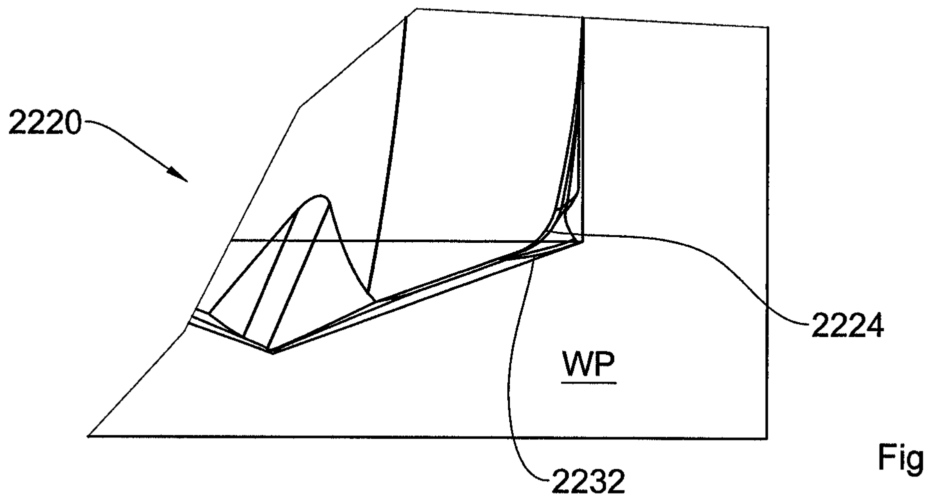


Fig. 42B

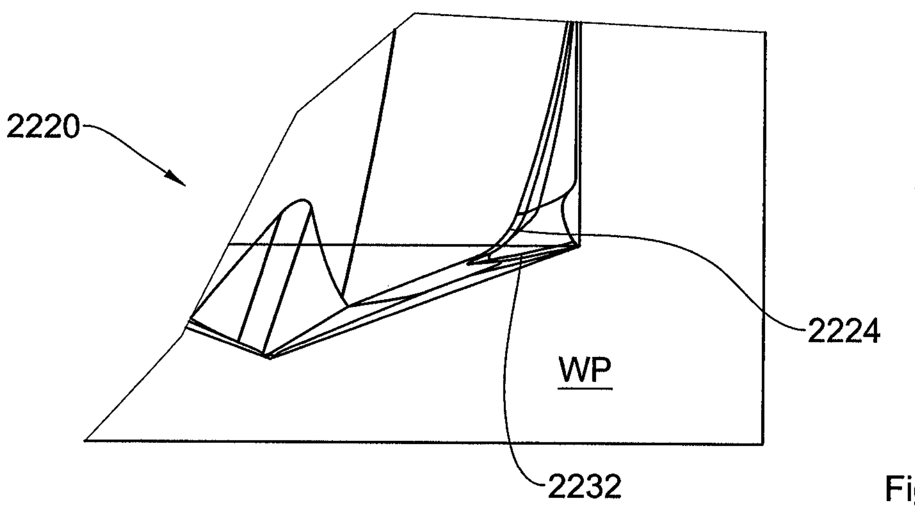


Fig. 42C

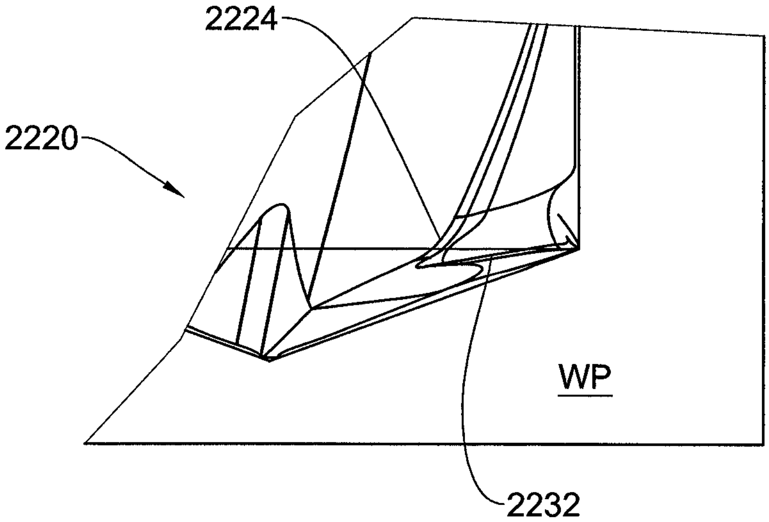


Fig. 42D

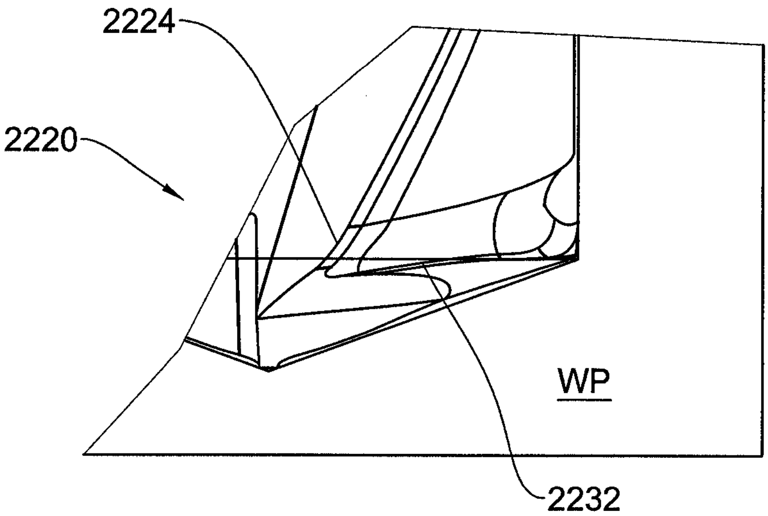


Fig. 42E

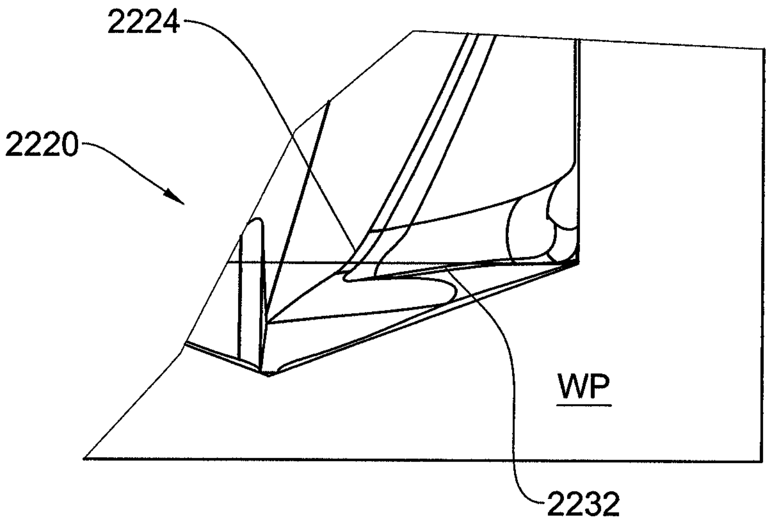


Fig. 42F

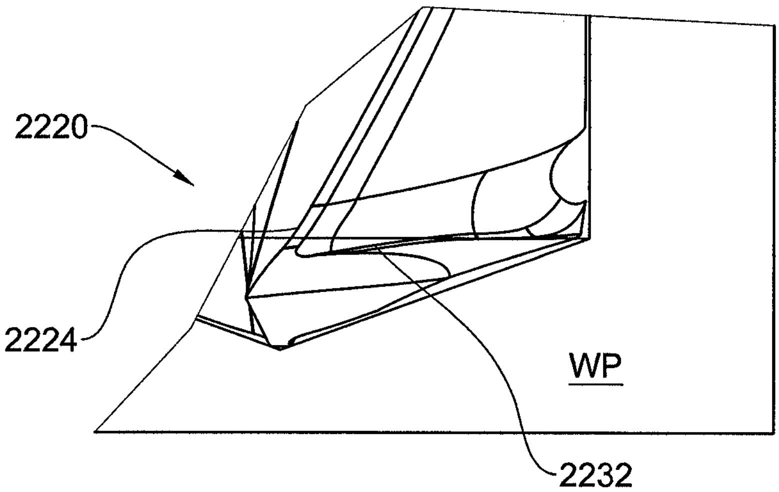


Fig. 42G

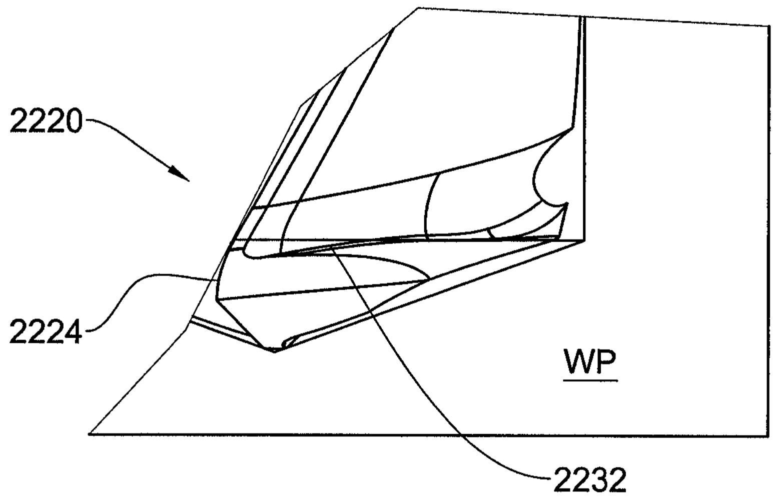


Fig. 42H

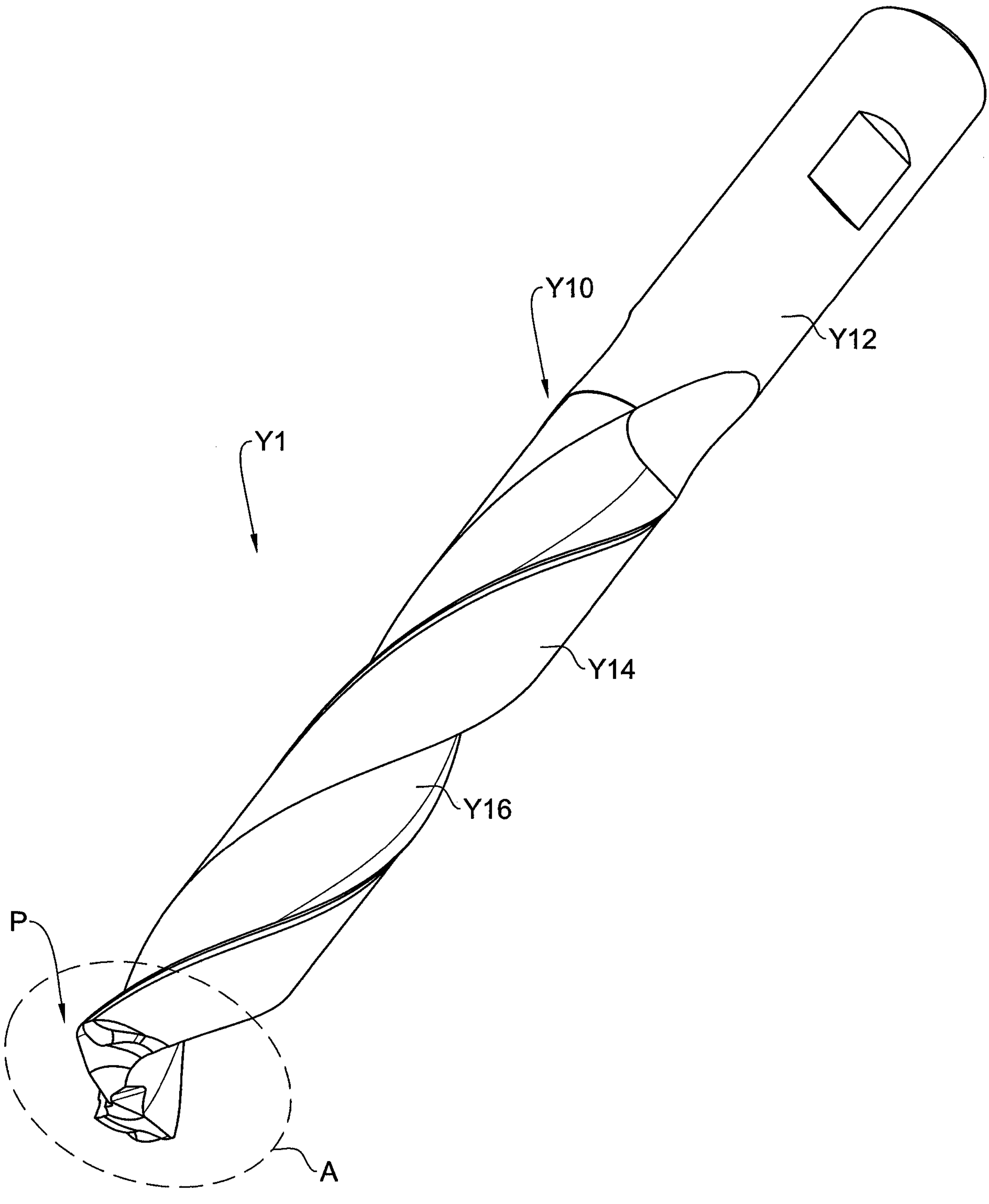


Fig. 43A

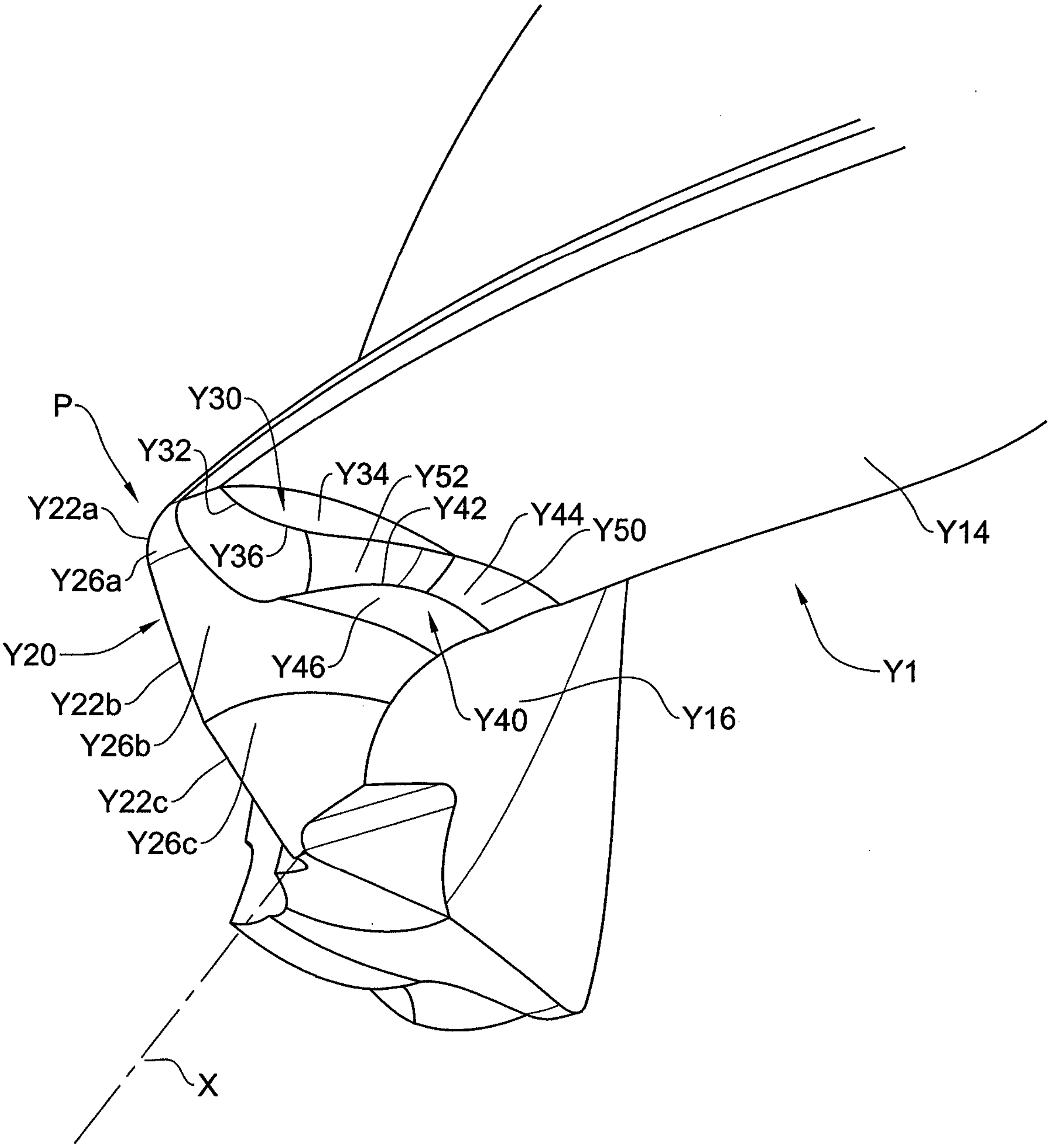

Y30
P
Y32
Y34
Y52
Y42
Y44
Y50
Y22a
Y36
Y14
Y26a
Y20
Y46
Y1
Y22b
Y40
Y16
Y26b
Y22c
Y26c
X

Fig. 43B

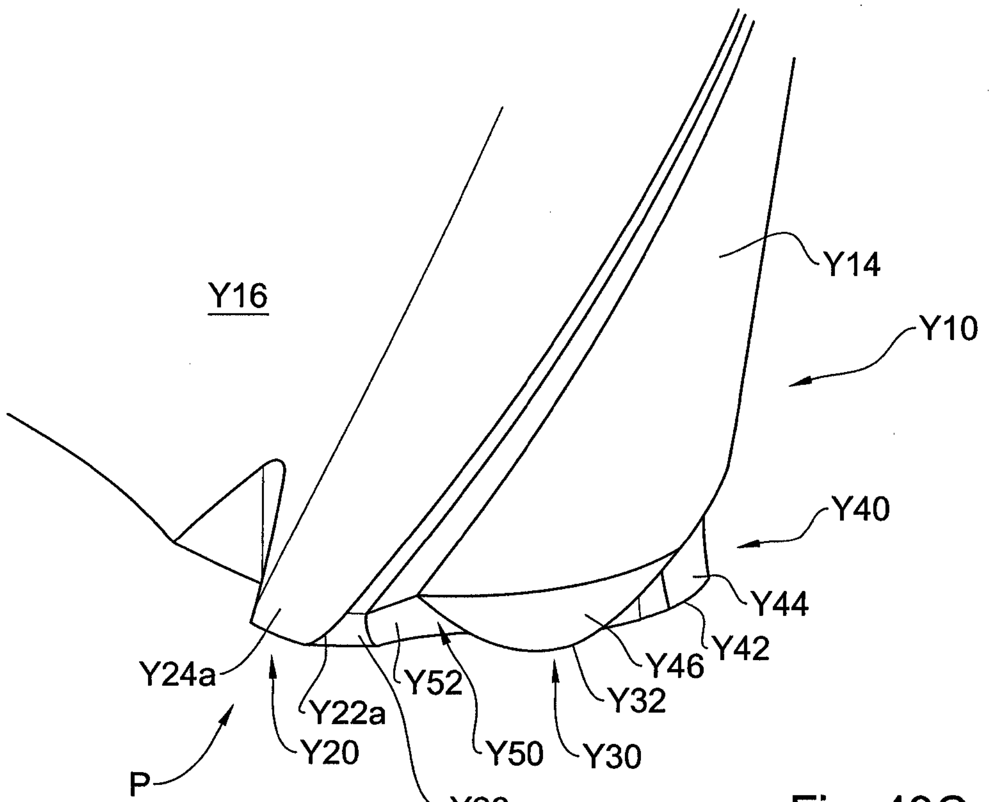


Fig. 43C

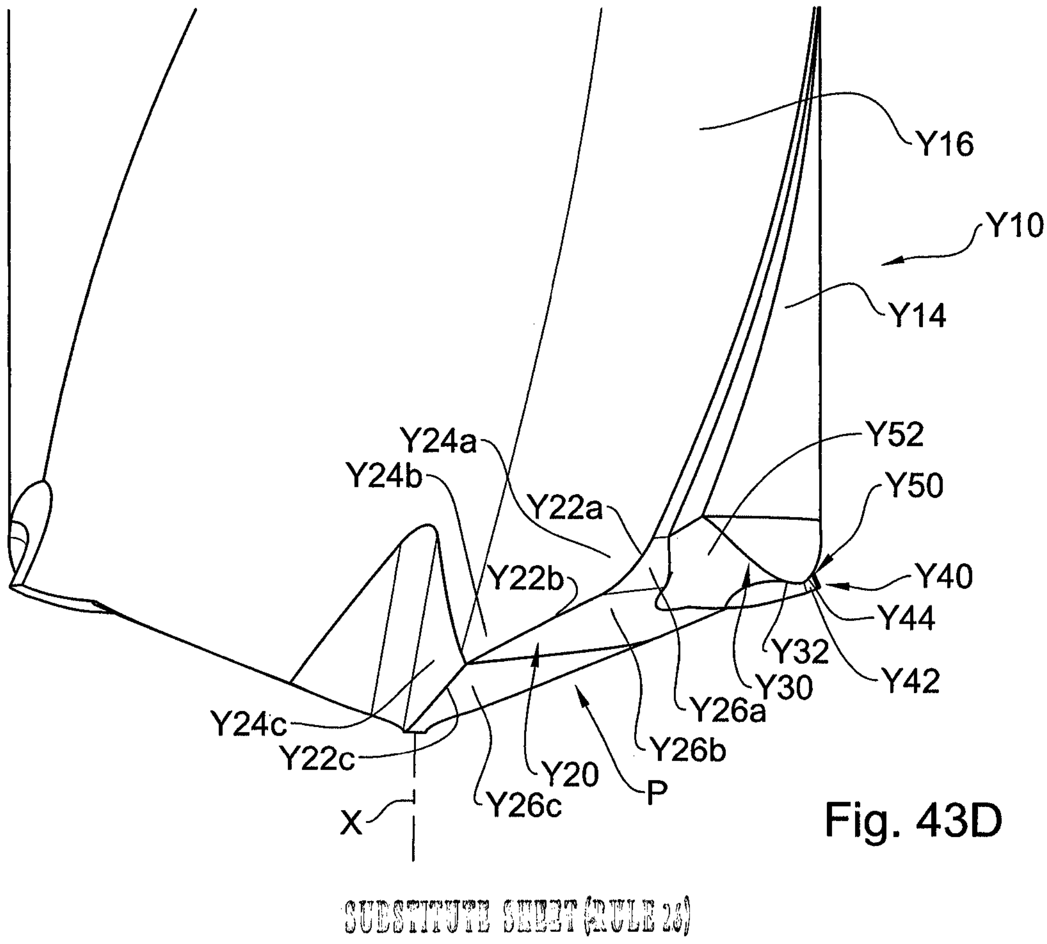


Fig. 43D

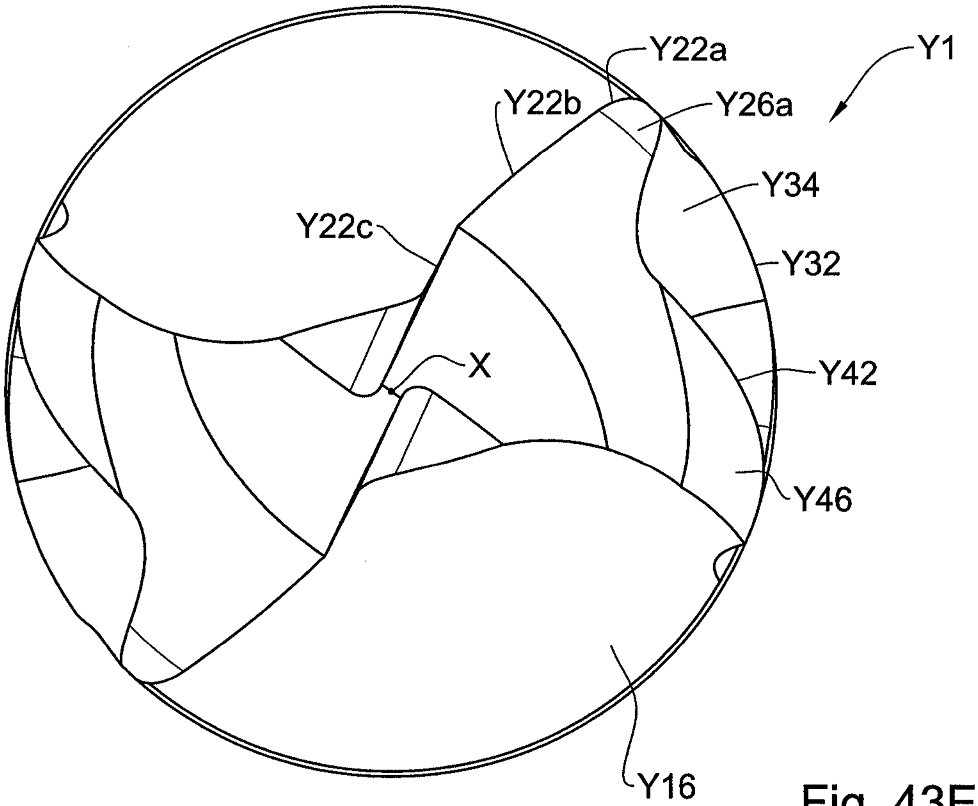


Fig. 43E

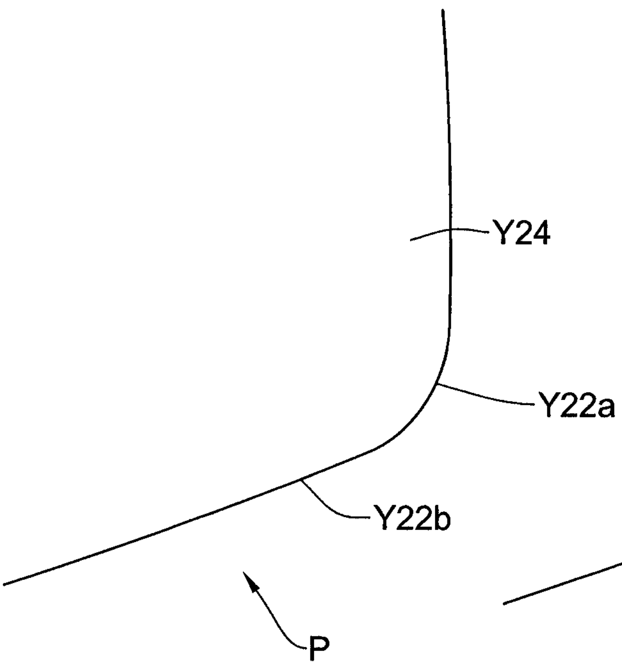


Fig. 44A

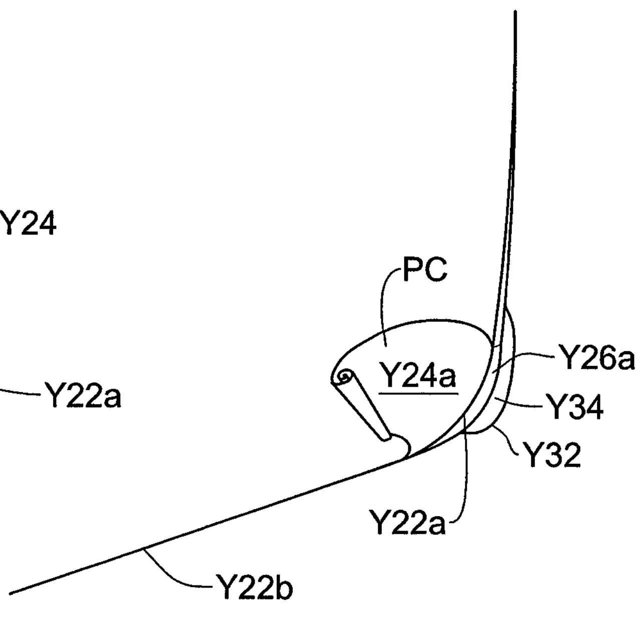


Fig. 44B

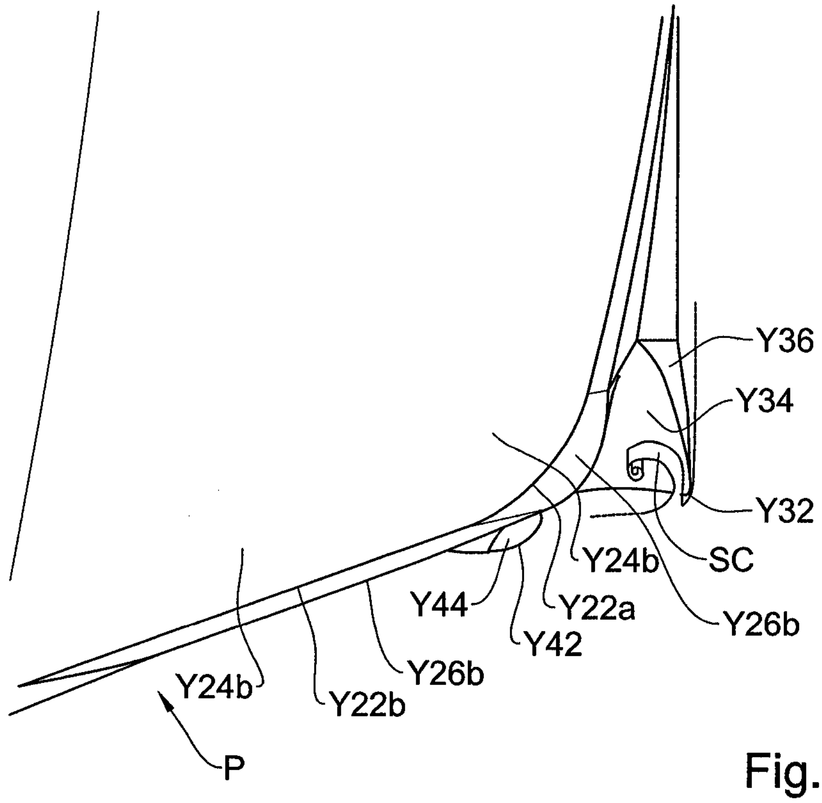


Fig. 44C

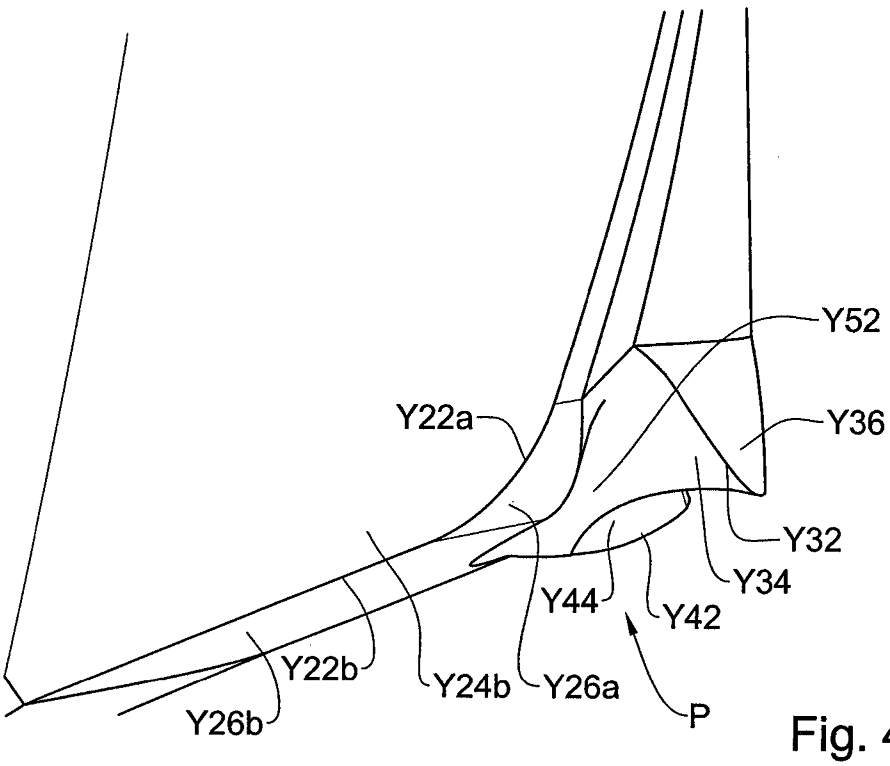


Fig. 44D

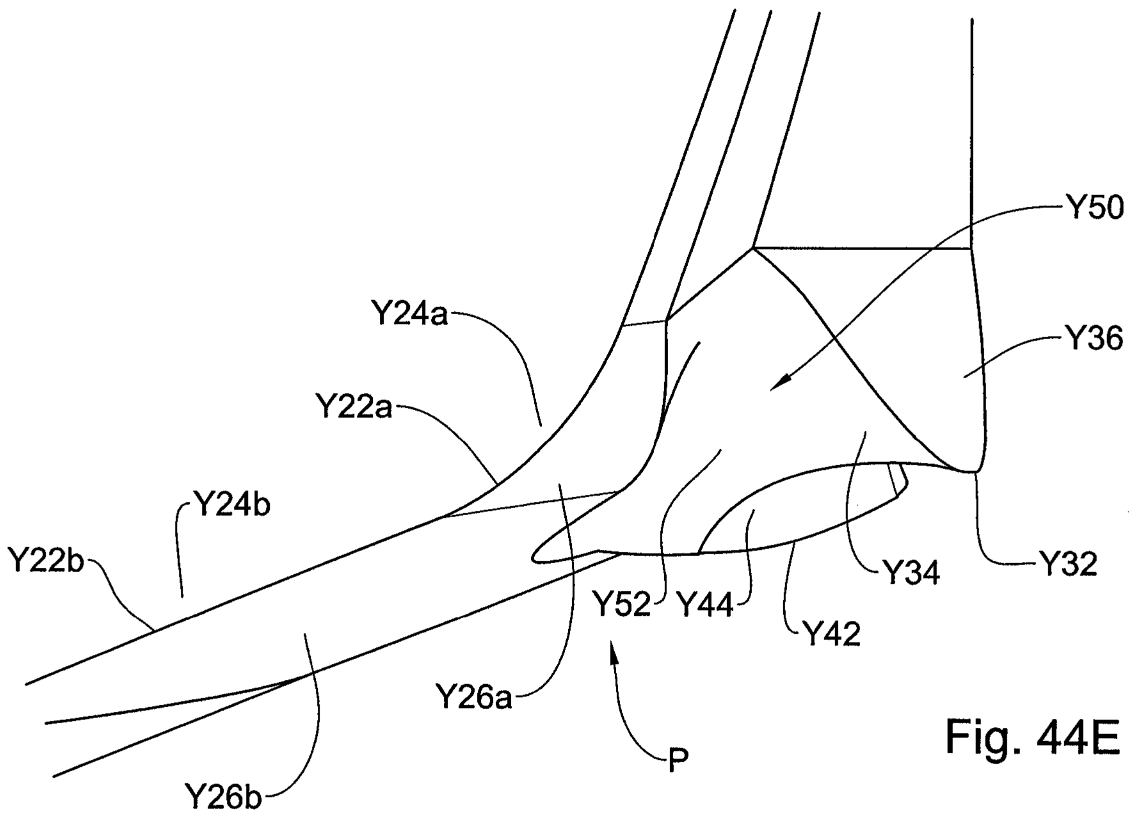


Fig. 44E

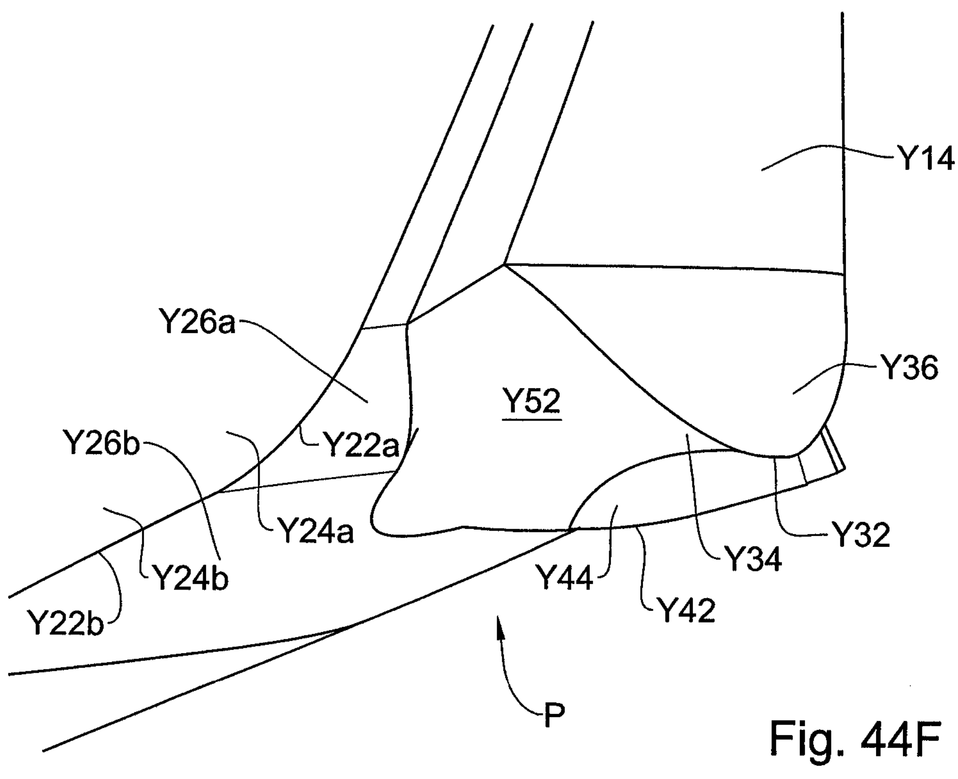


Fig. 44F

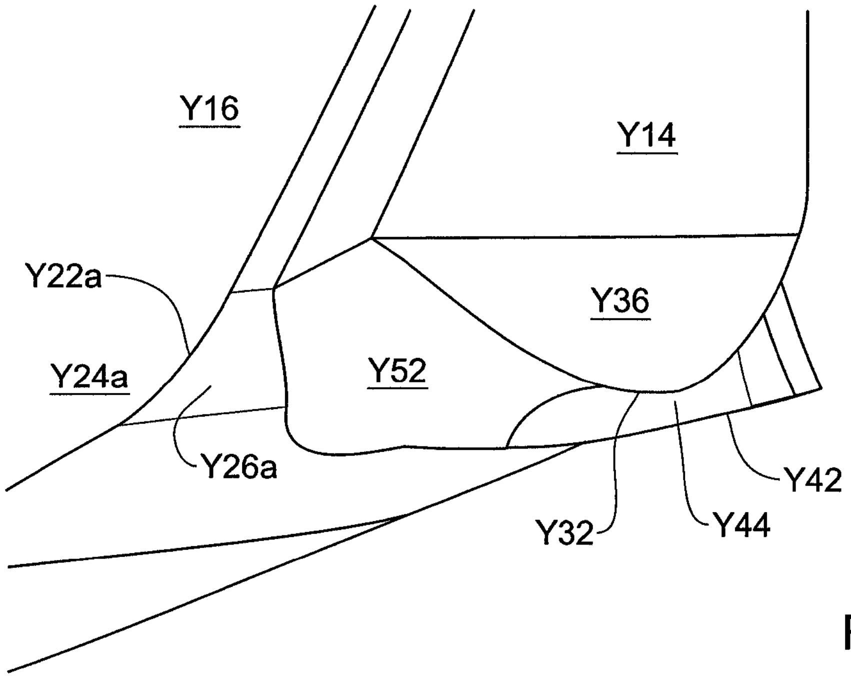


Fig. 44G

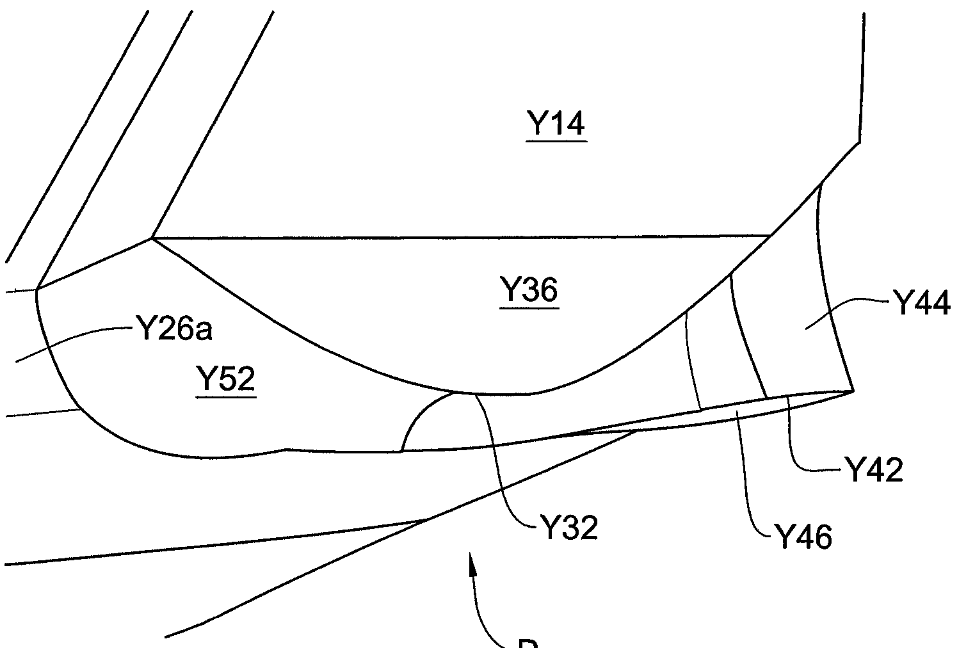


Fig. 44H

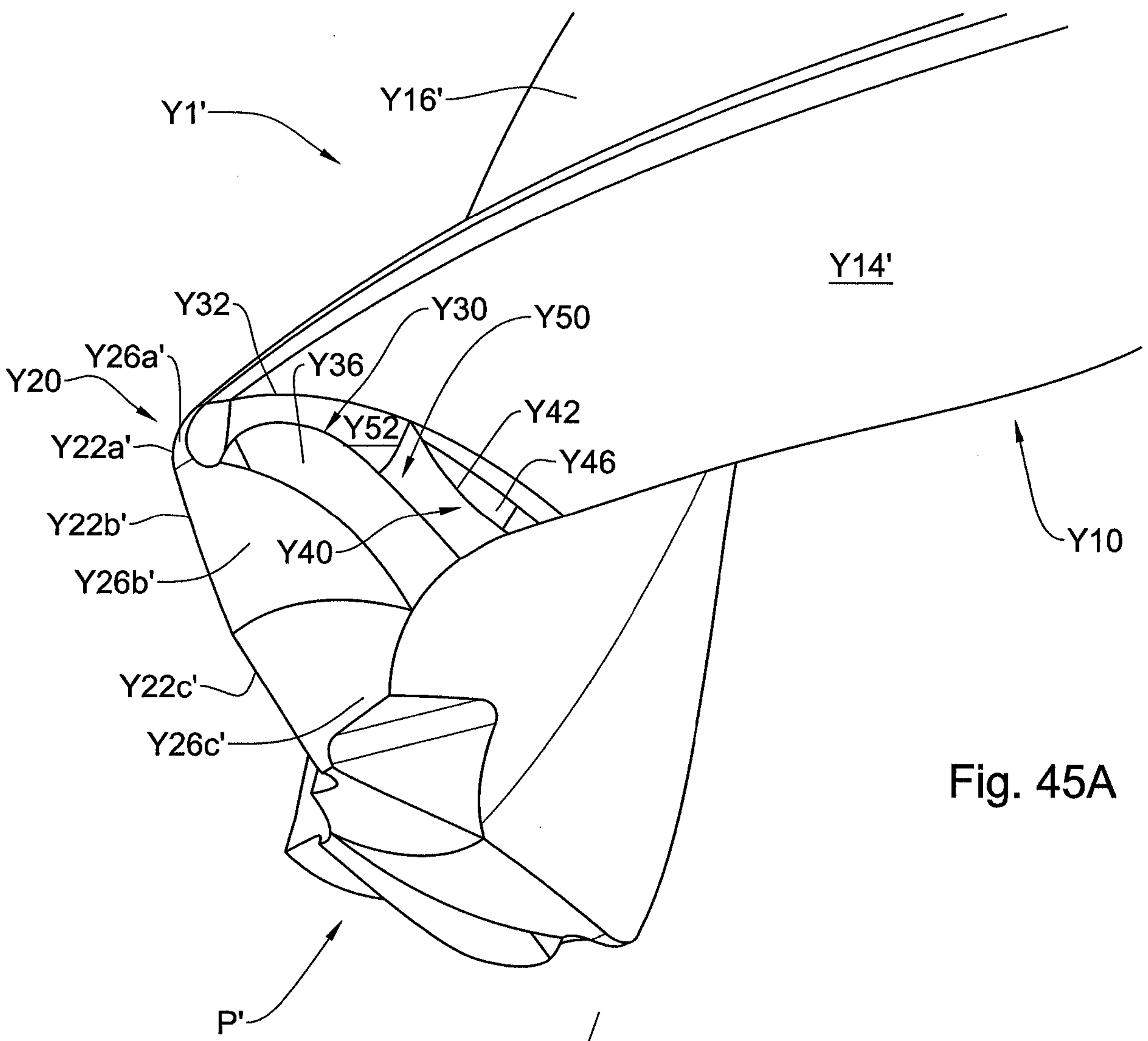


Fig. 45A

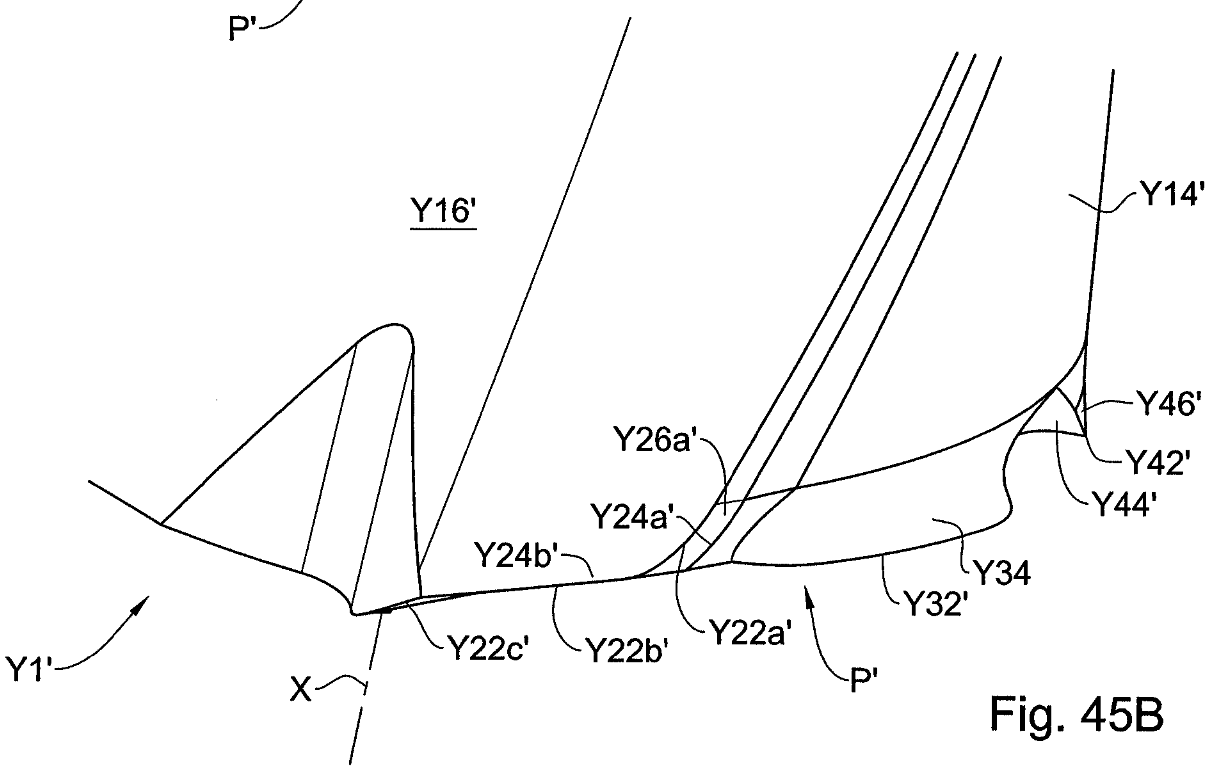


Fig. 45B

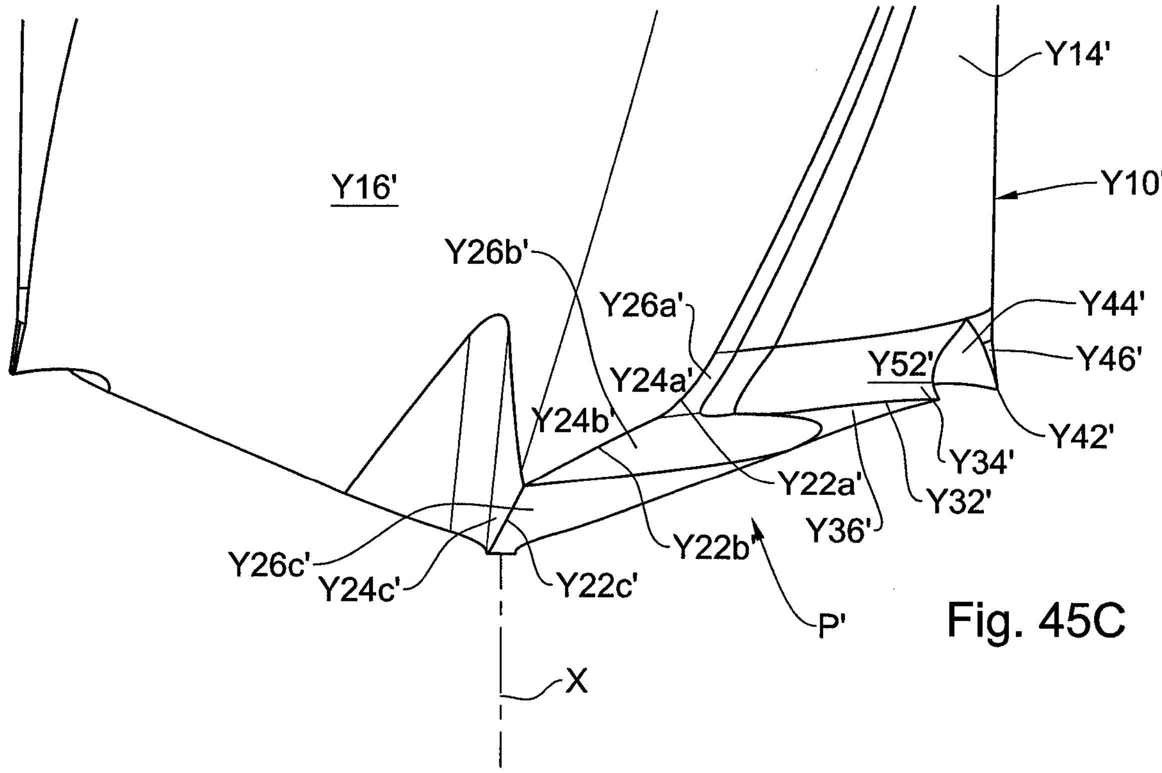


Fig. 45C

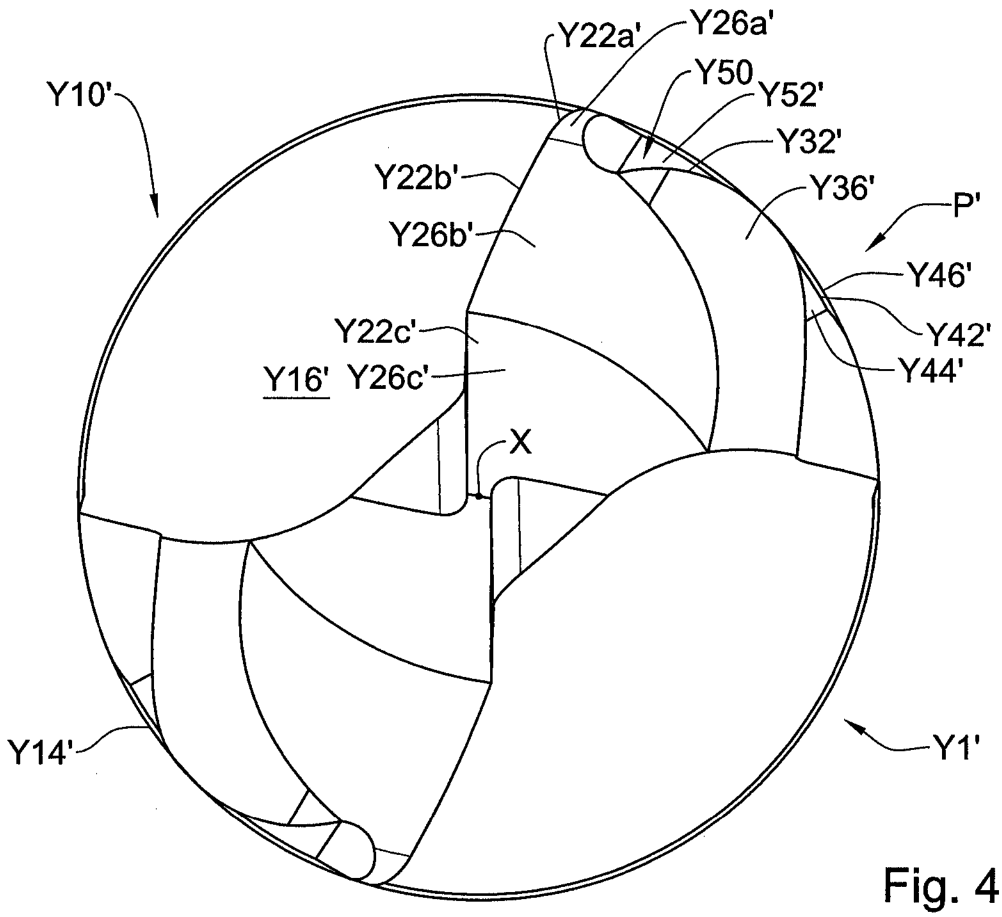


Fig. 45D

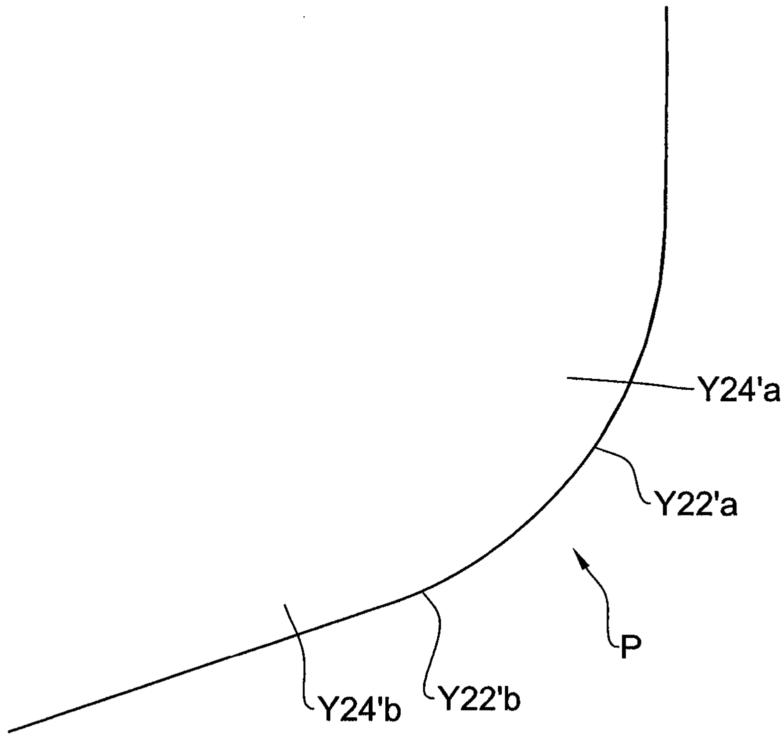


Fig. 46A

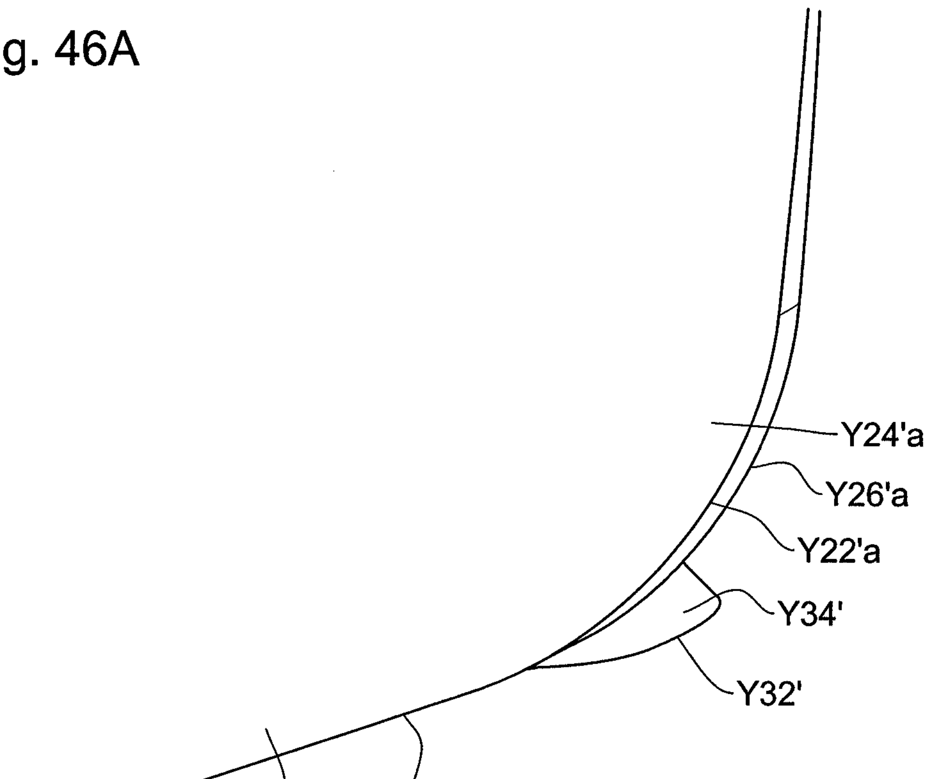


Fig. 46B

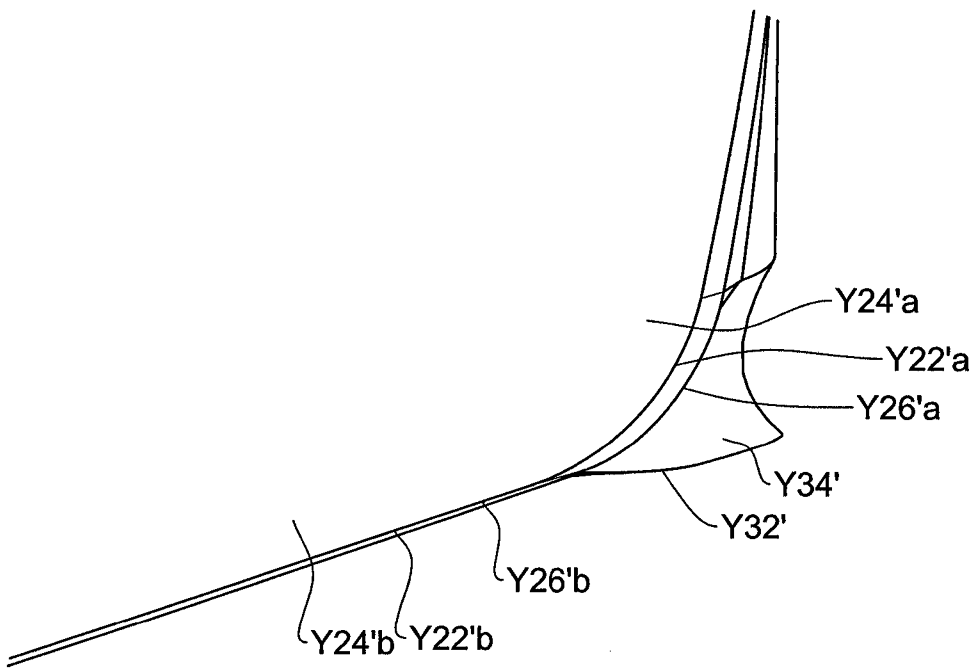


Fig. 46C

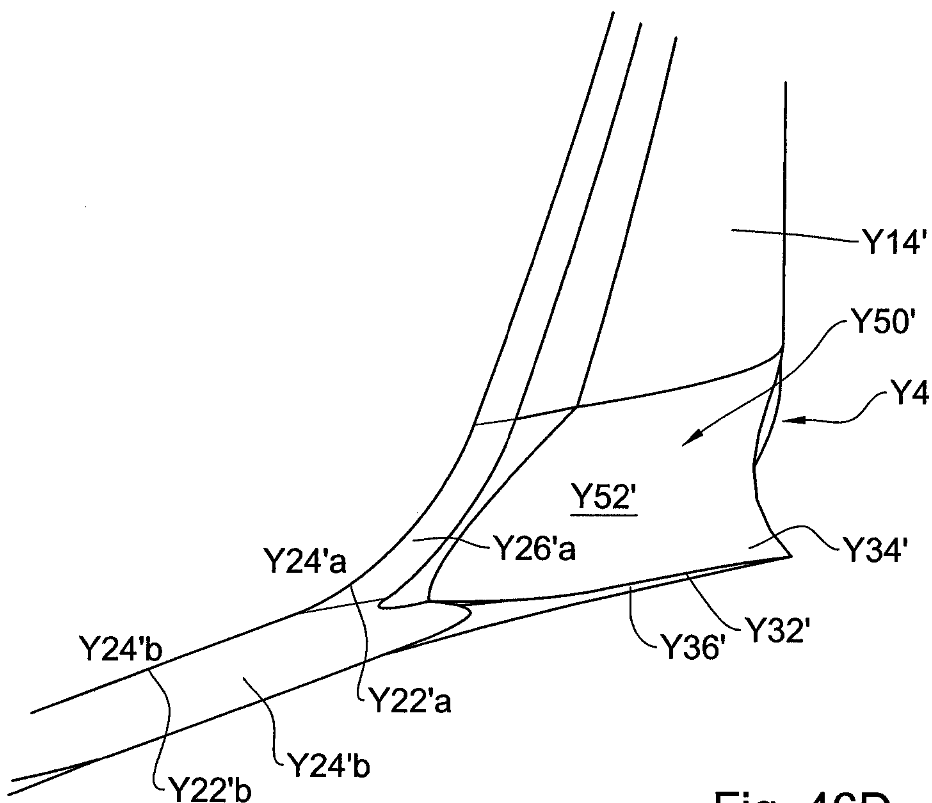


Fig. 46D

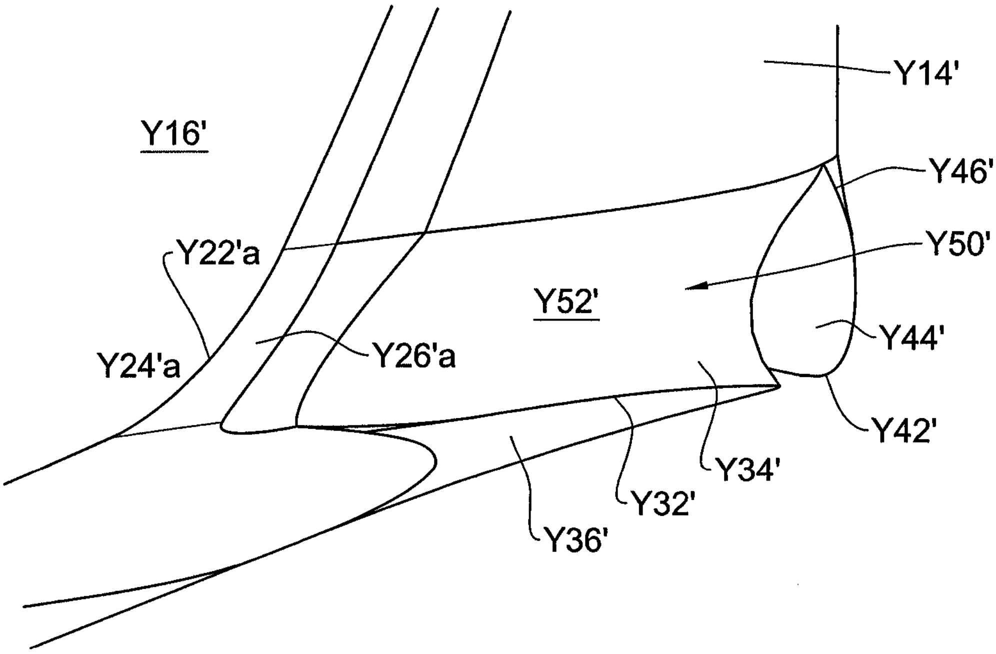


Fig. 46E

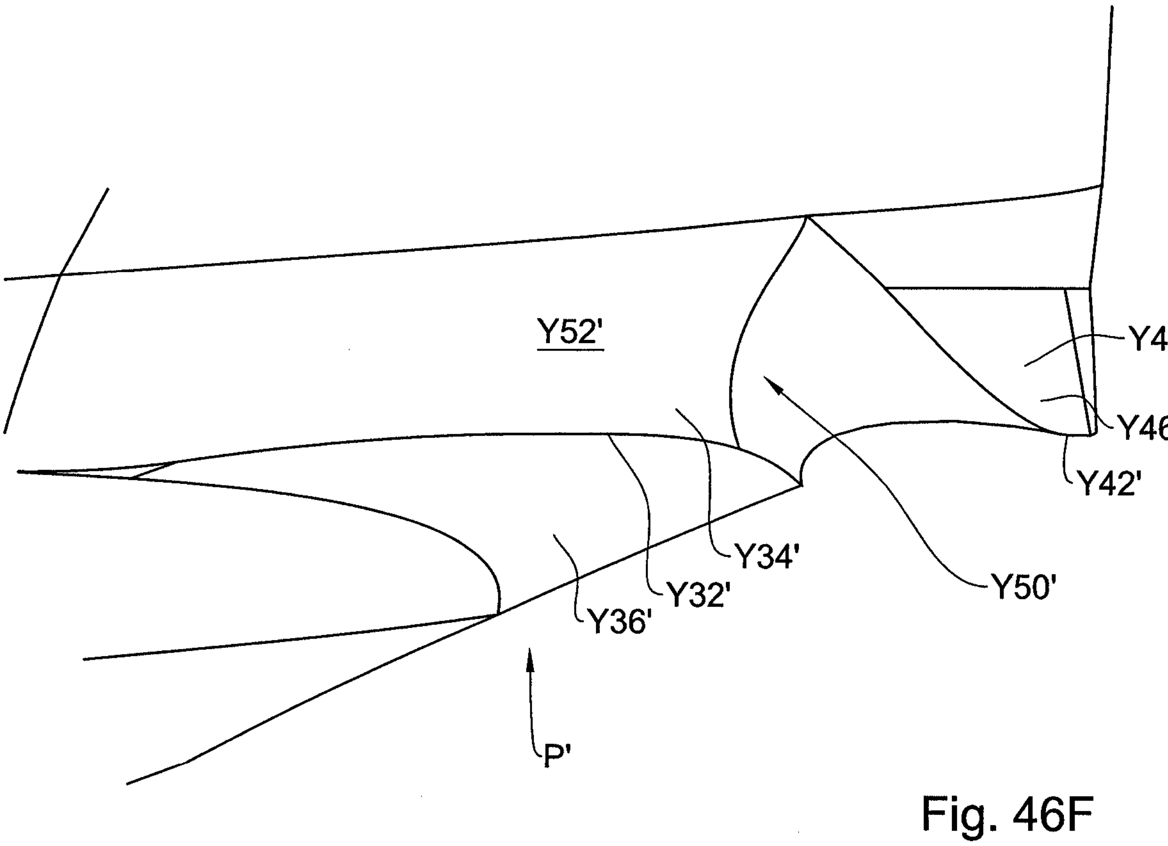


Fig. 46F

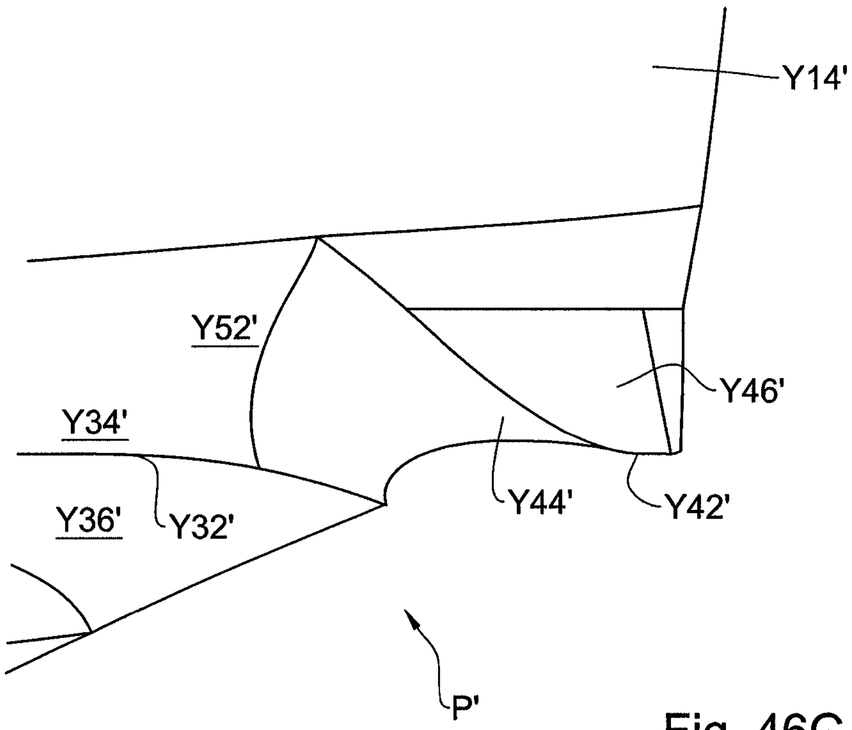


Fig. 46G

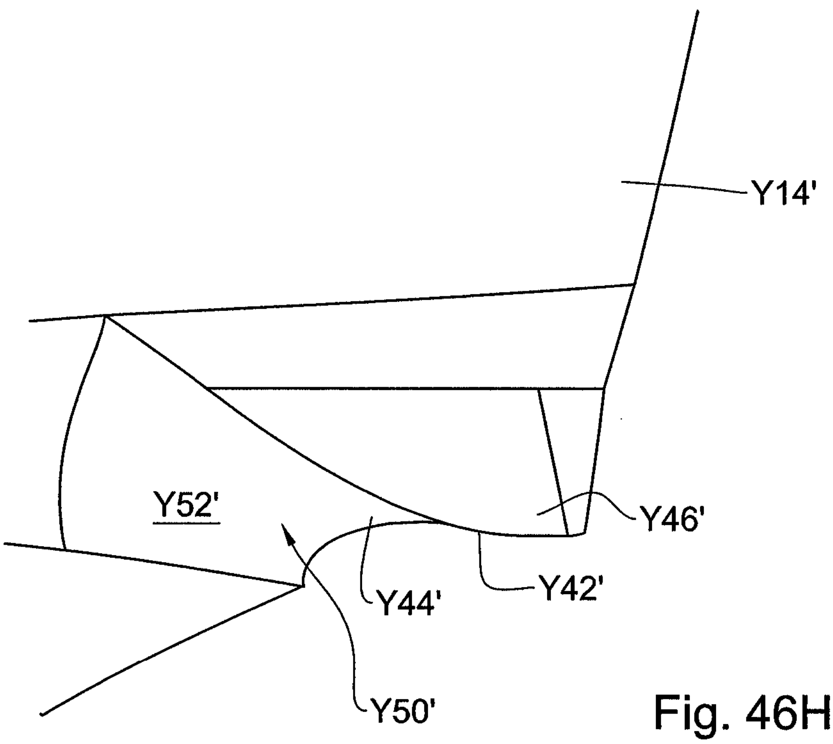


Fig. 46H

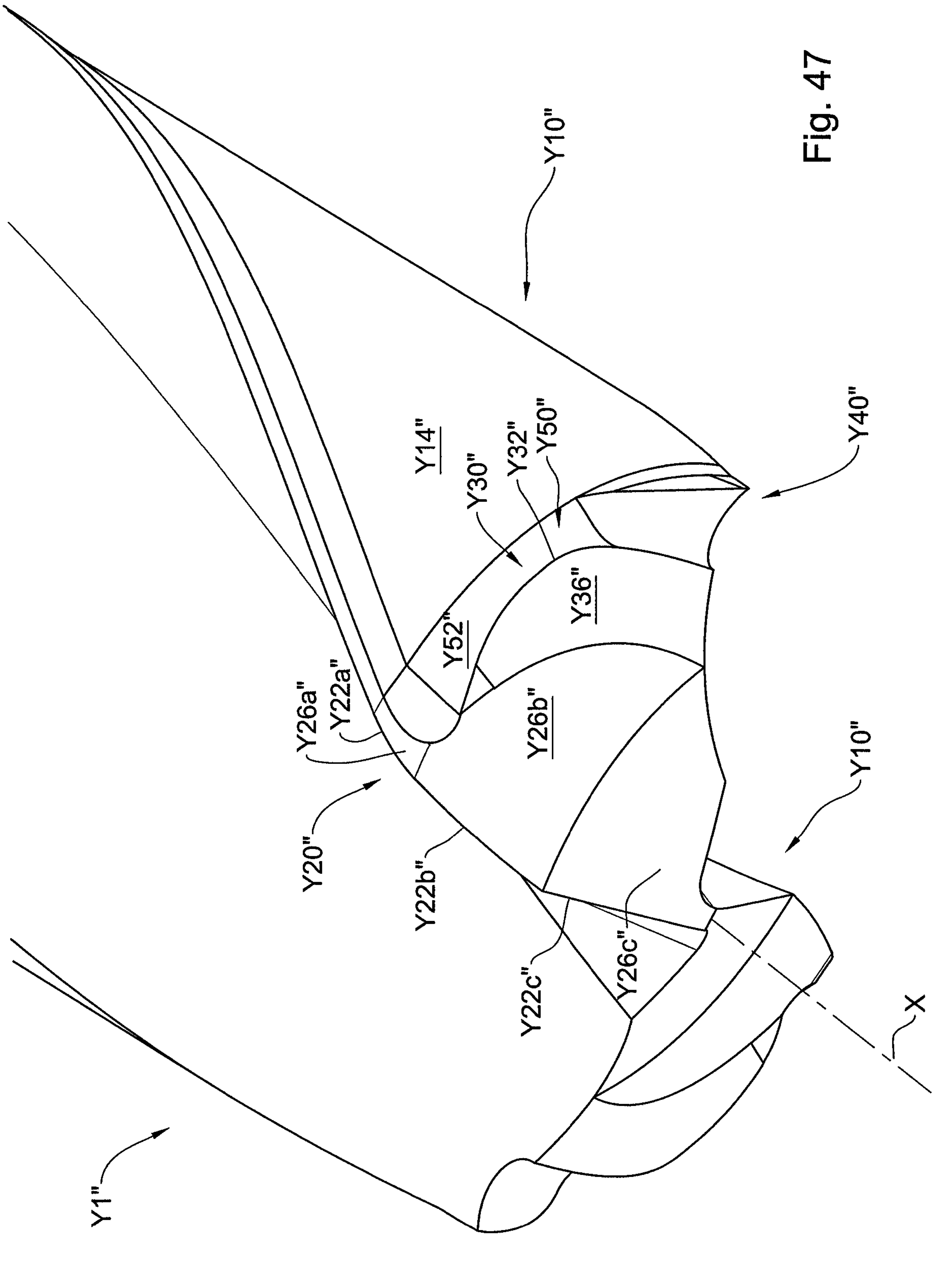

Y10"
Y14"
Y30"
Y32"
Y50"
Y40"
Y36"
Y52"
Y26b"
Y26a"
Y22a"
Y20"
Y22b"
Y10"
Y22c"
Y26c"
X
Y1"

Fig. 47

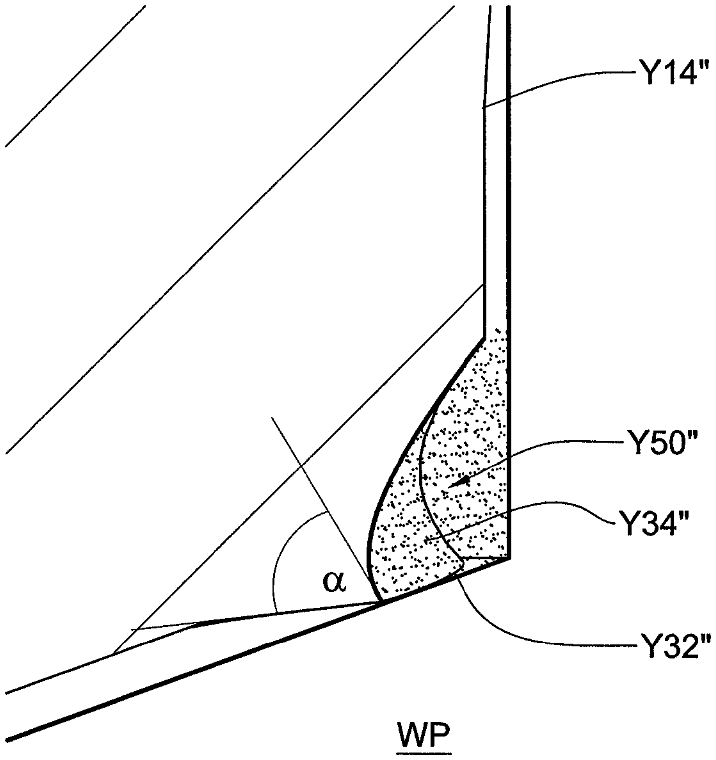


Fig. 48A

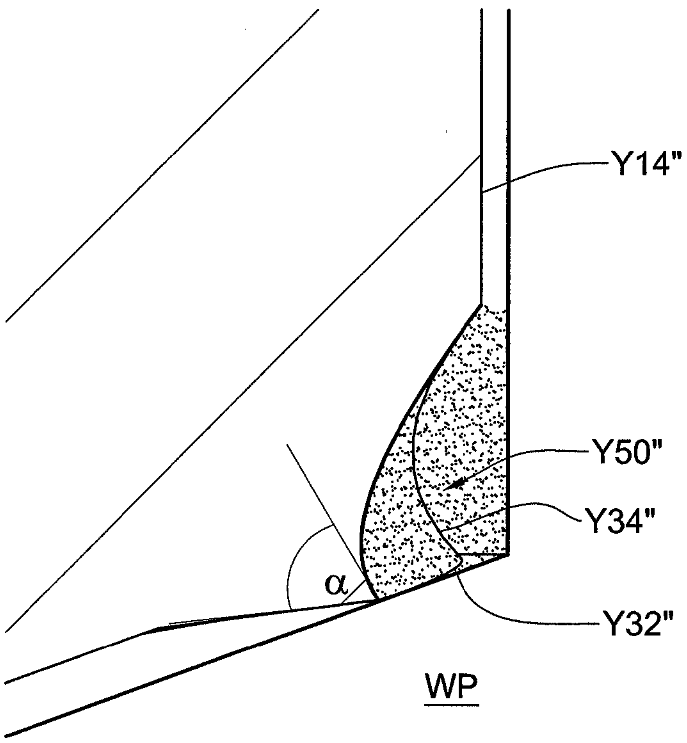


Fig. 48B

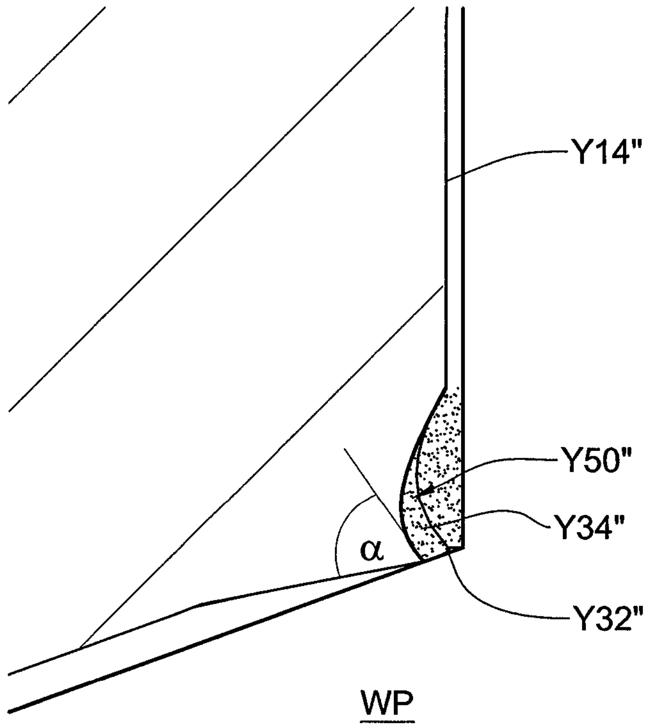


Fig. 48C

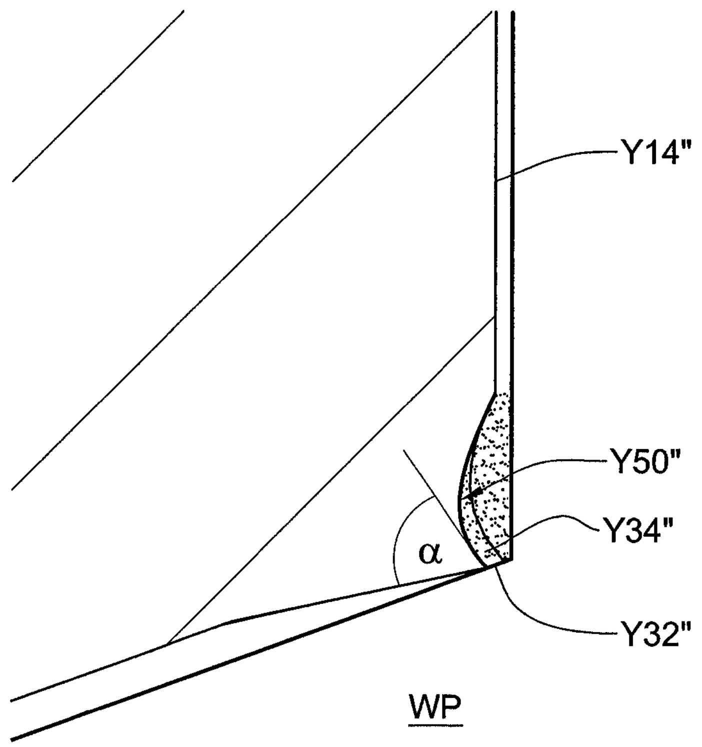


Fig. 48D

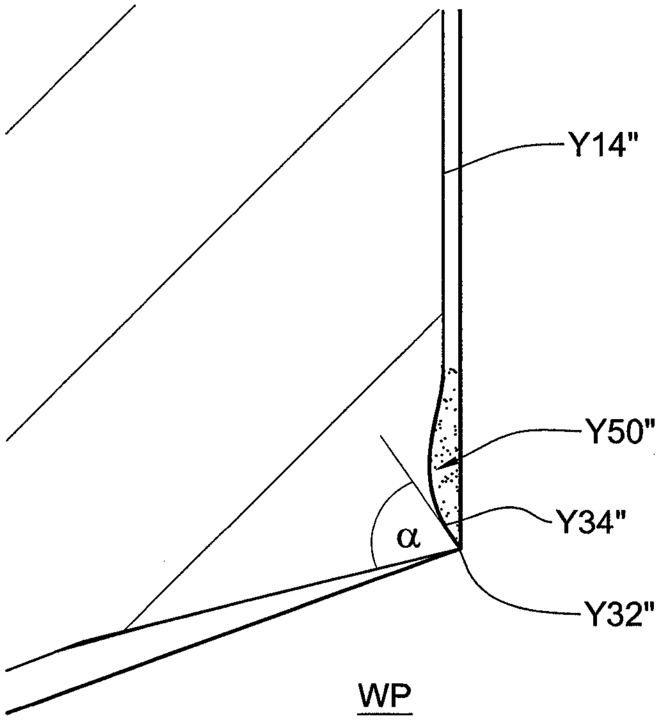


Fig. 48E

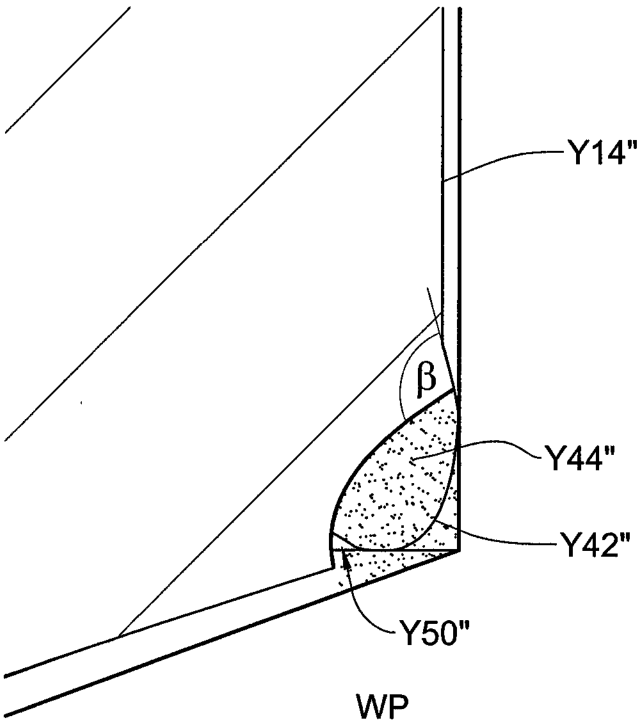


Fig. 48F

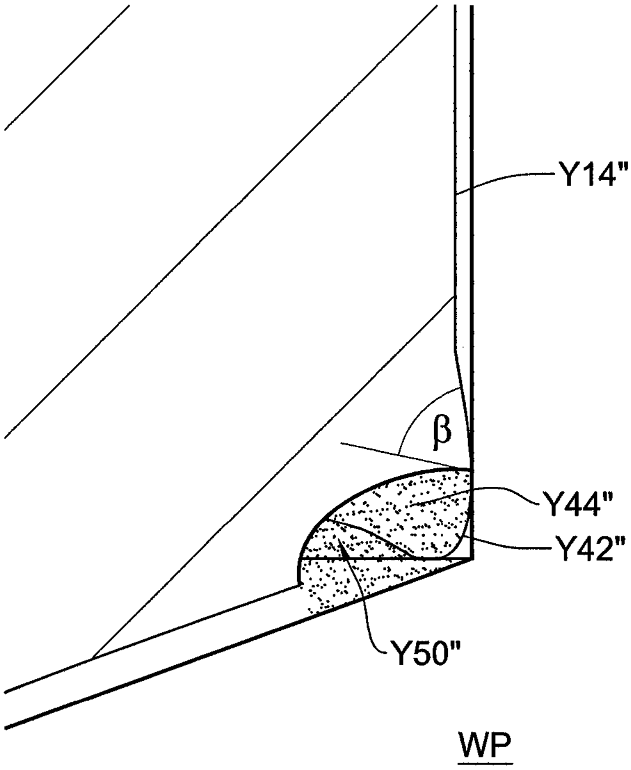


Fig. 48G

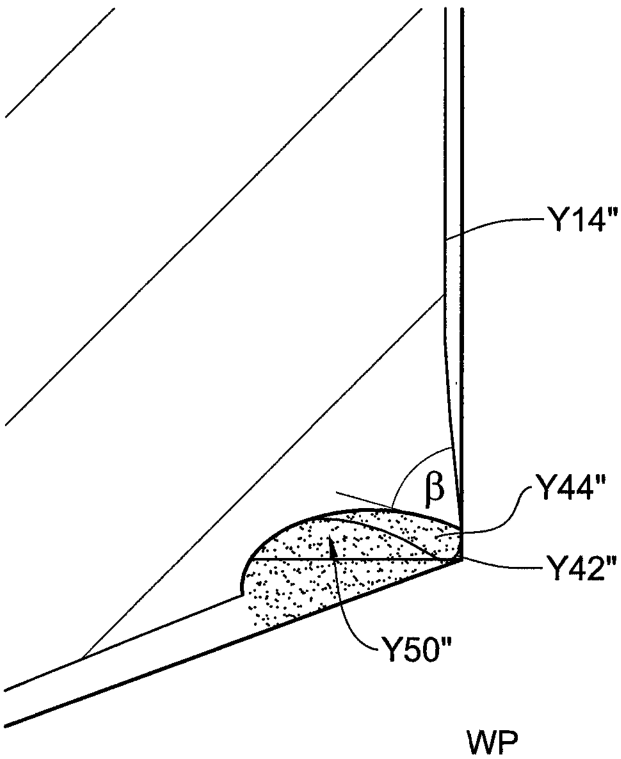


Fig. 48H

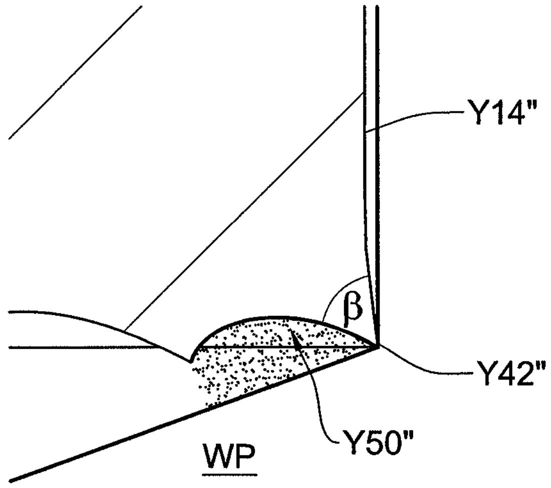


Fig. 48I

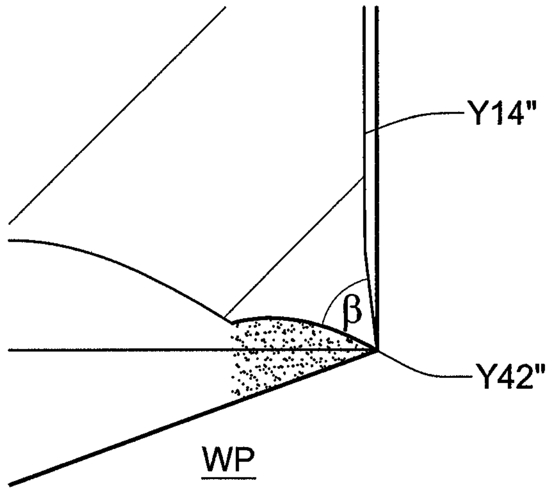


Fig. 48J

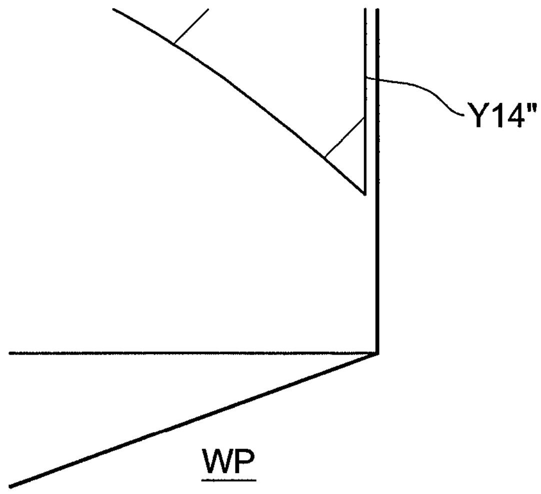


Fig. 48K

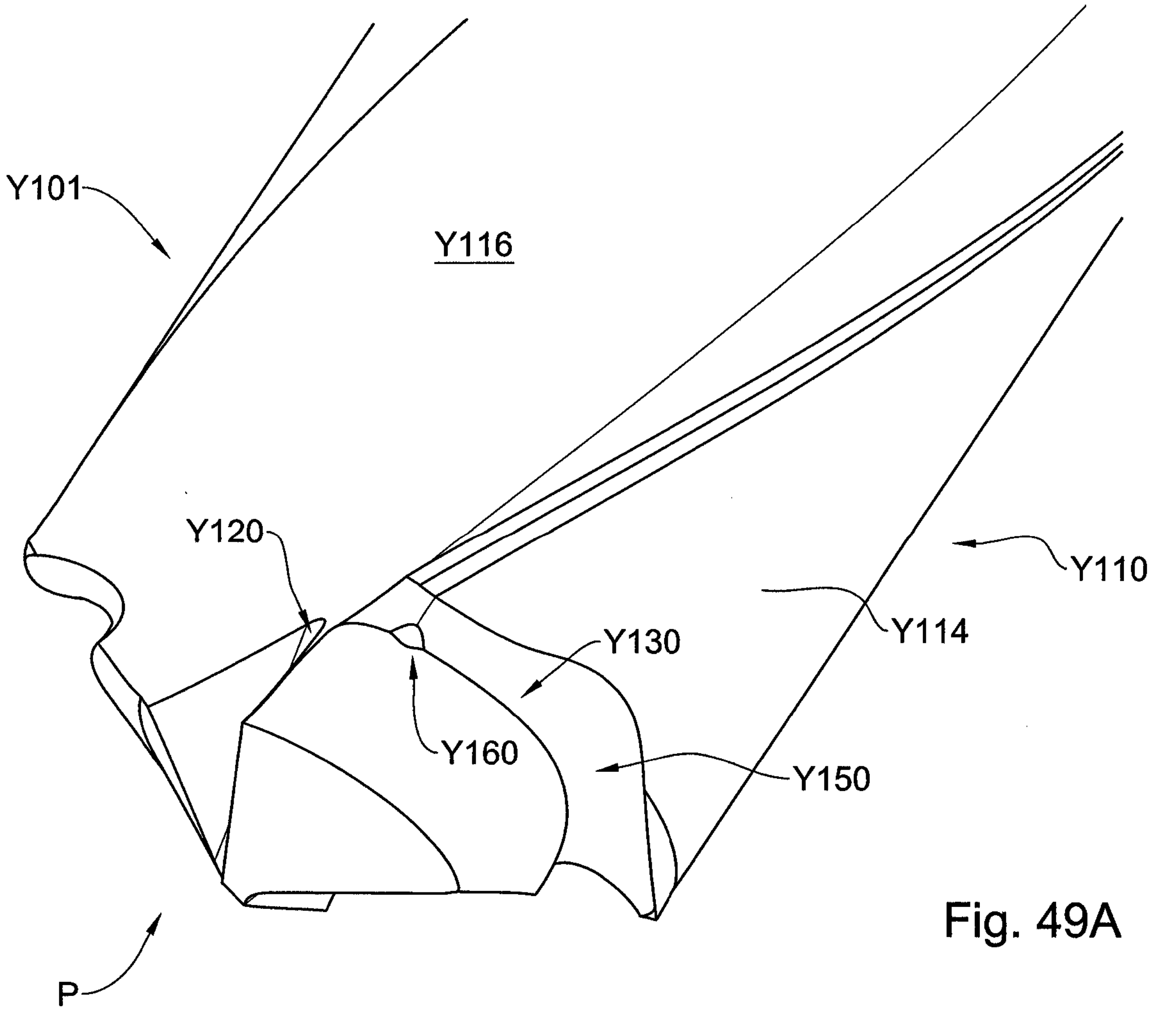


Fig. 49A

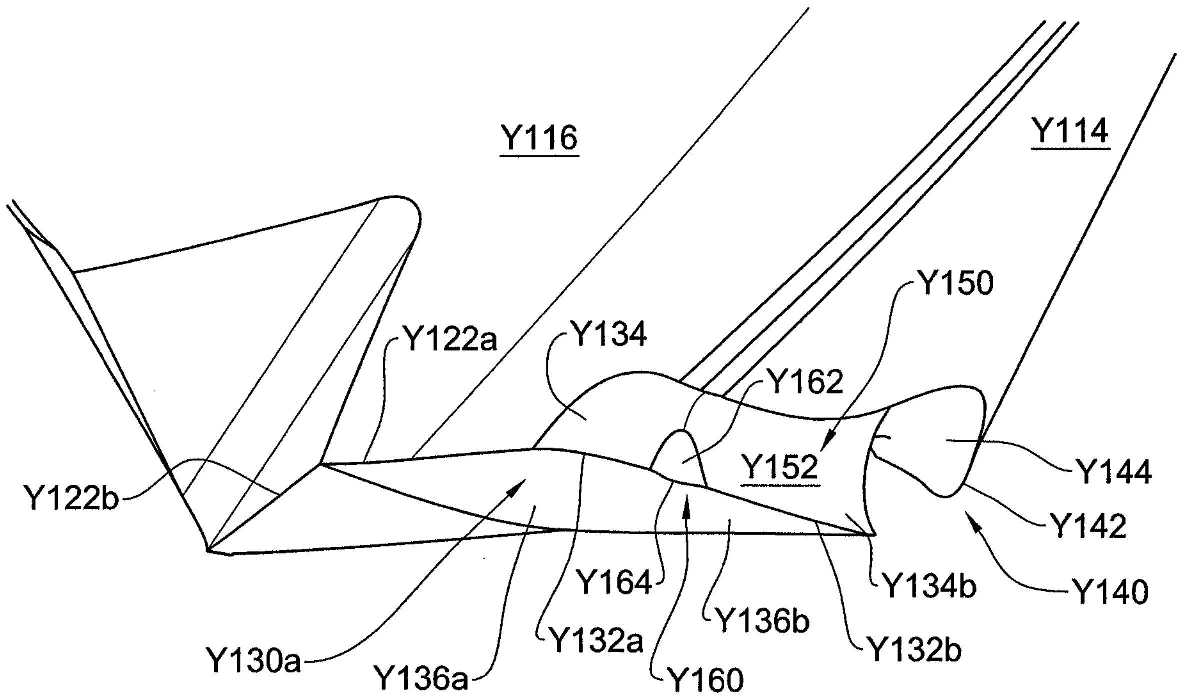


Fig. 49B

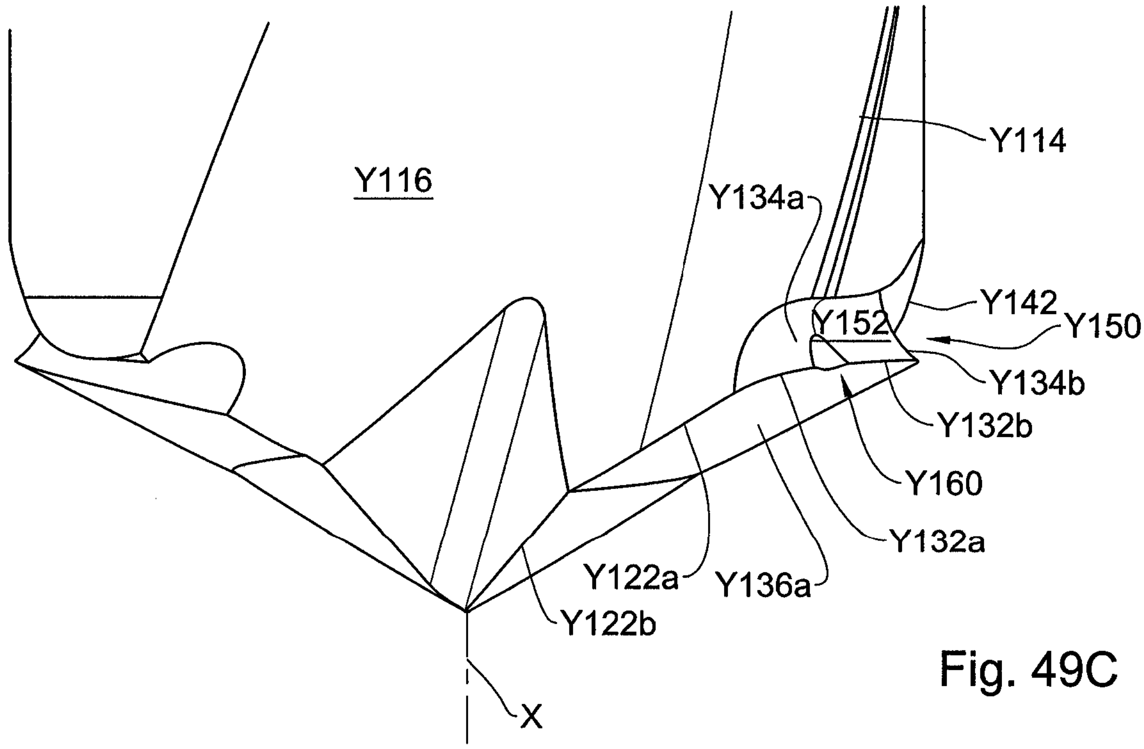


Fig. 49C

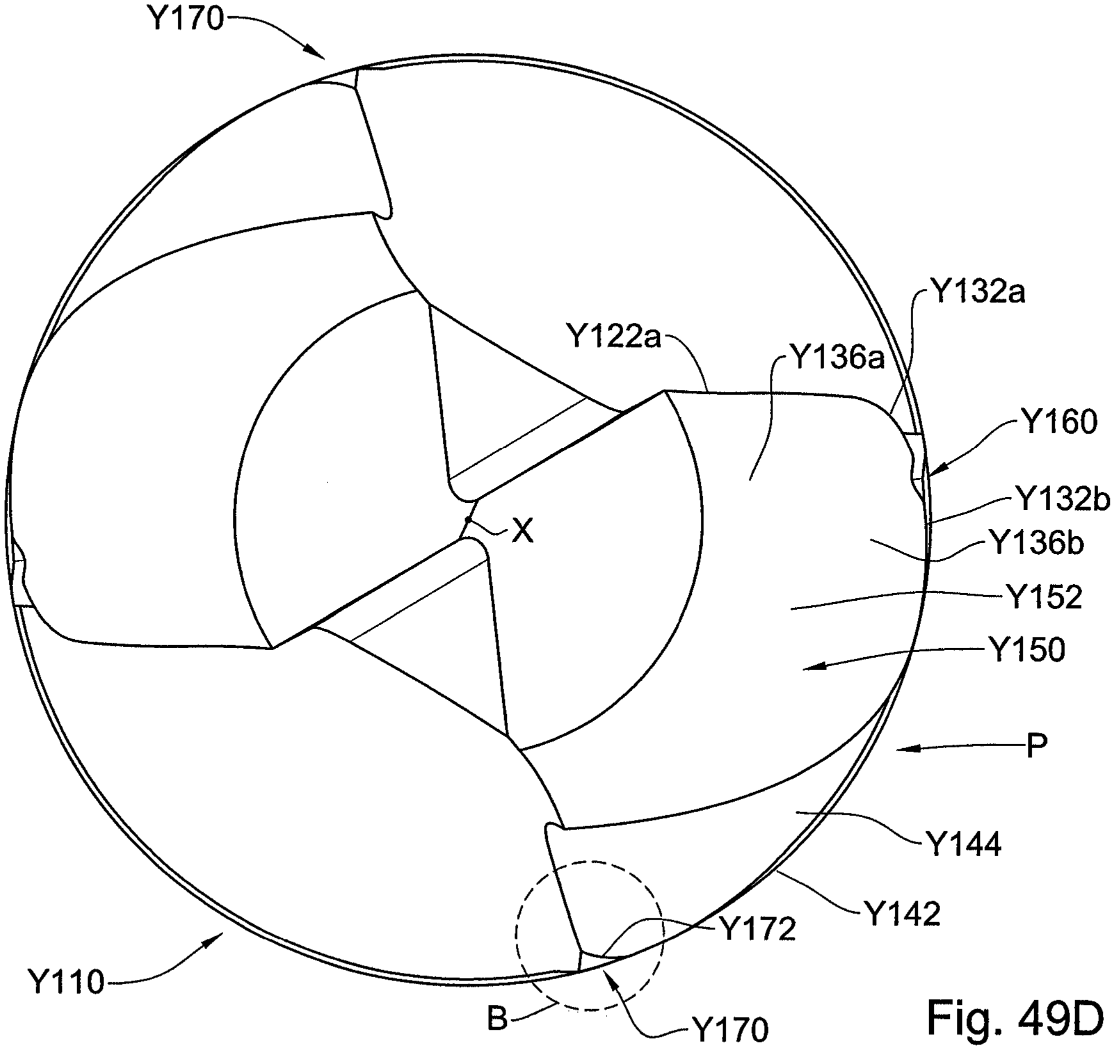


Fig. 49D

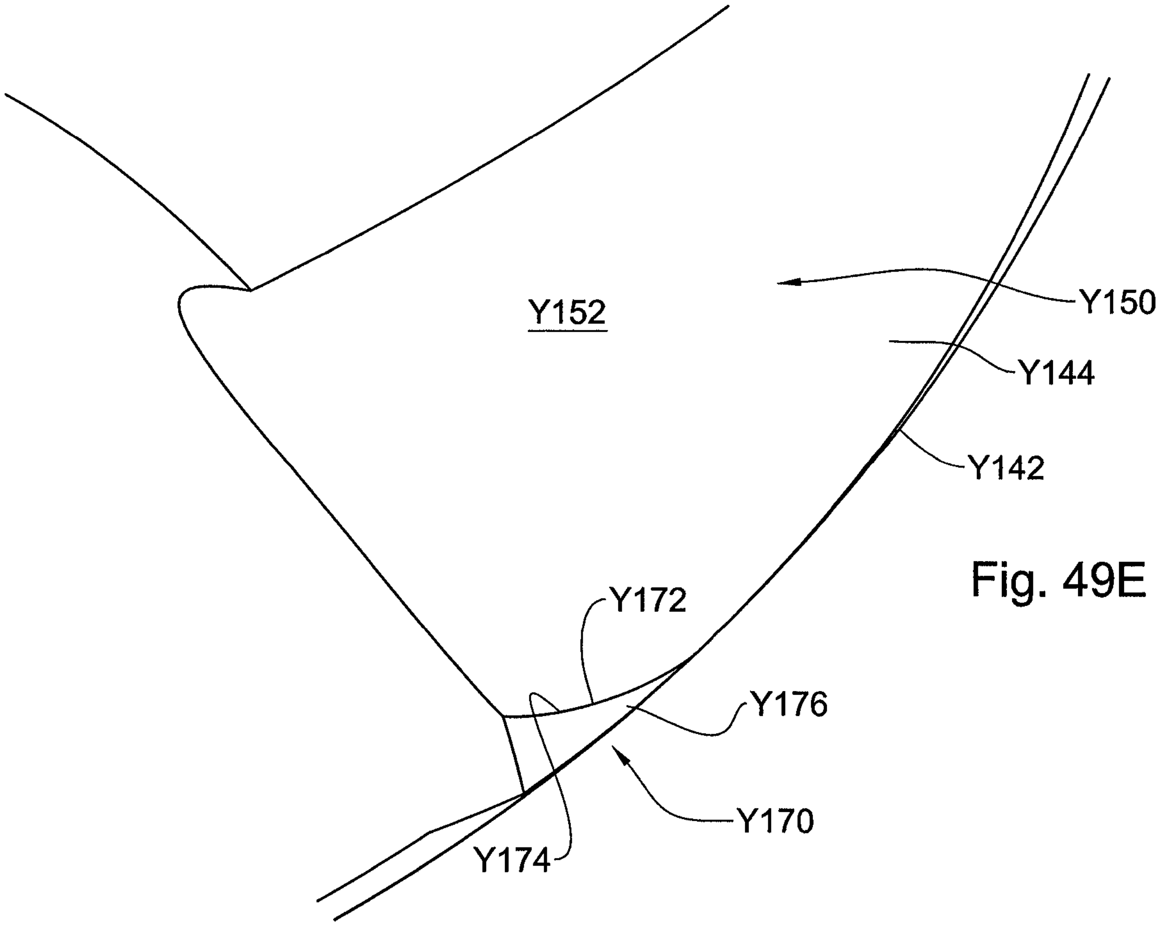


Fig. 49E

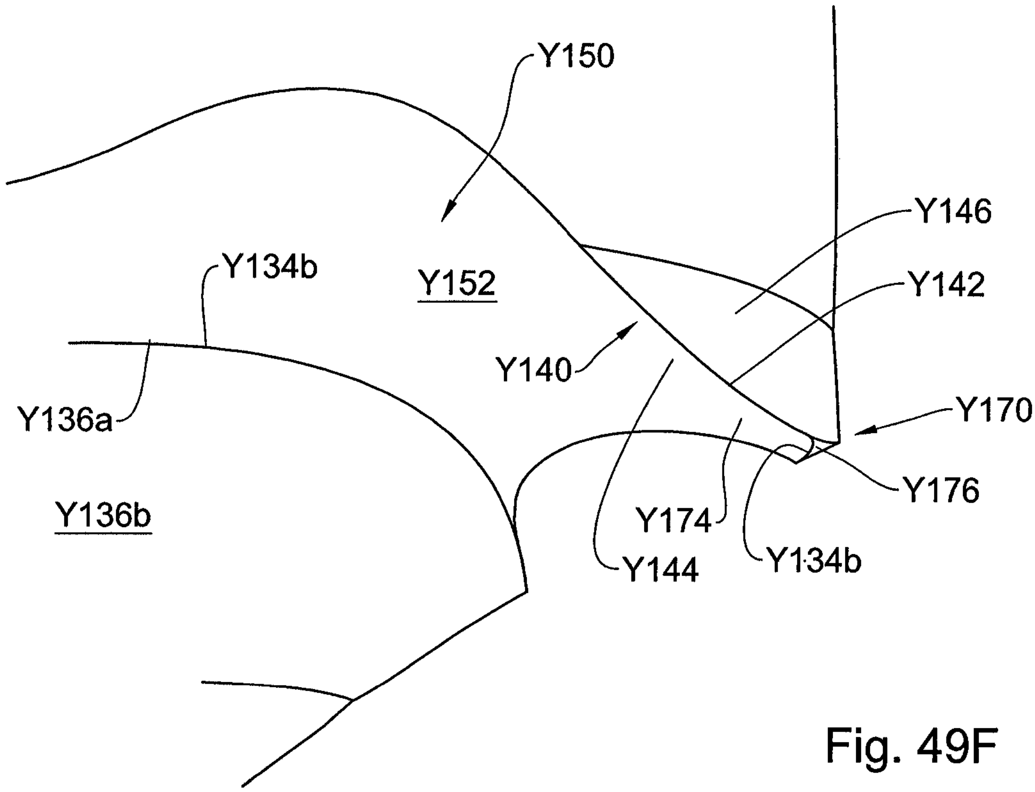


Fig. 49F

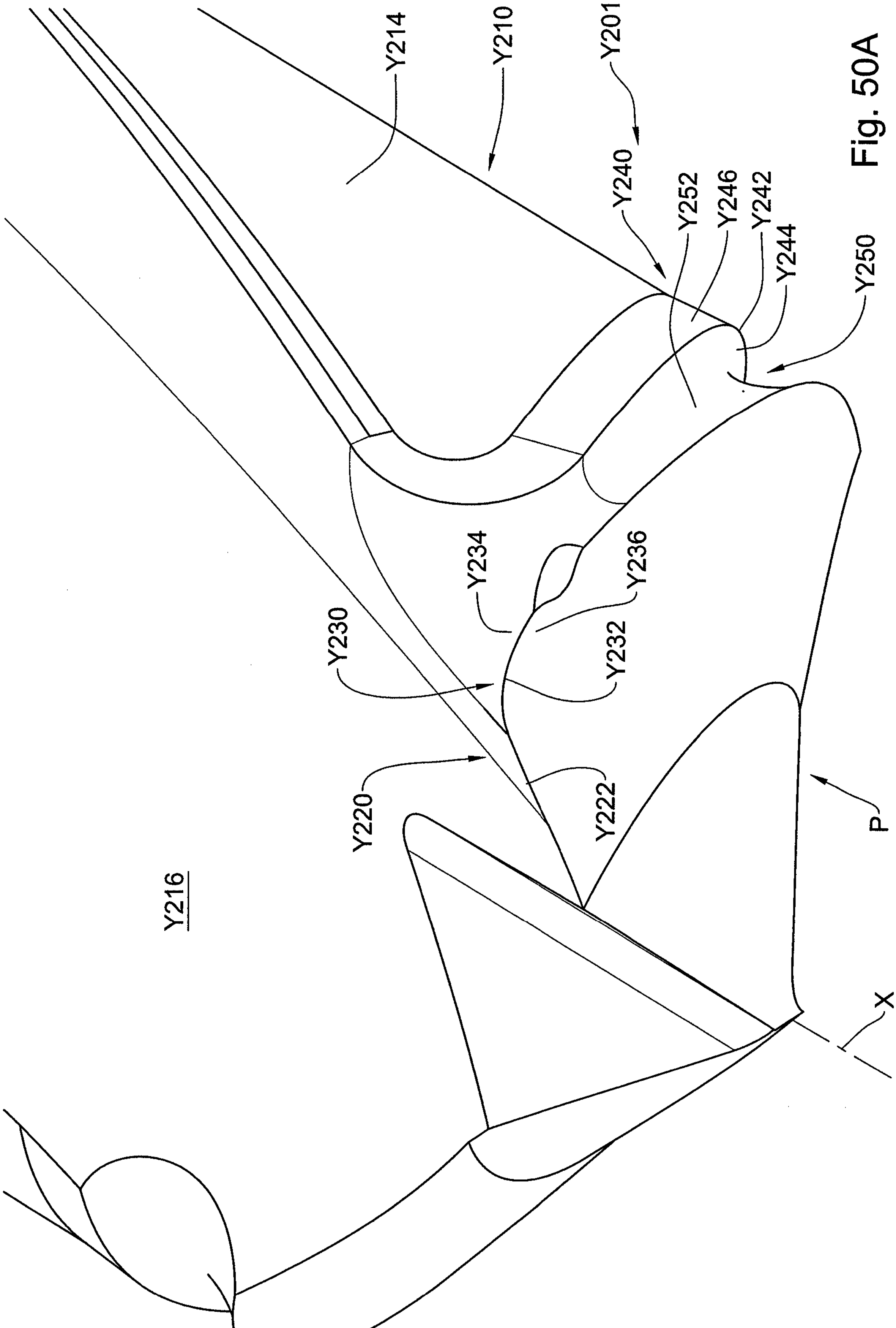

Y214
Y210
Y201
Y240
Y252
Y246
Y242
Y244
Y250
Y234
Y236
Y230
Y232
Y220
Y222
P
Y216
X

Fig. 50A

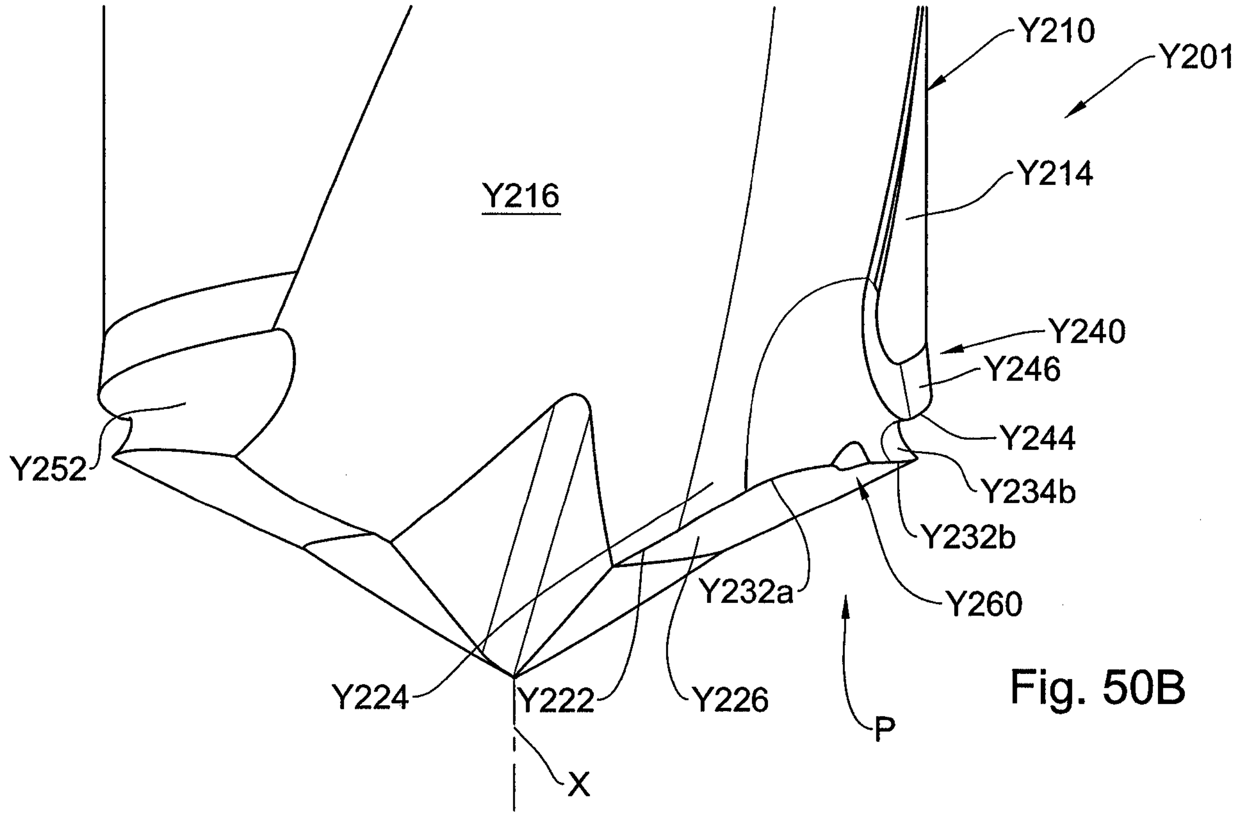


Fig. 50B

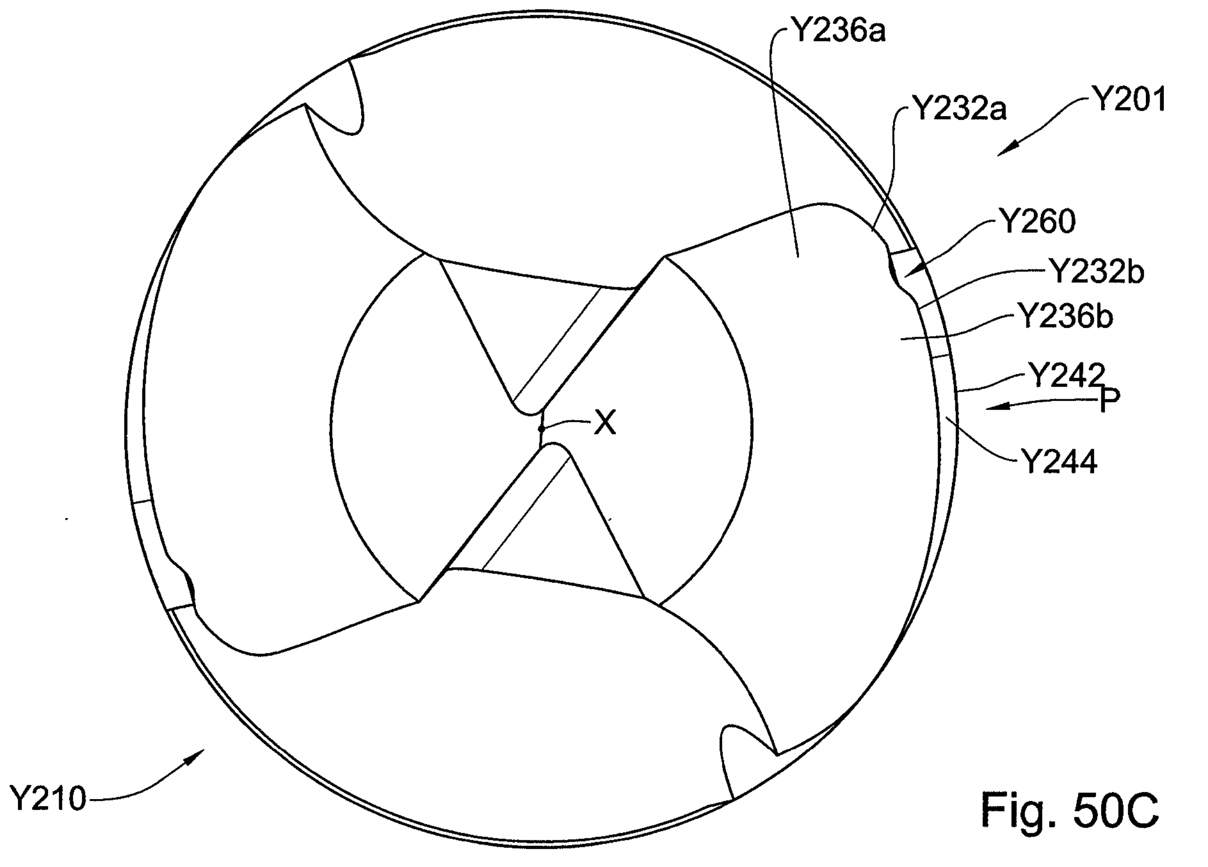


Fig. 50C

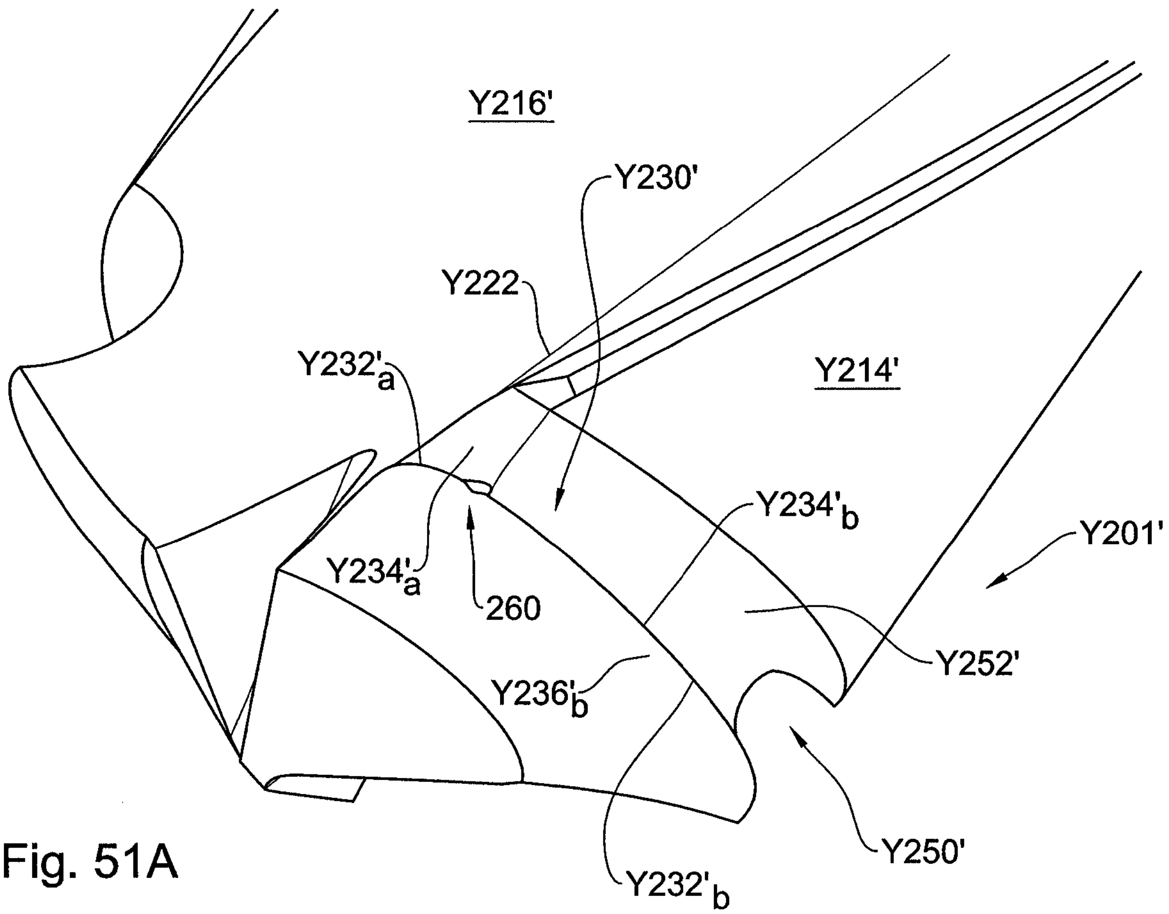


Fig. 51A

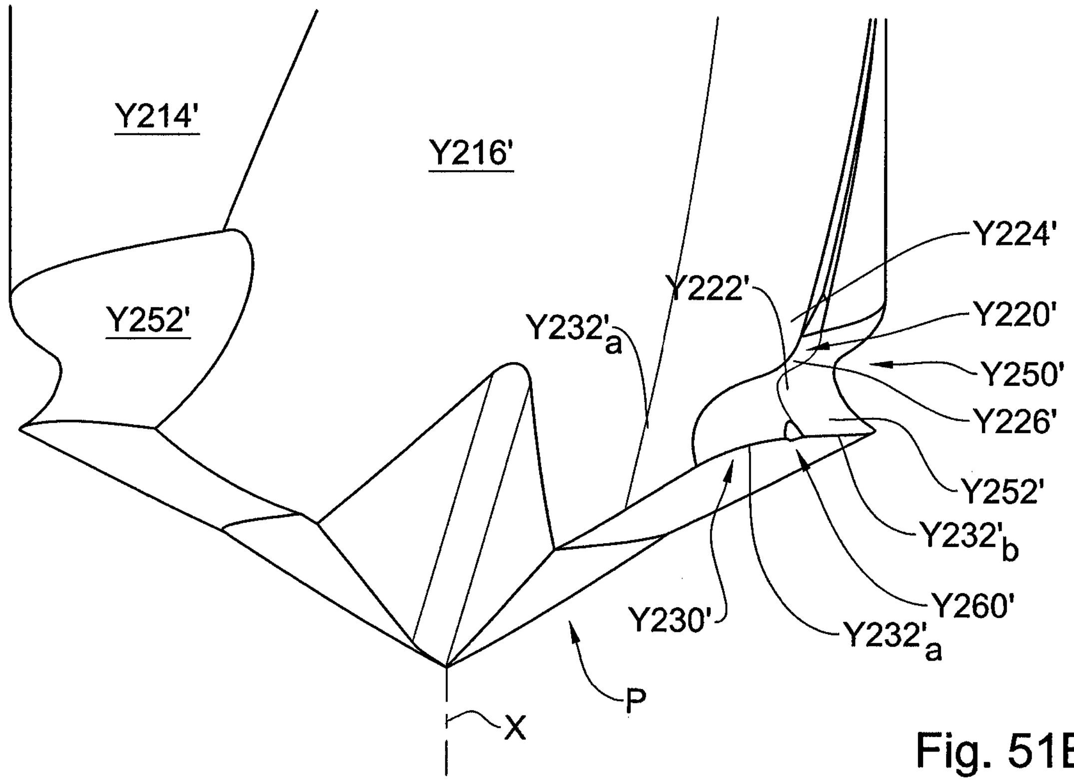


Fig. 51B

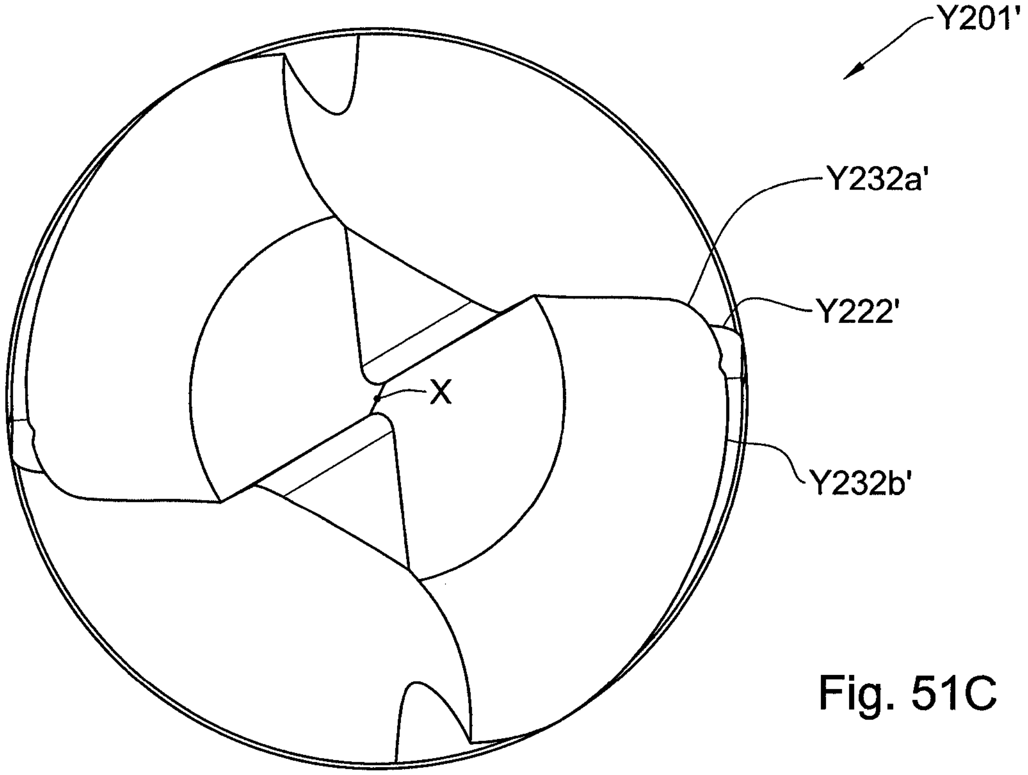


Fig. 51C

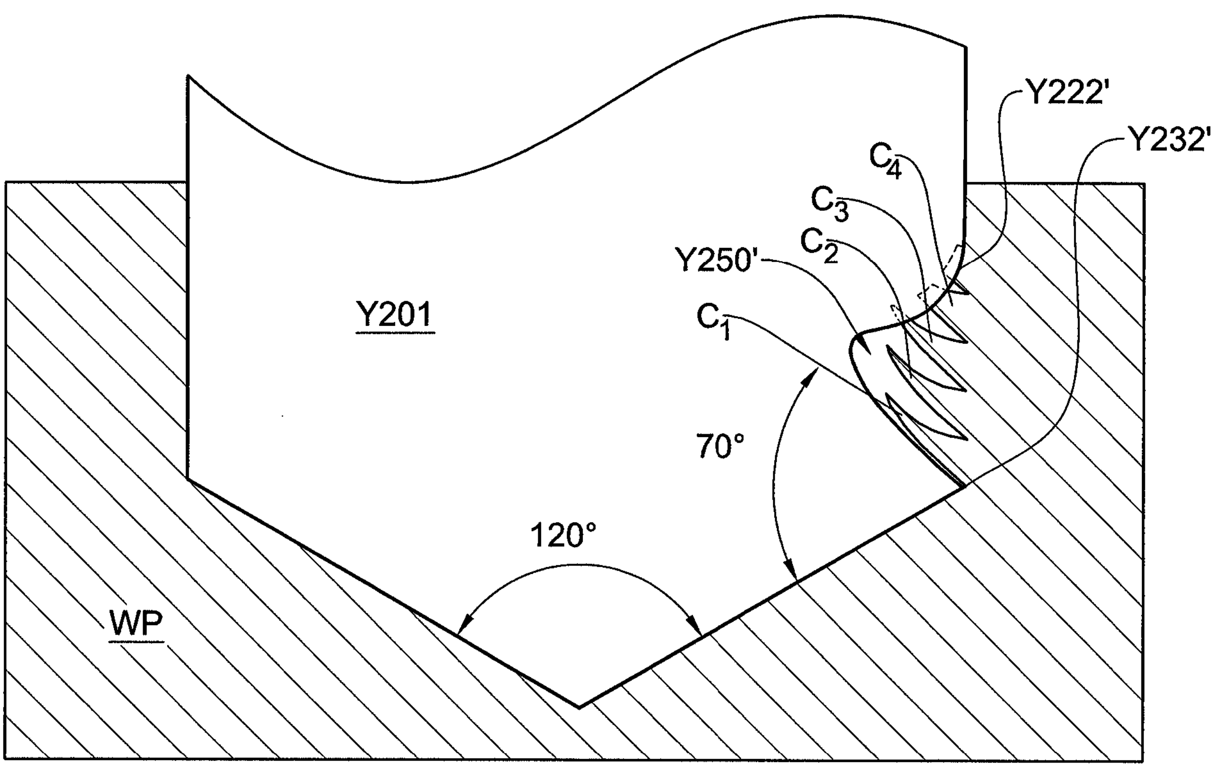


Fig. 51D

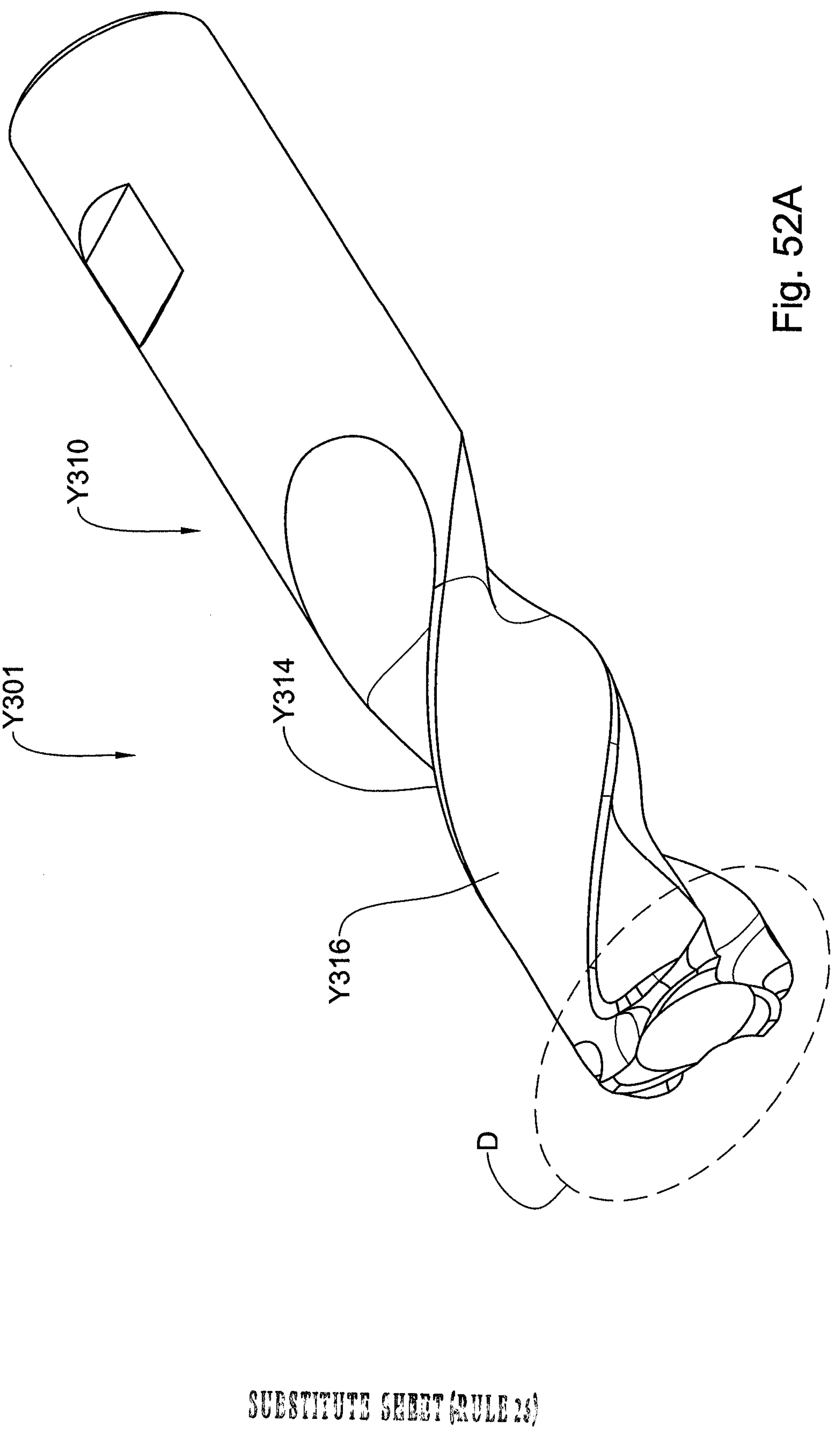


Fig. 52A

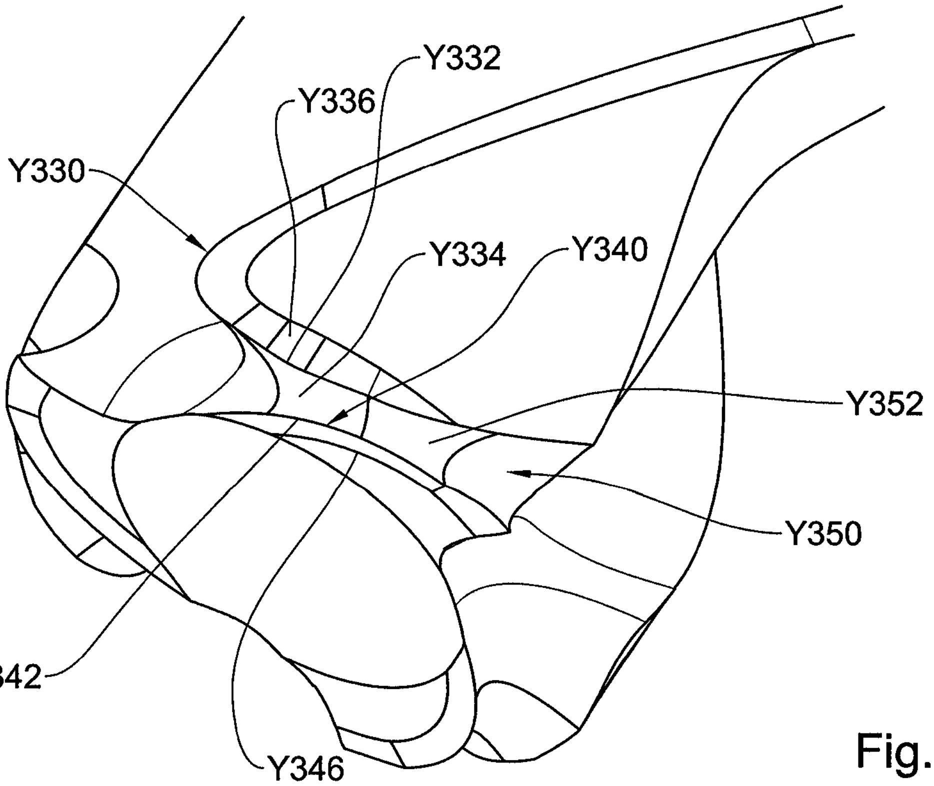


Fig. 52B

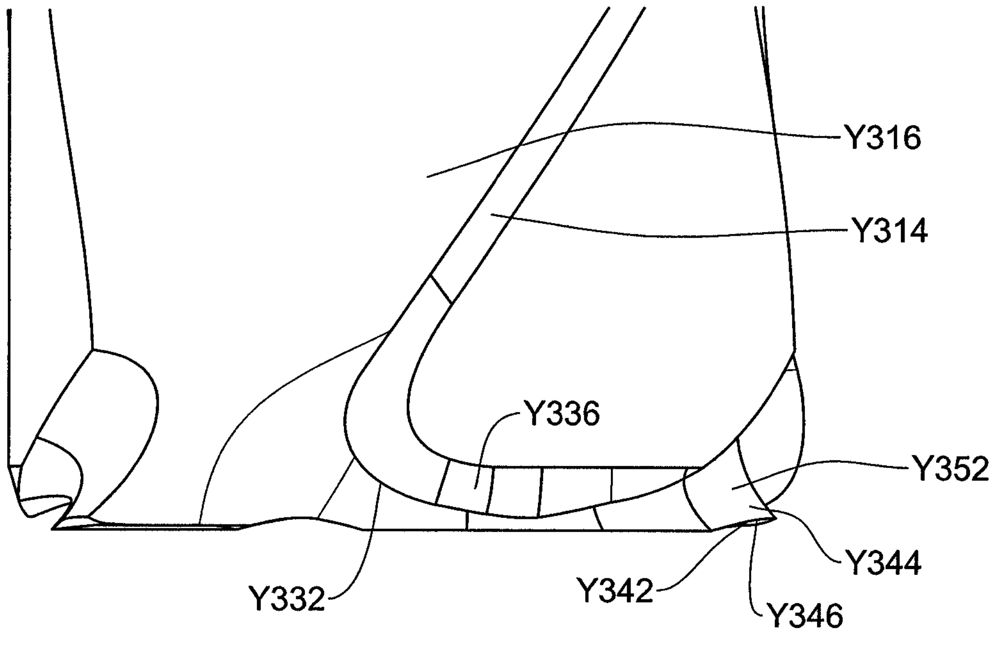


Fig. 52C

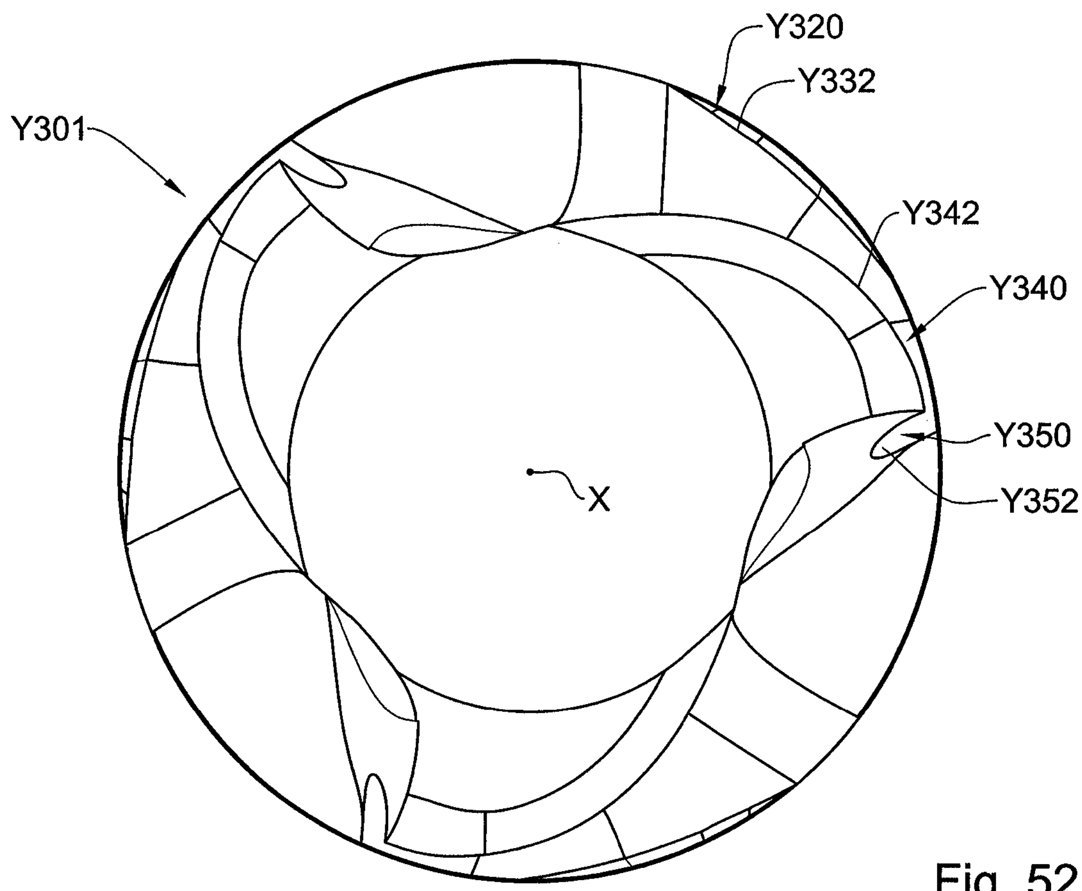


Fig. 52D

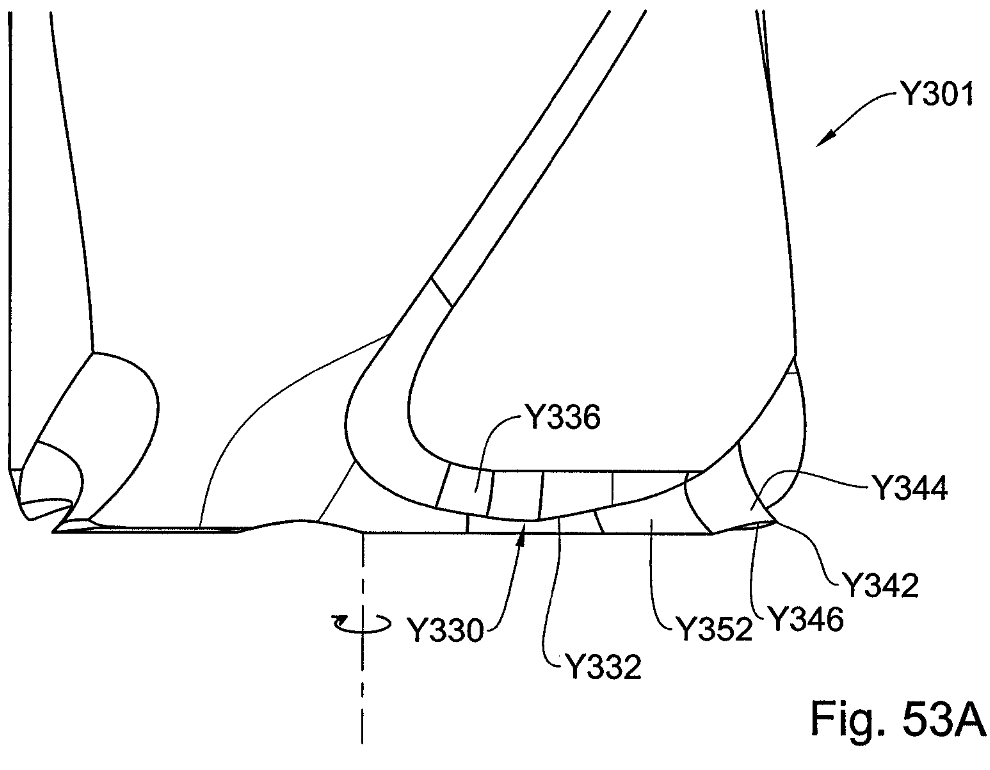


Fig. 53A

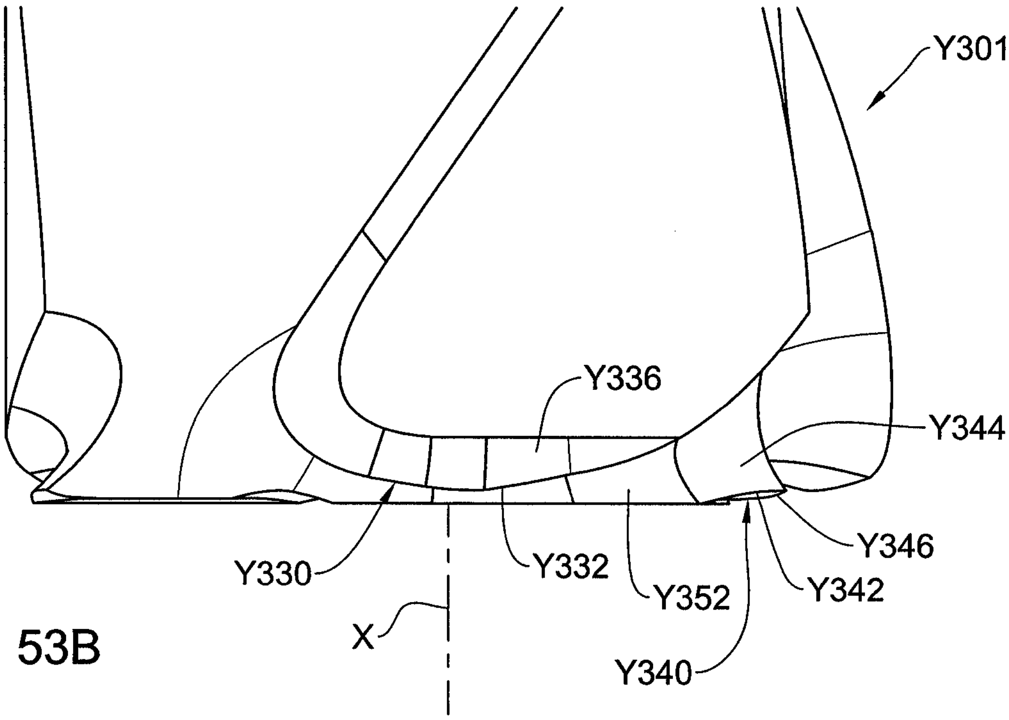


Fig. 53B

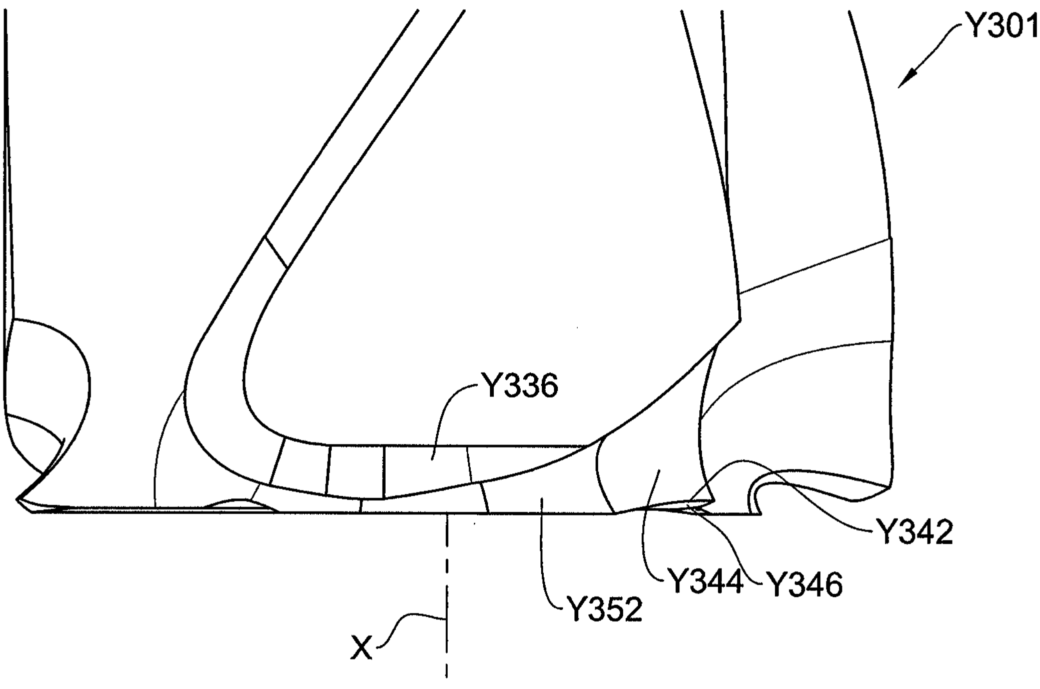


Fig. 53C

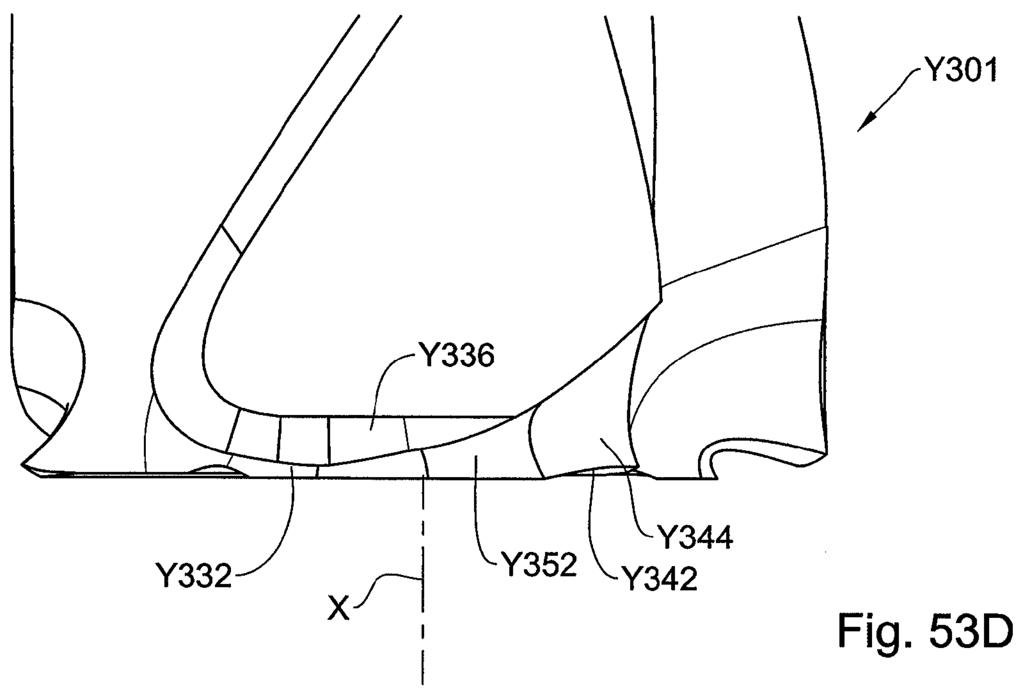


Fig. 53D

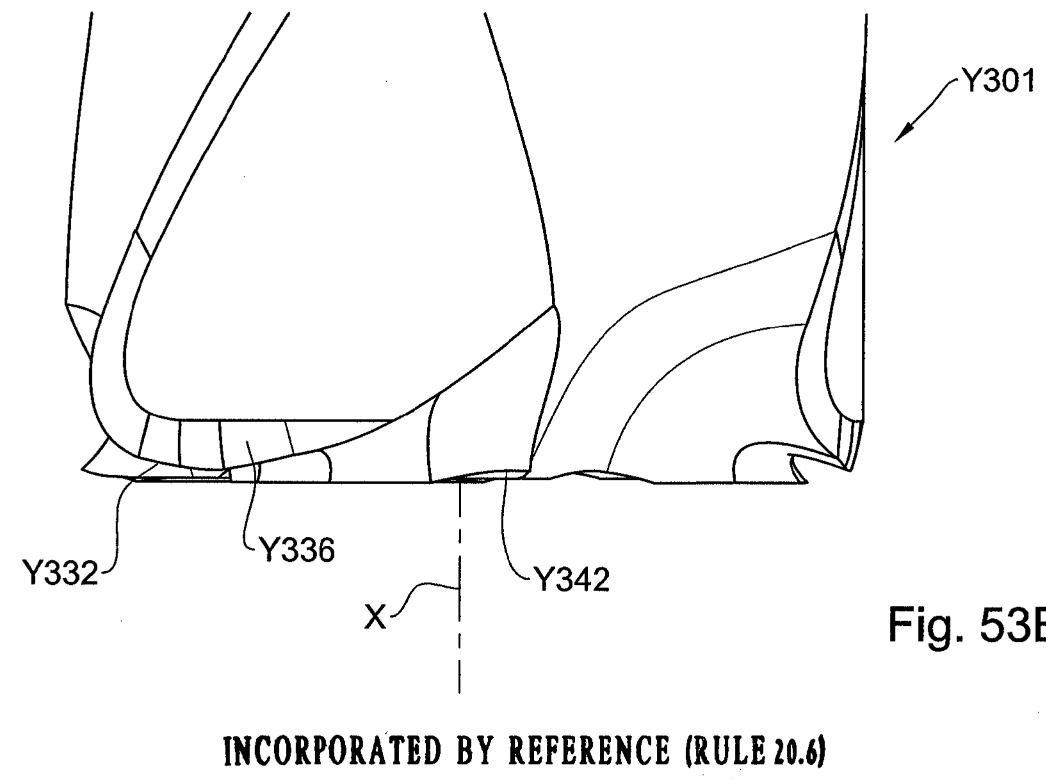


Fig. 53E

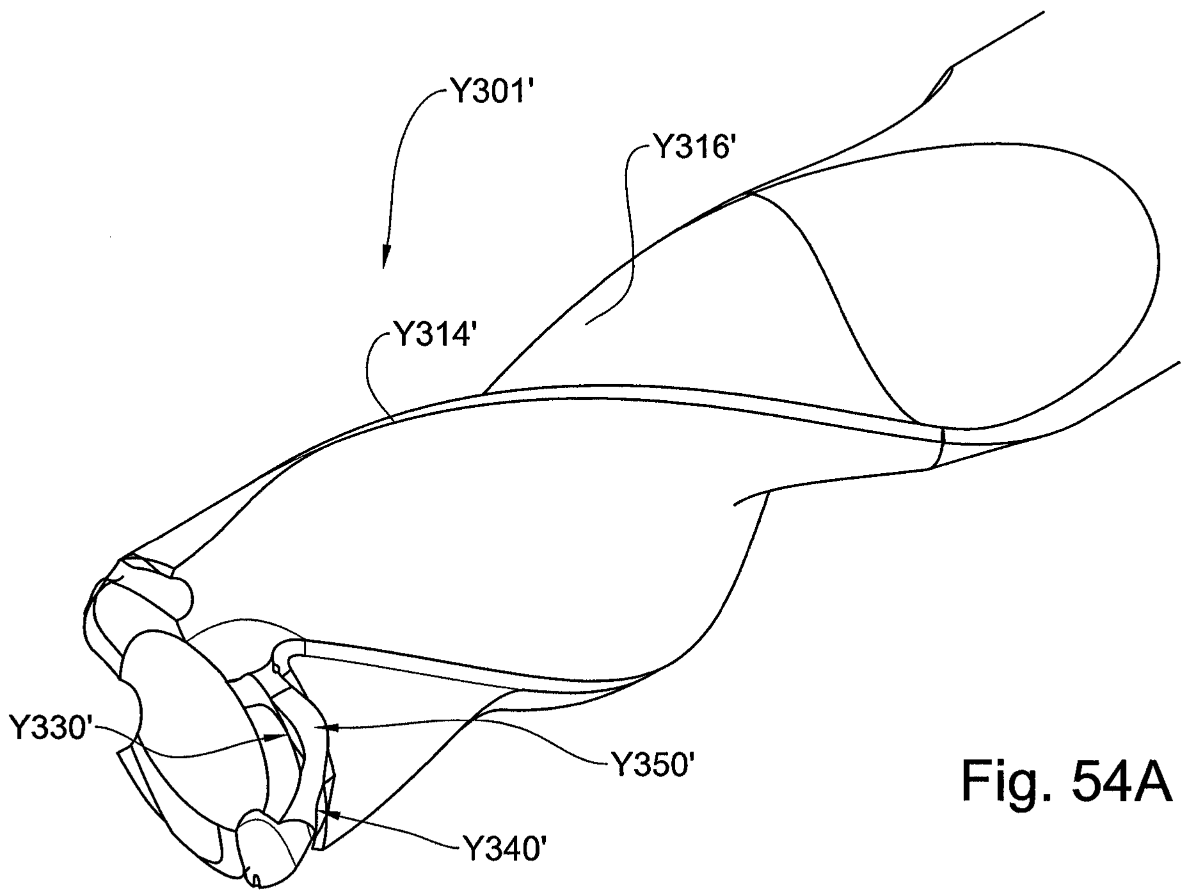


Fig. 54A

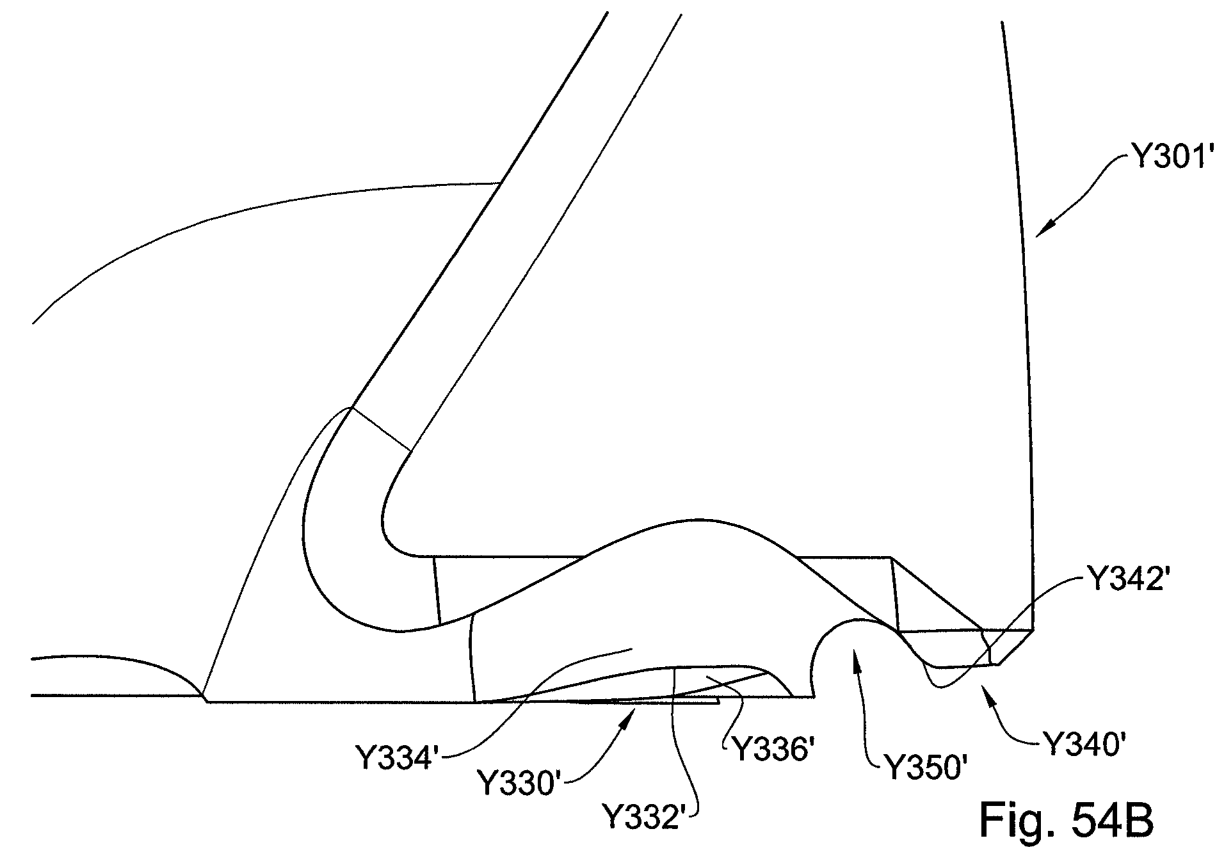


Fig. 54B

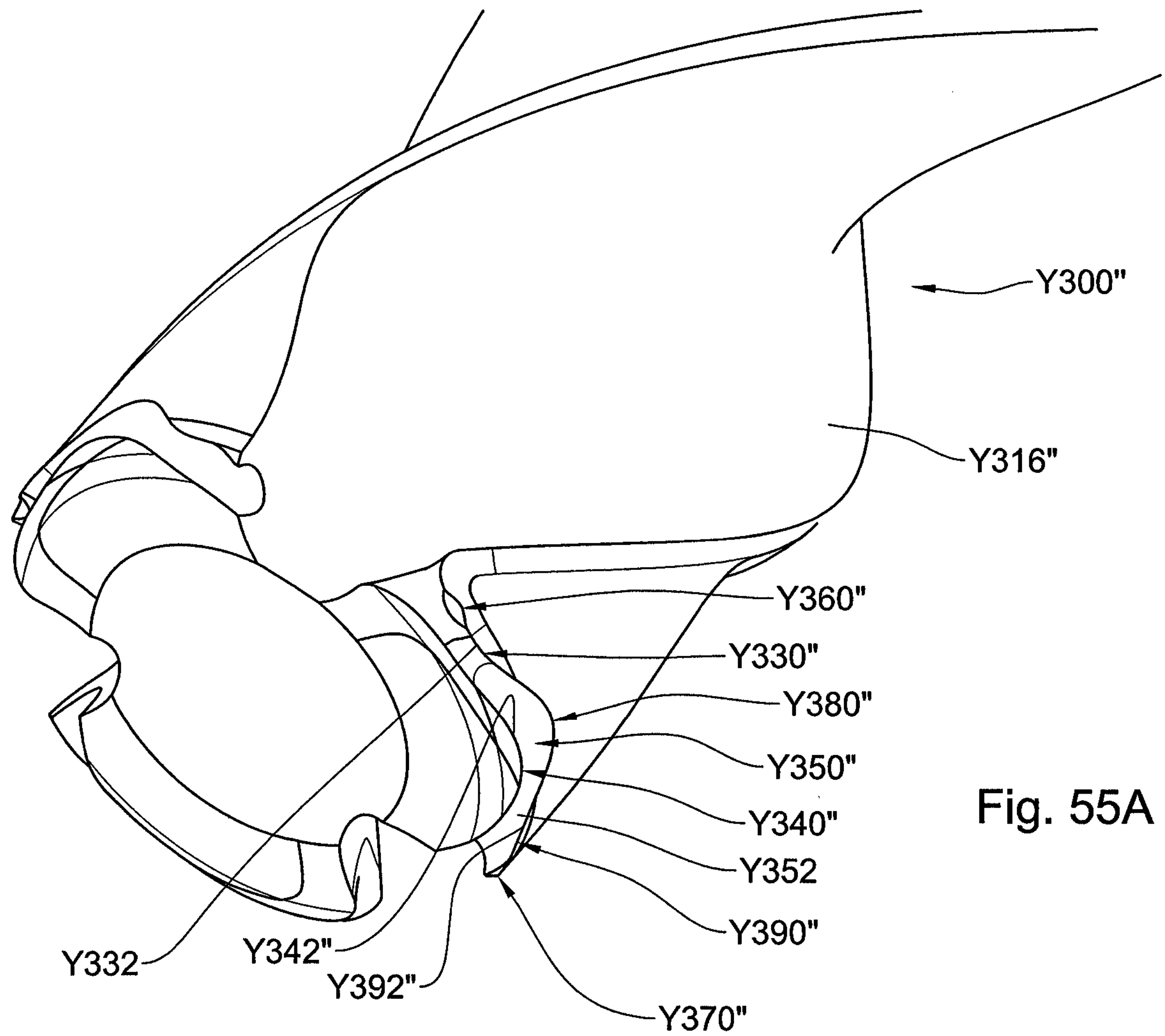


Fig. 55A

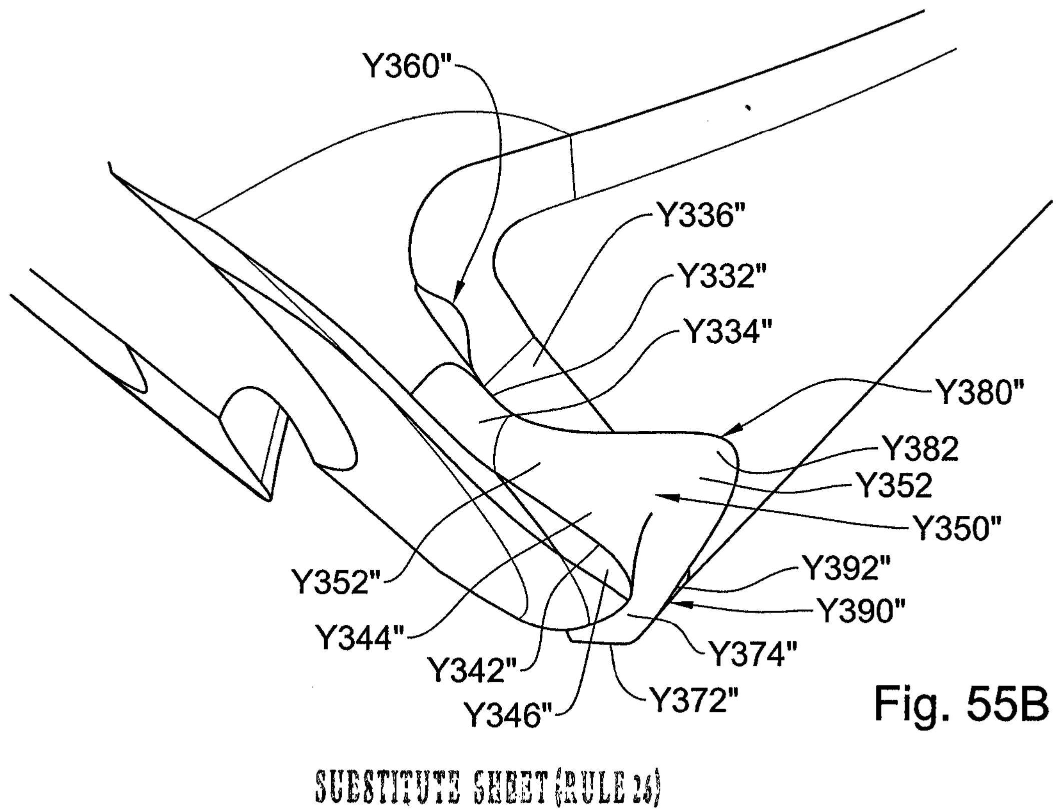


Fig. 55B

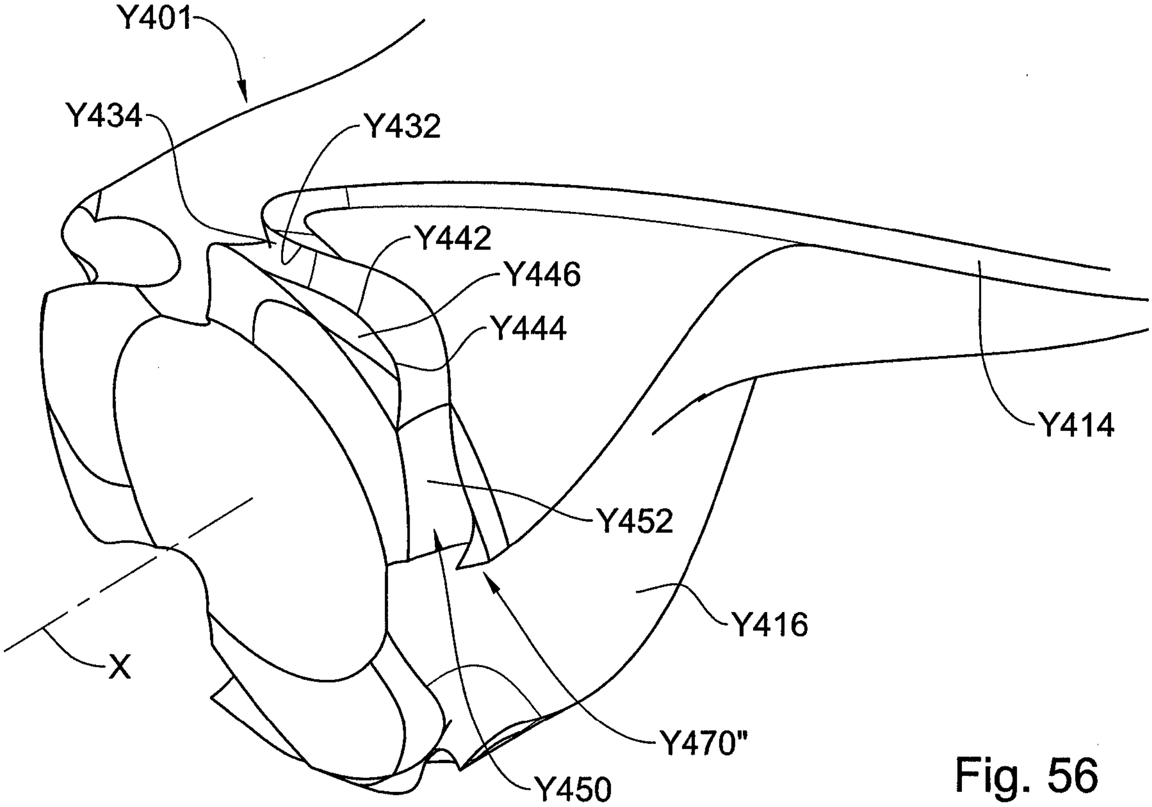

Y401
Y434
Y432
Y442
Y446
Y444
Y414
Y452
Y416
X
Y470"
Y450

Fig. 56

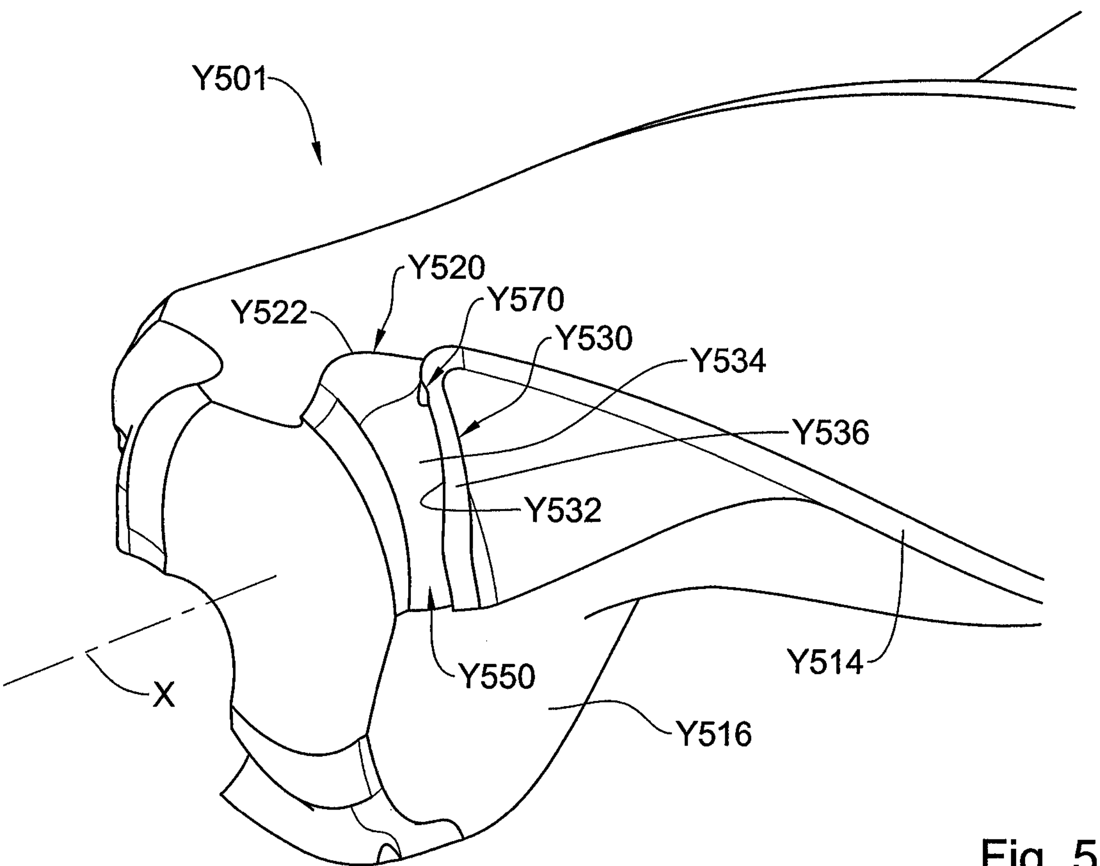

Y501
Y520
Y522
Y570
Y530
Y534
Y536
Y532
Y550
Y514
X
Y516

Fig. 57

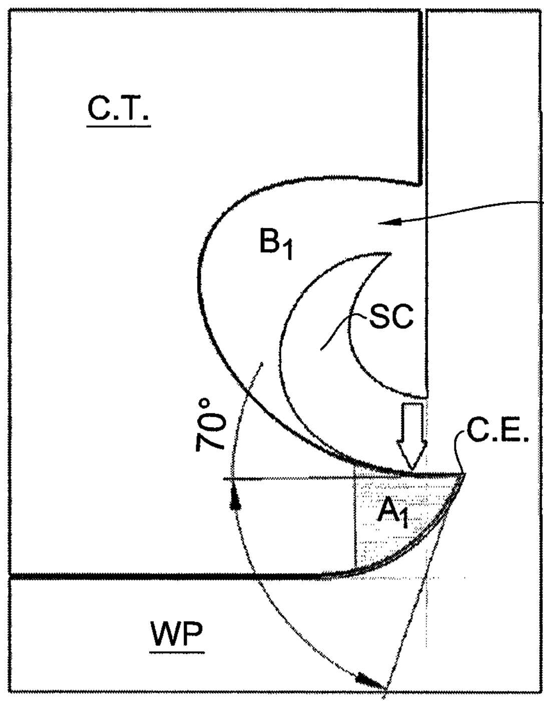


Fig. 58A

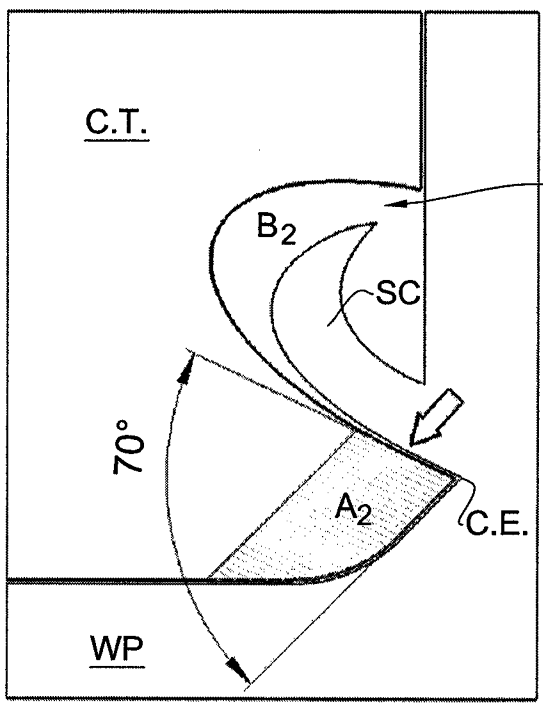


Fig. 58B

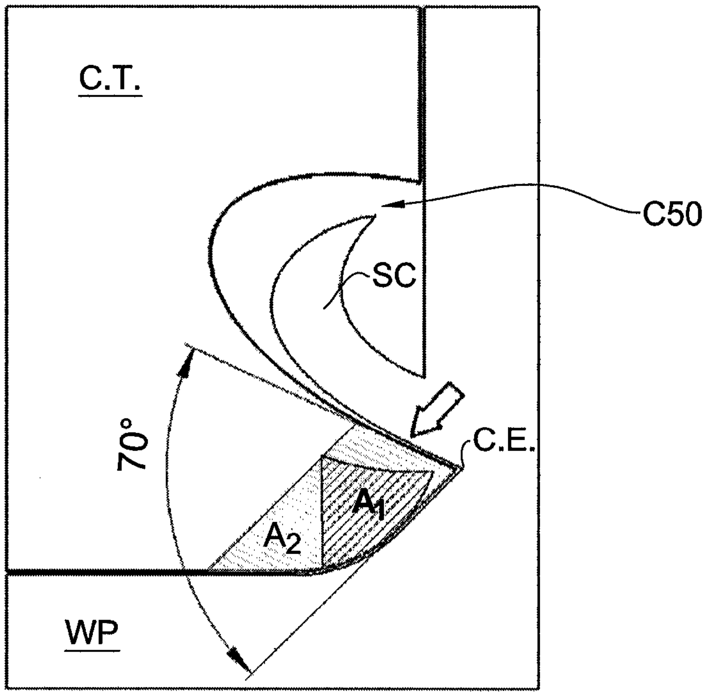


Fig. 58C

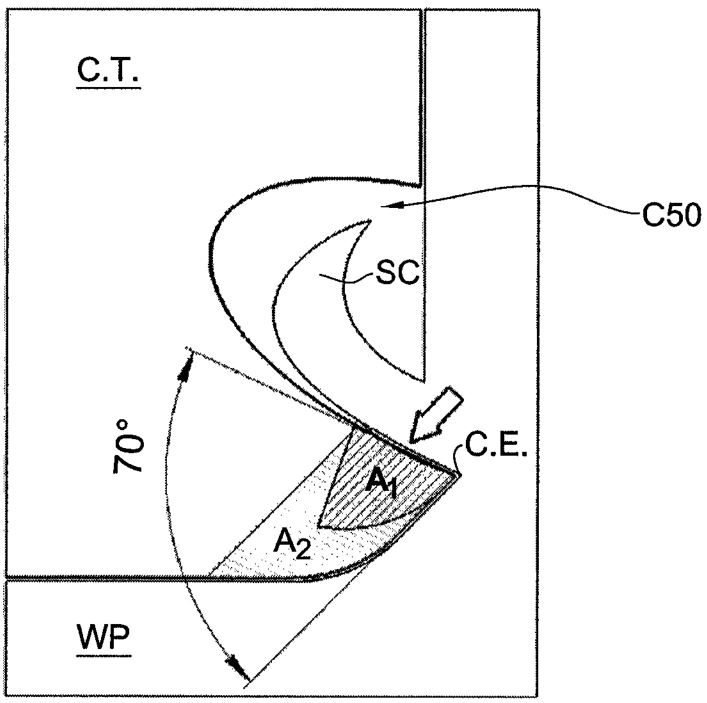


Fig. 58D

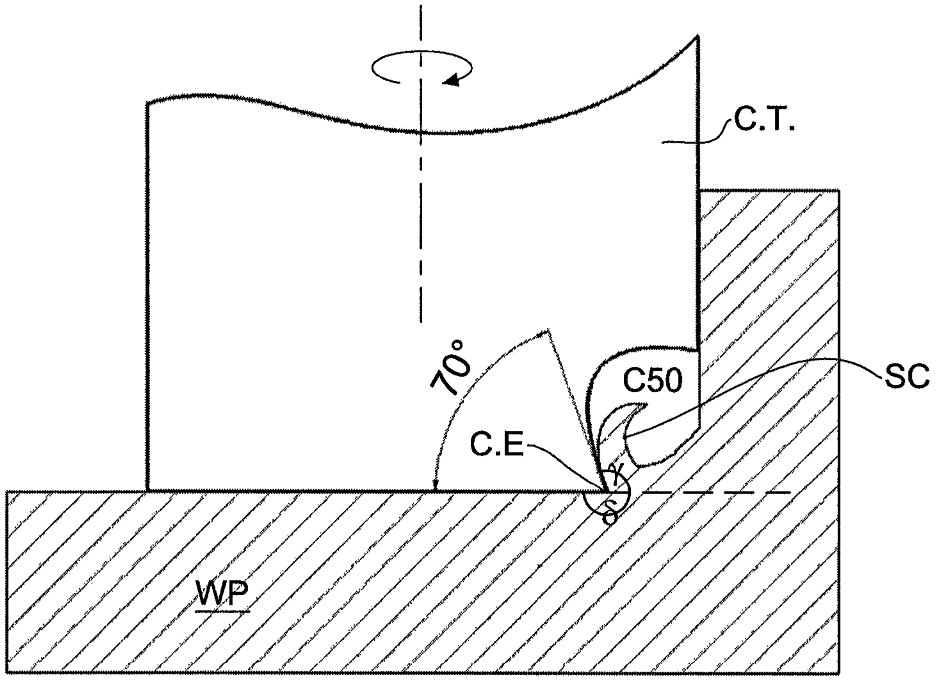


Fig. 59A

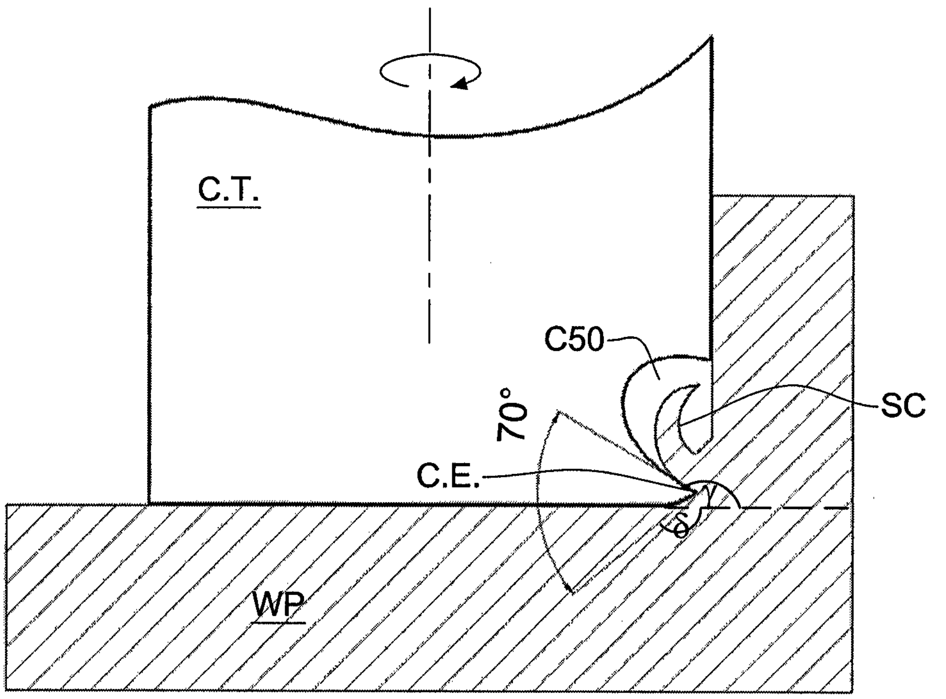


Fig. 59B

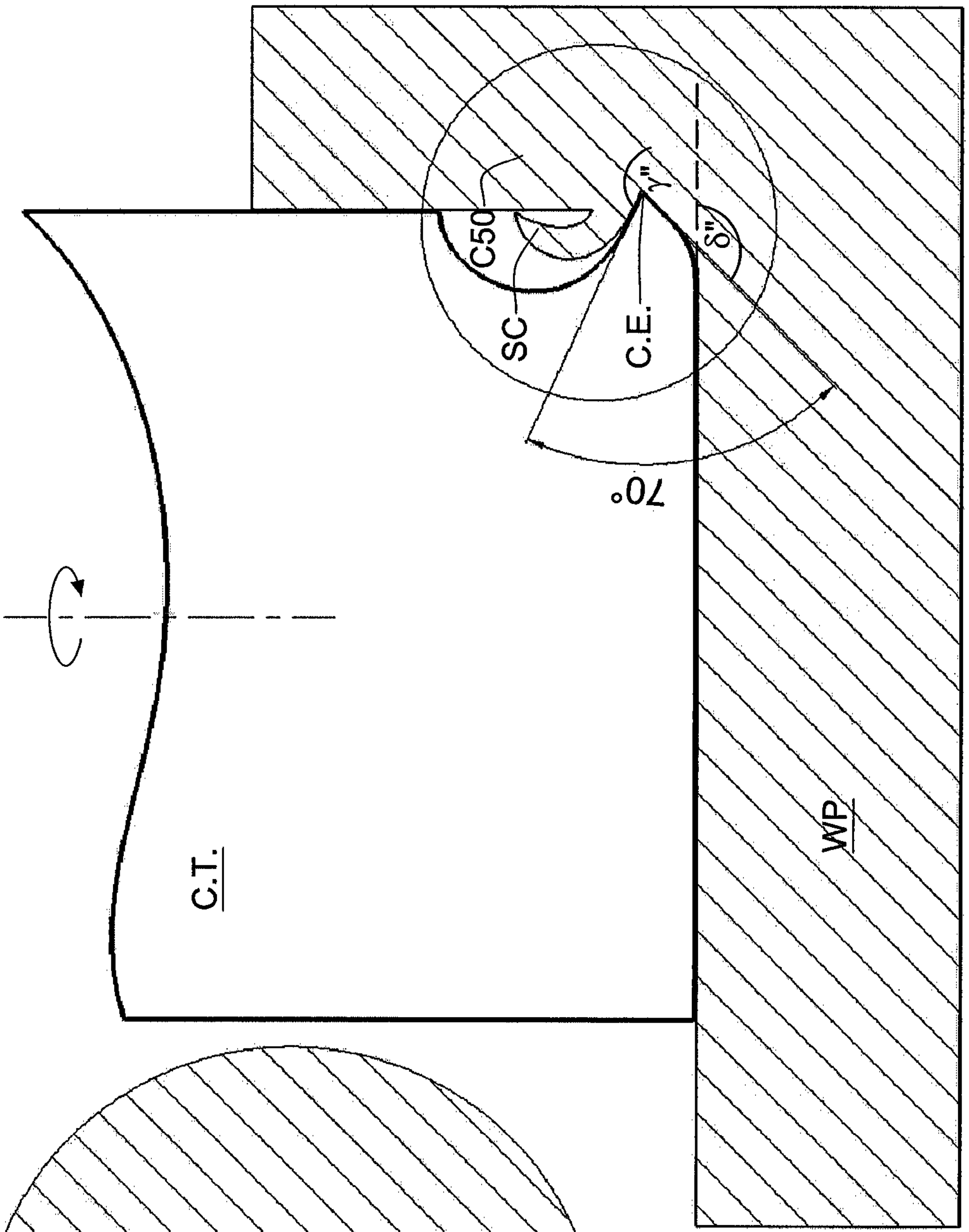


Fig. 59C

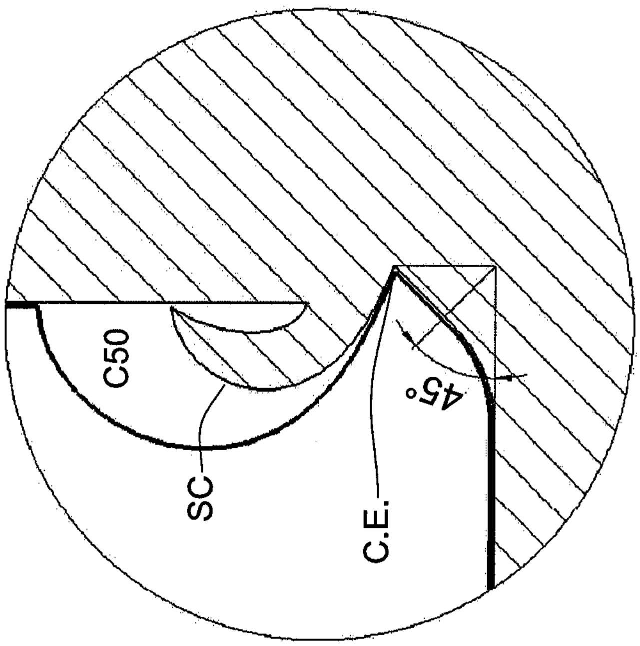


Fig. 59D

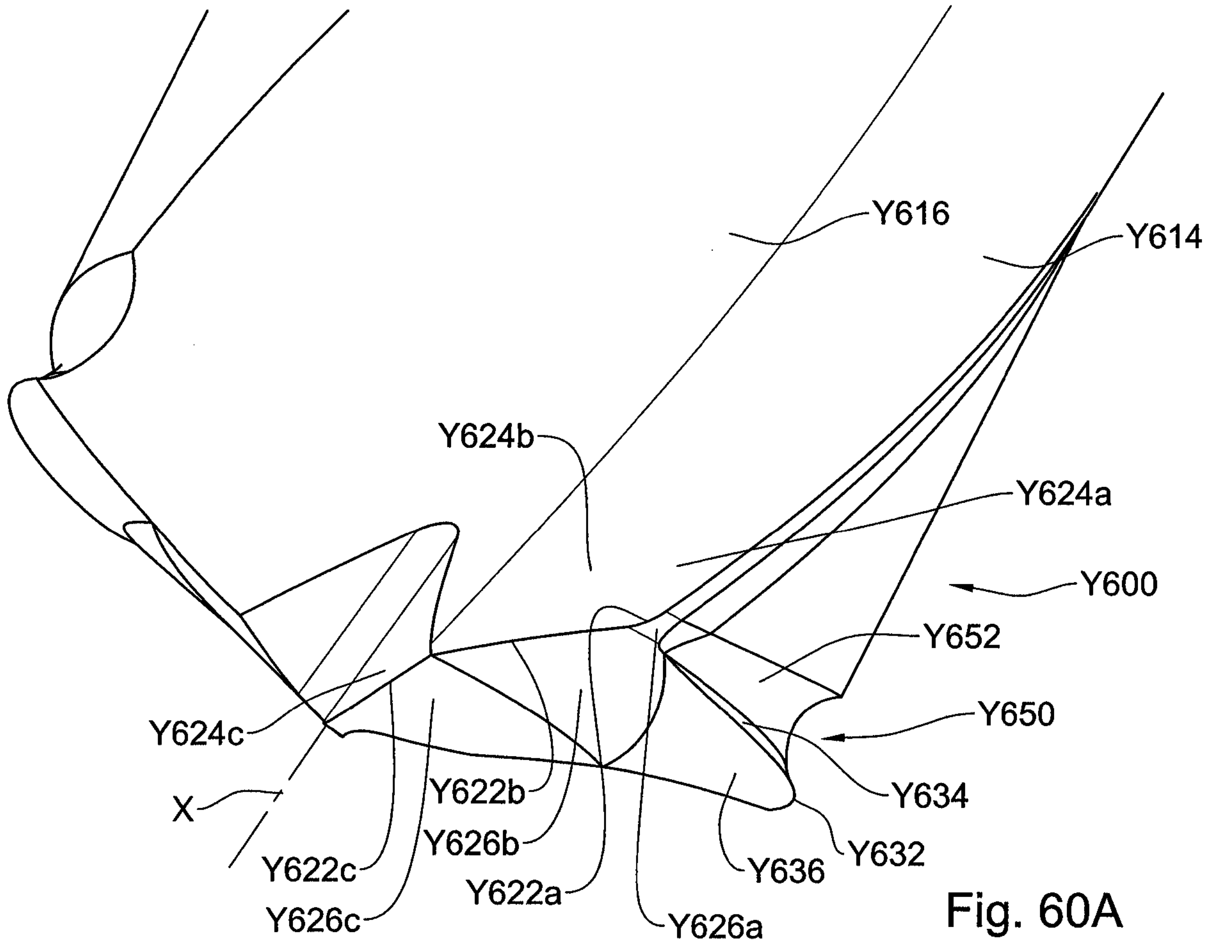


Fig. 60A

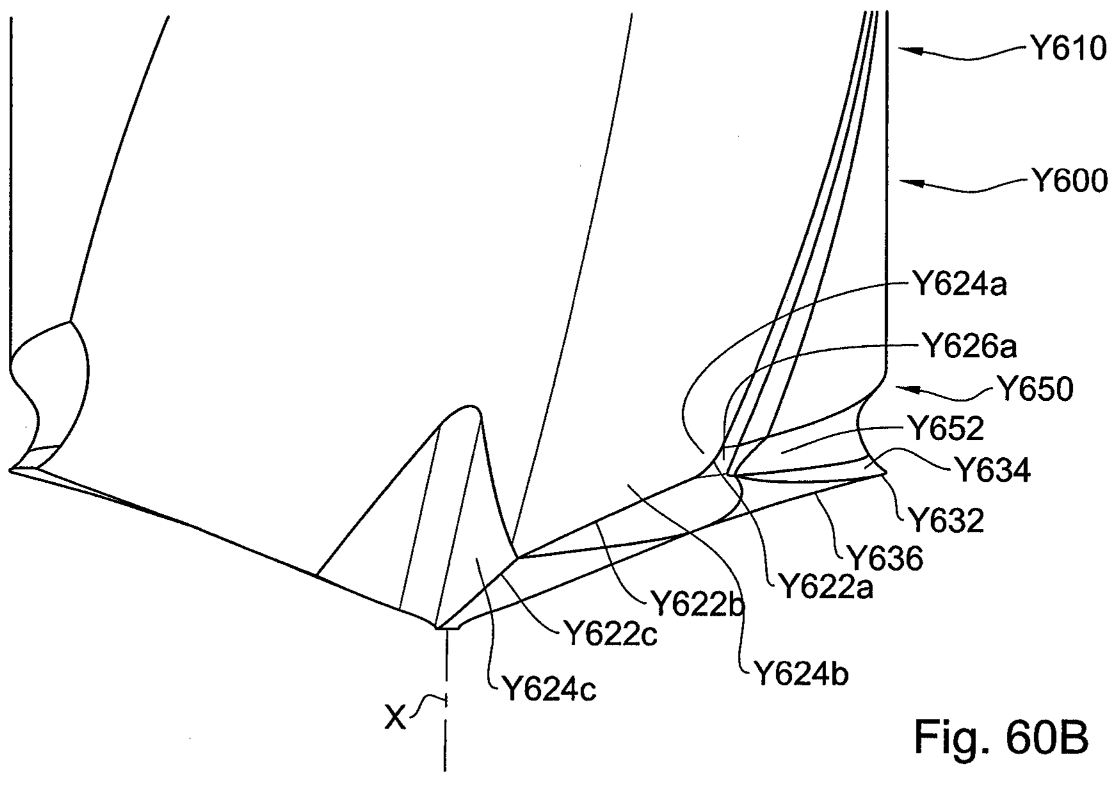


Fig. 60B

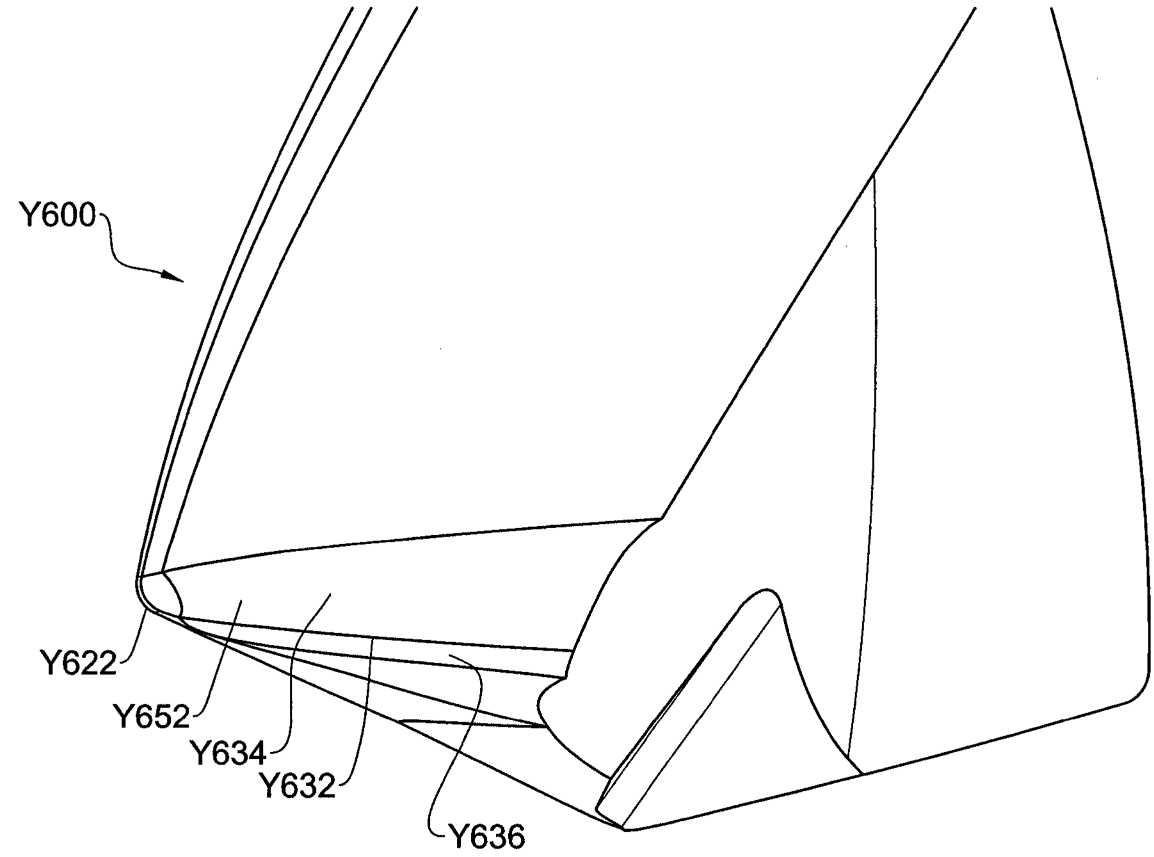


Fig. 60C

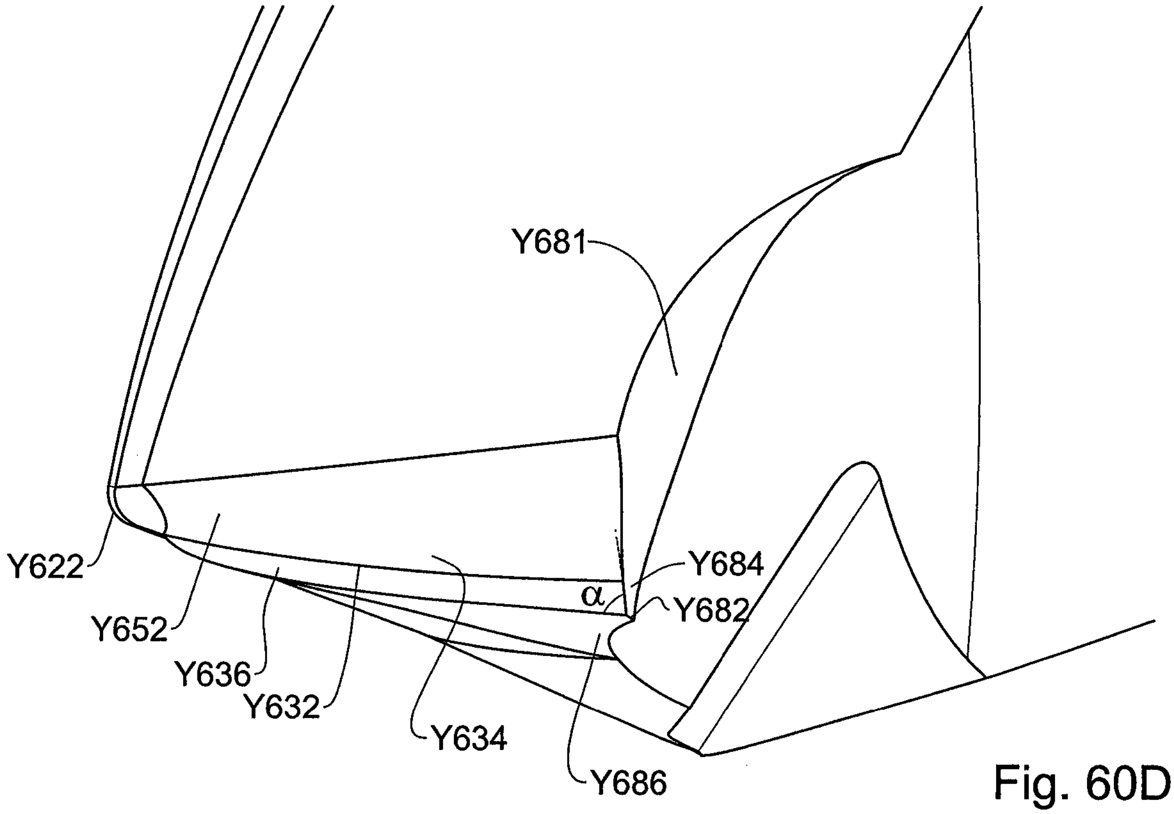


Fig. 60D

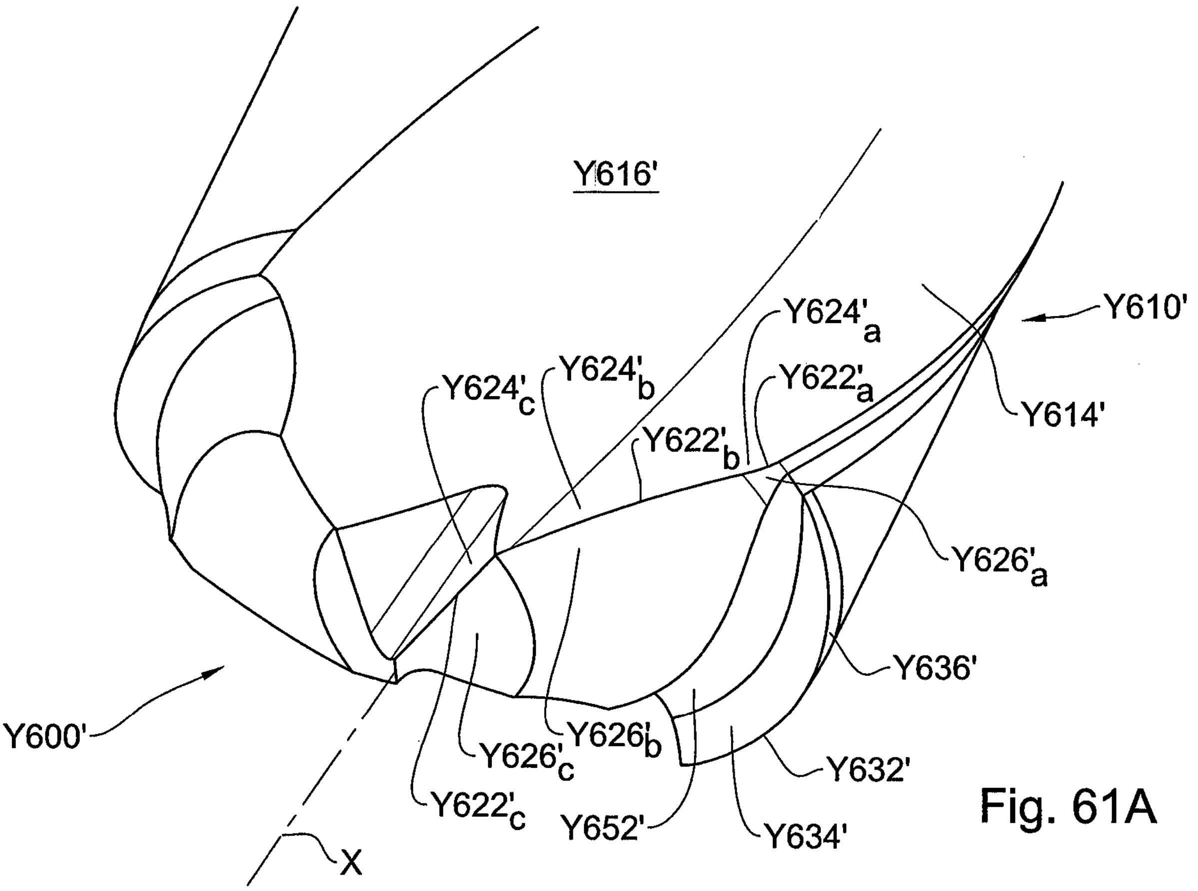


Fig. 61A

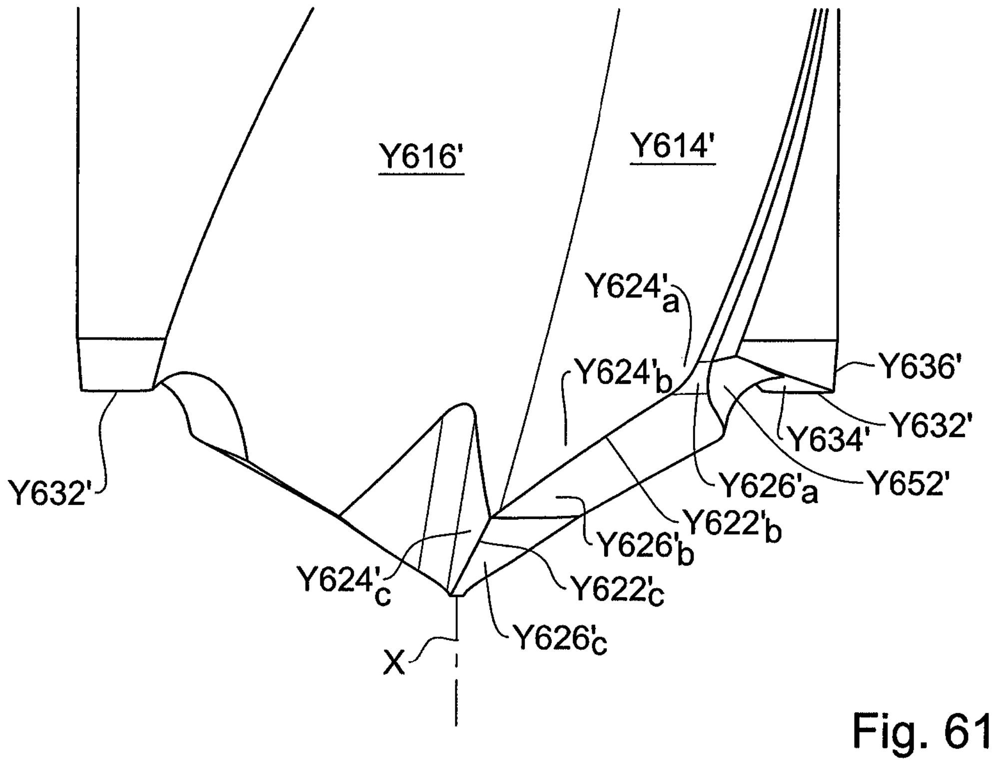


Fig. 61B

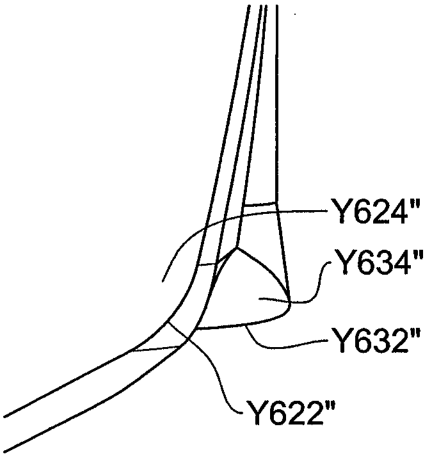


Fig. 61C

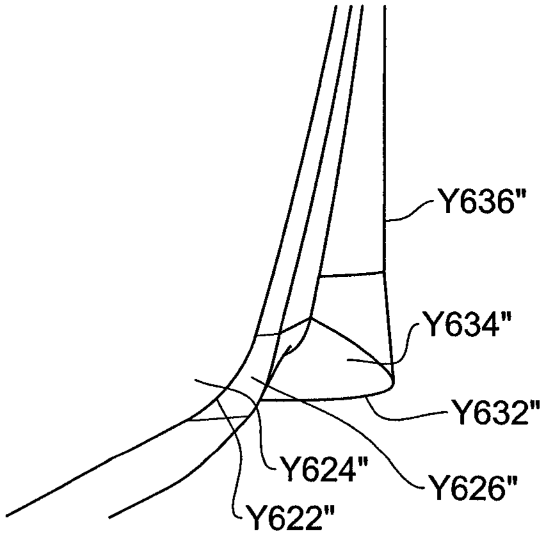


Fig. 61D

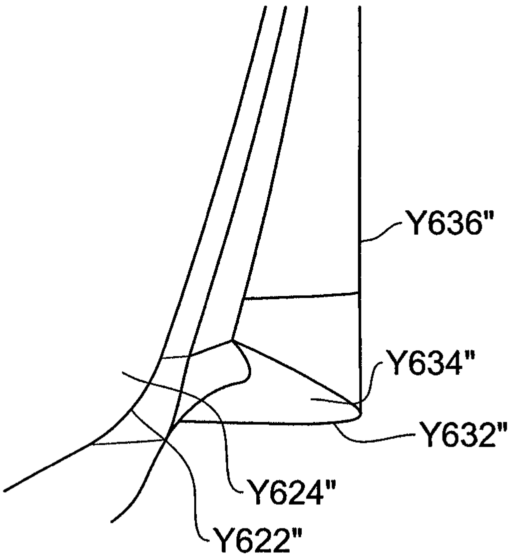


Fig. 61E

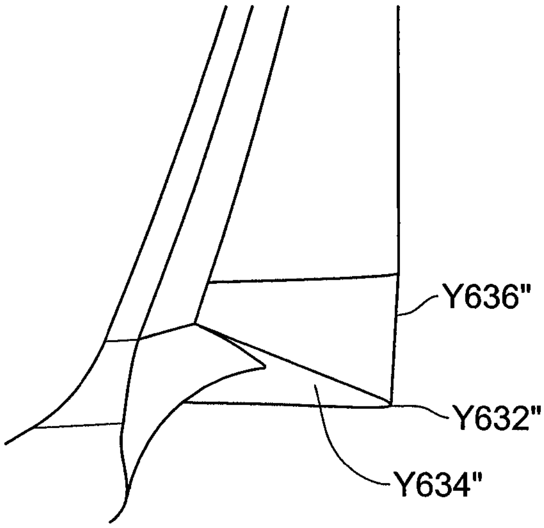


Fig. 61F

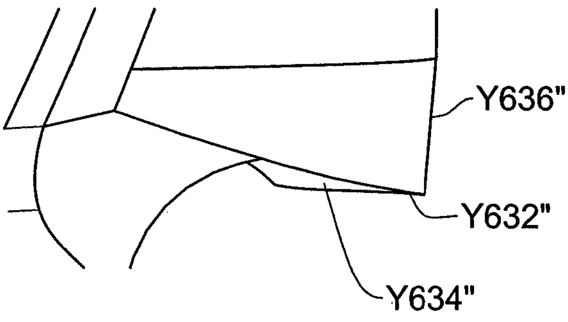


Fig. 61G

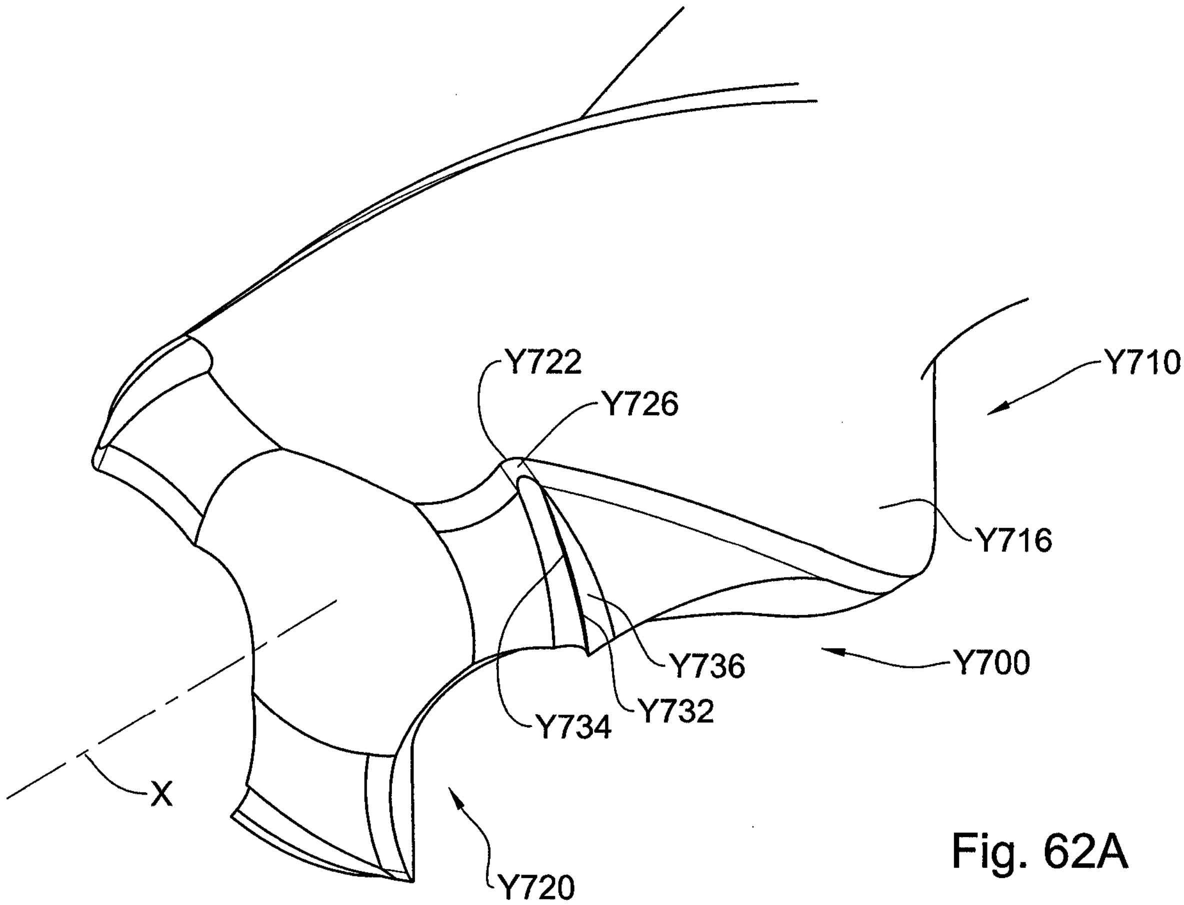


Fig. 62A

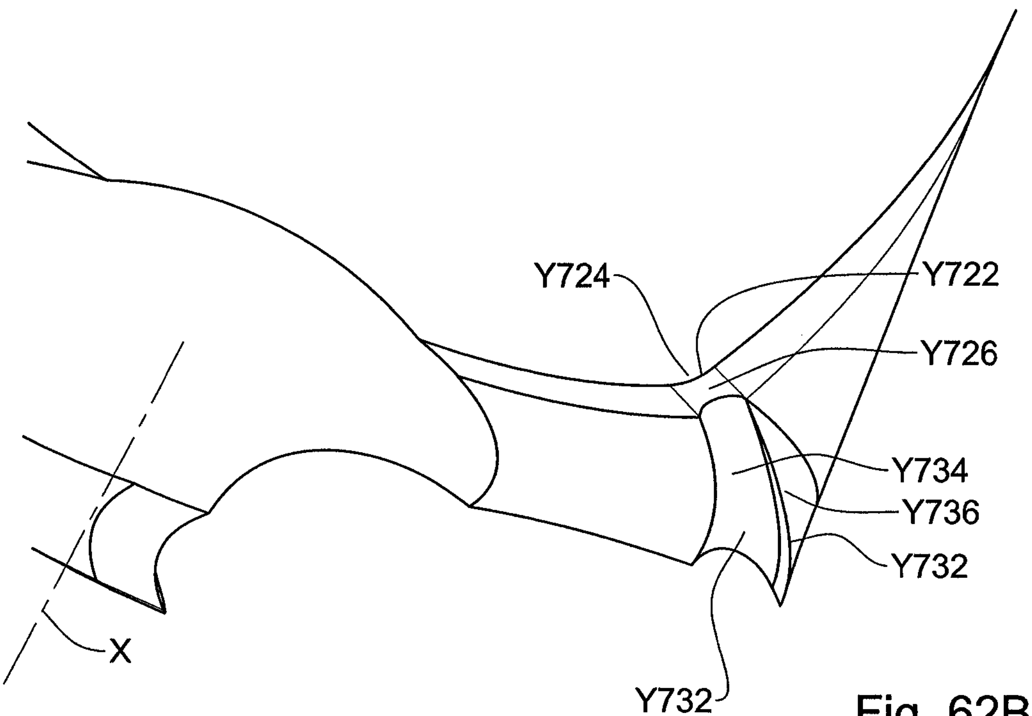


Fig. 62B

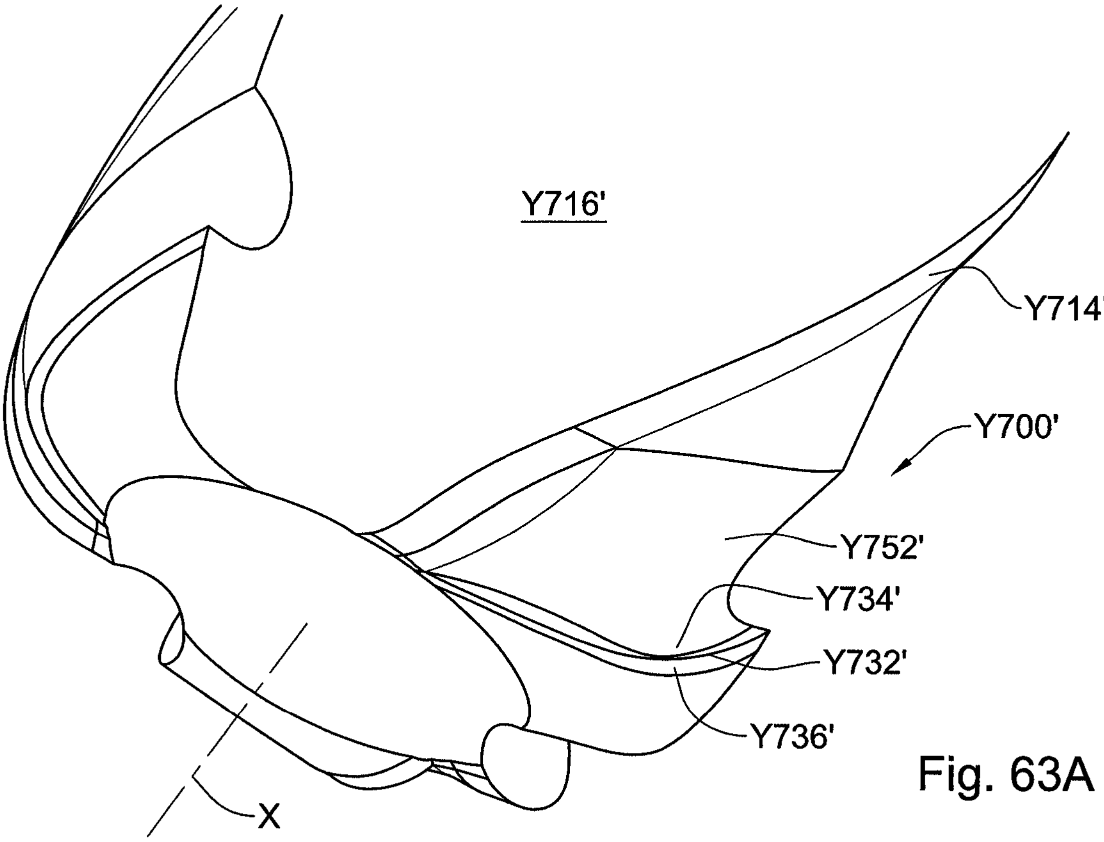


Fig. 63A

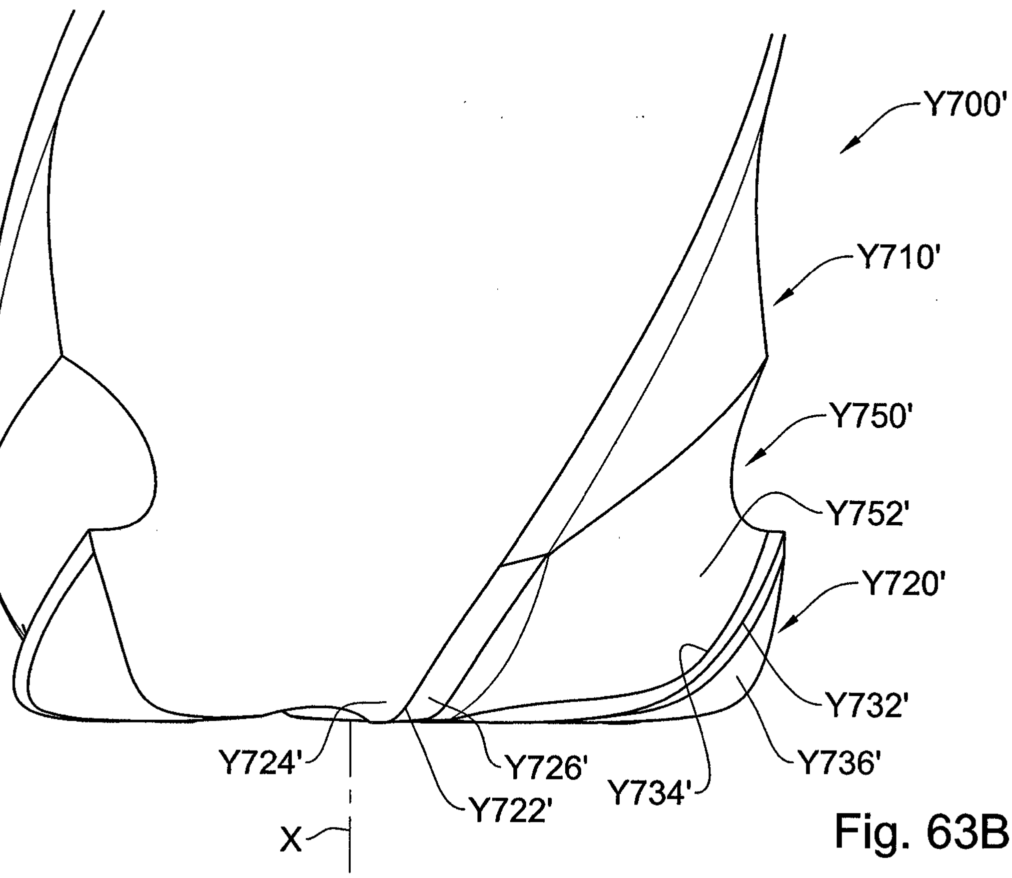


Fig. 63B

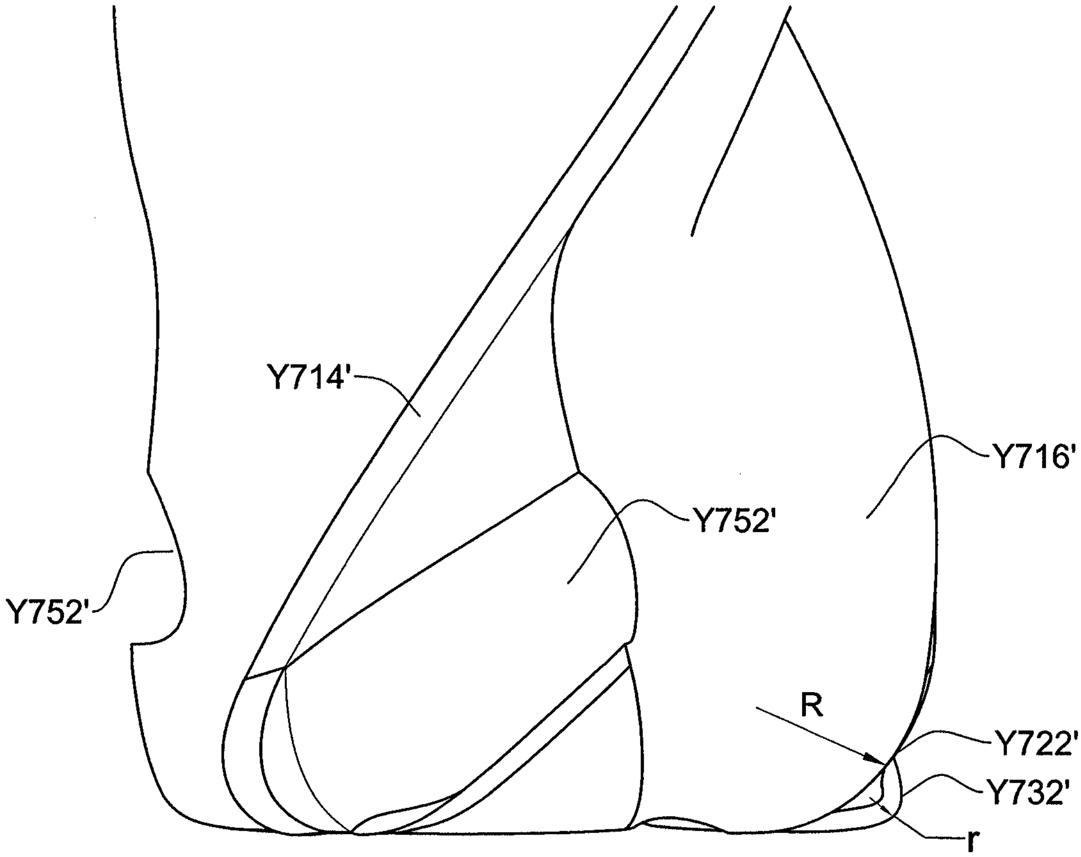


Fig. 63C

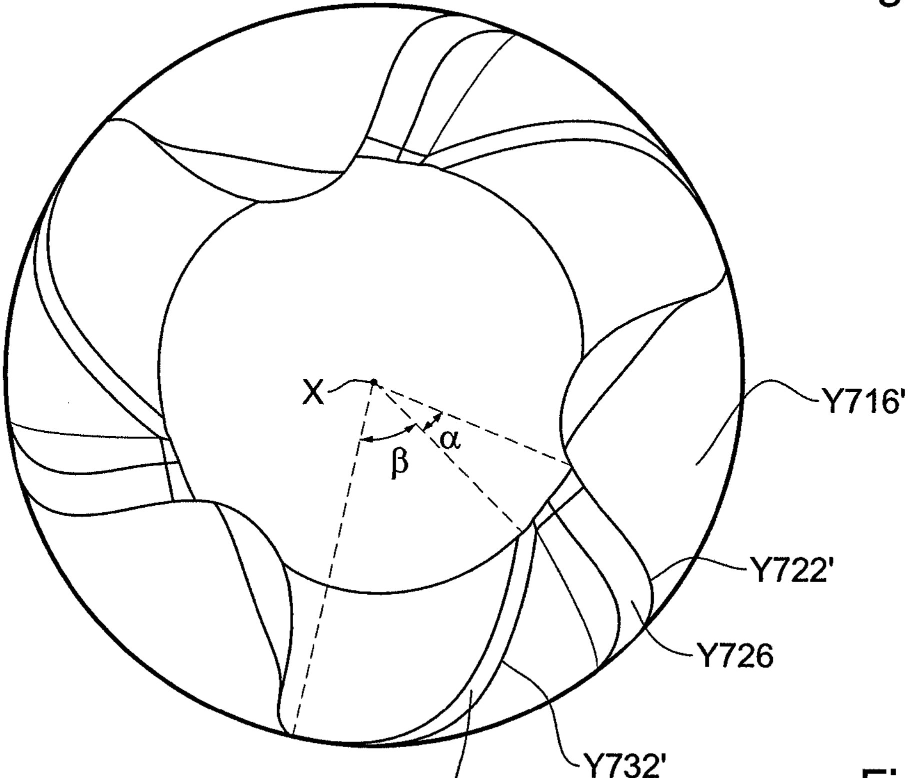


Fig. 63D

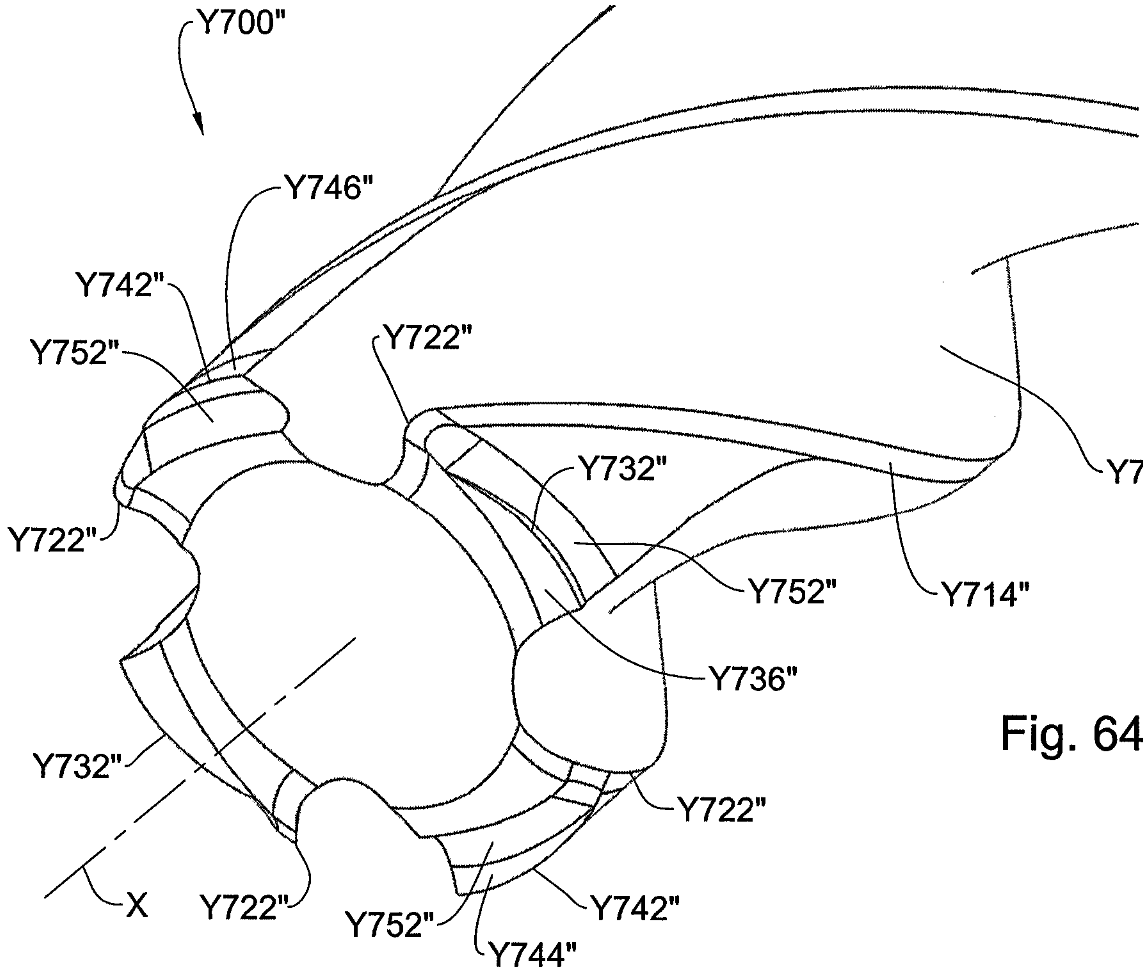


Fig. 64A

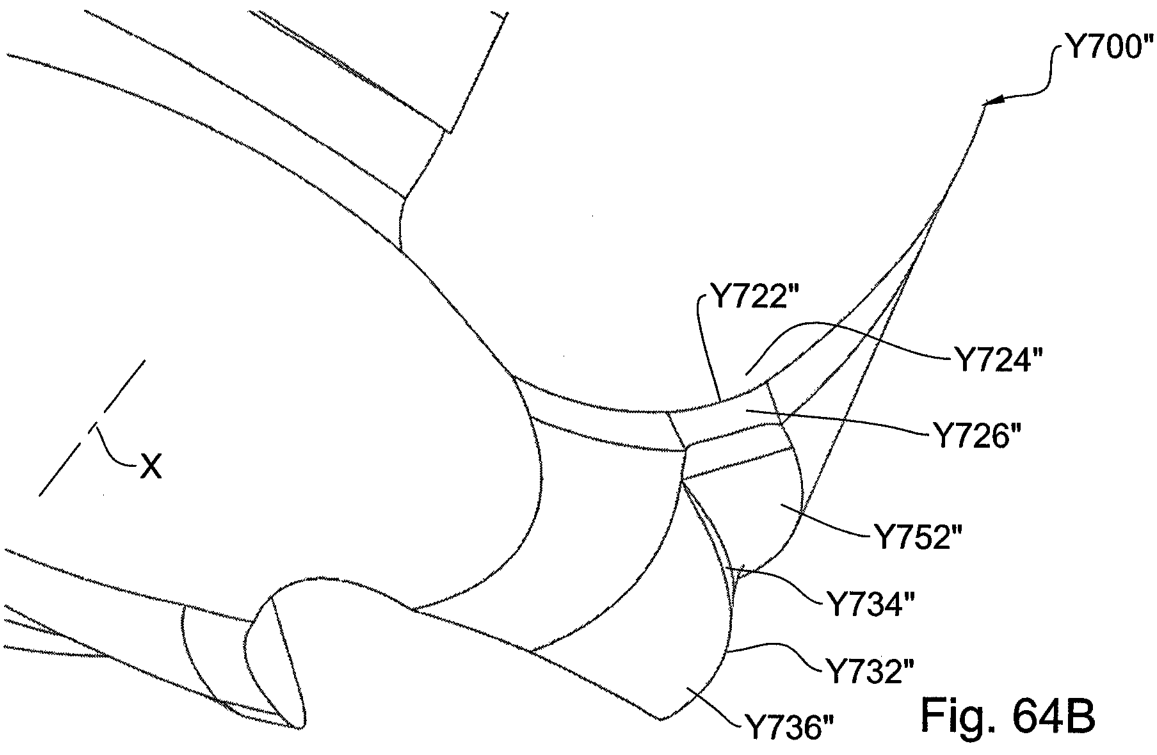


Fig. 64B

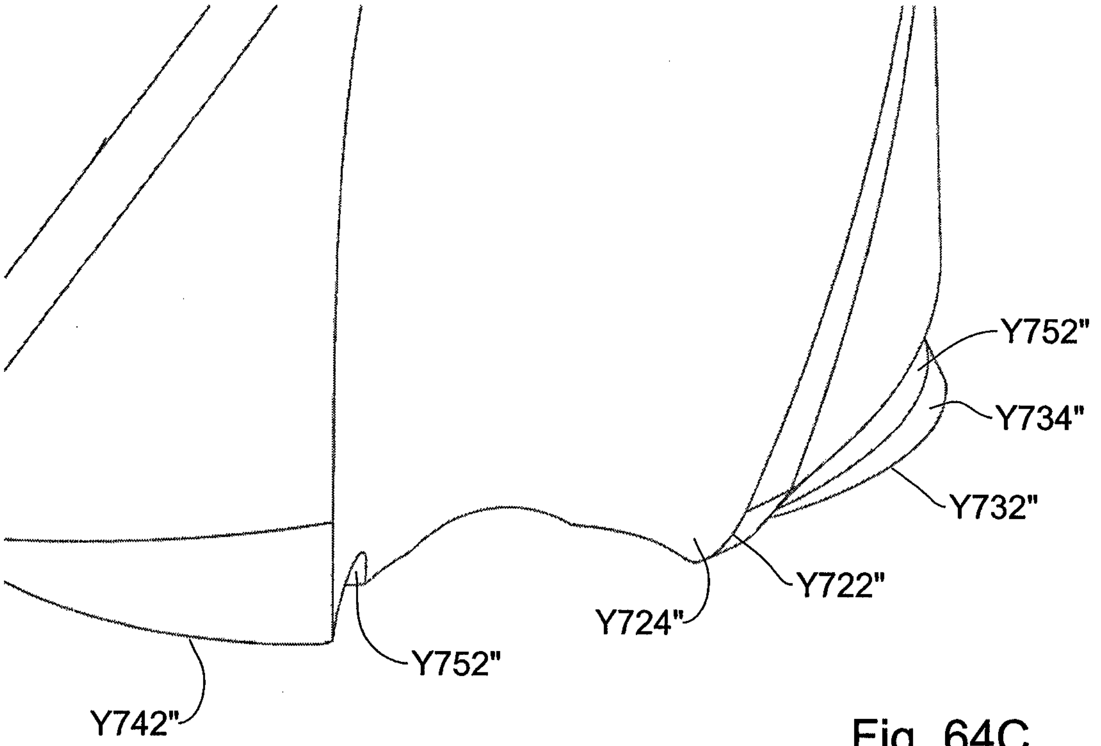


Fig. 64C

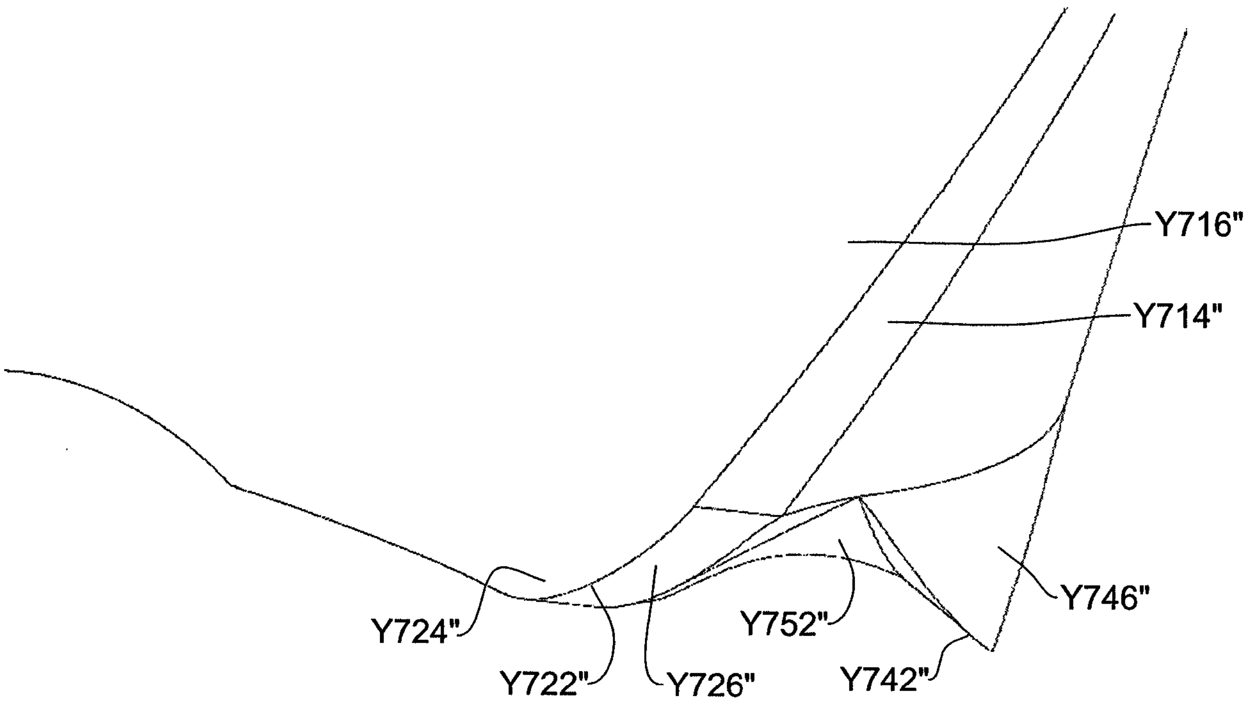


Fig. 64D

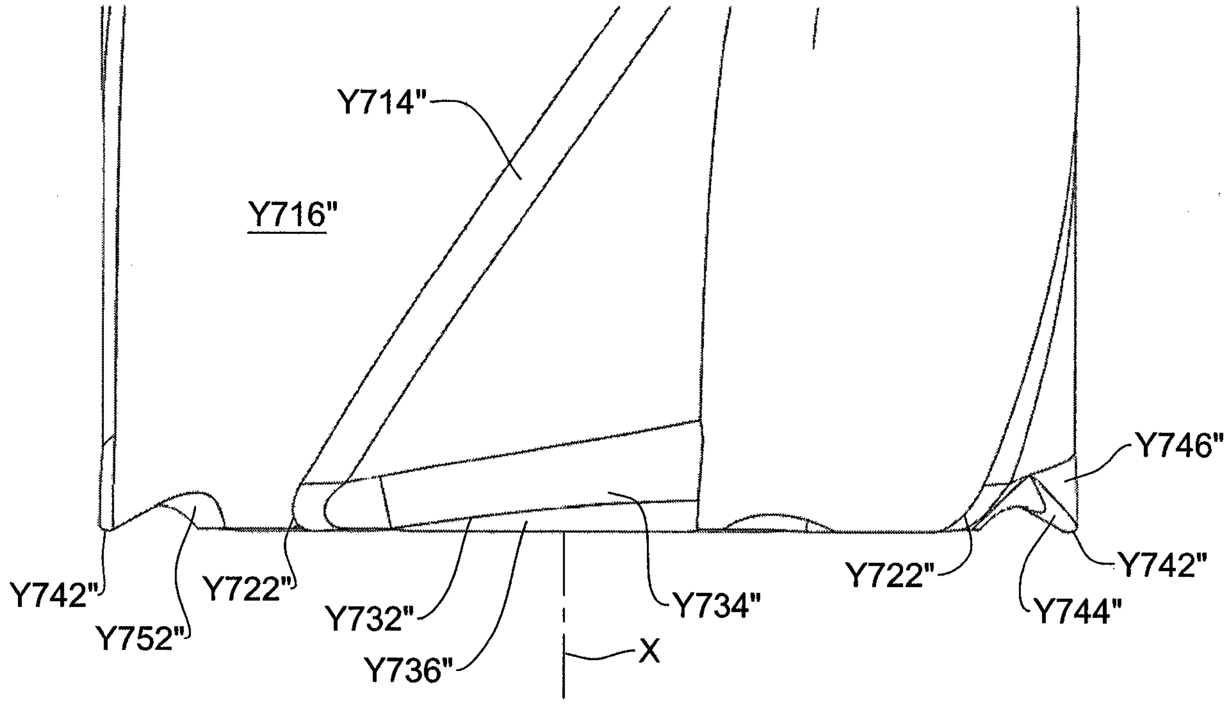


Fig. 64E

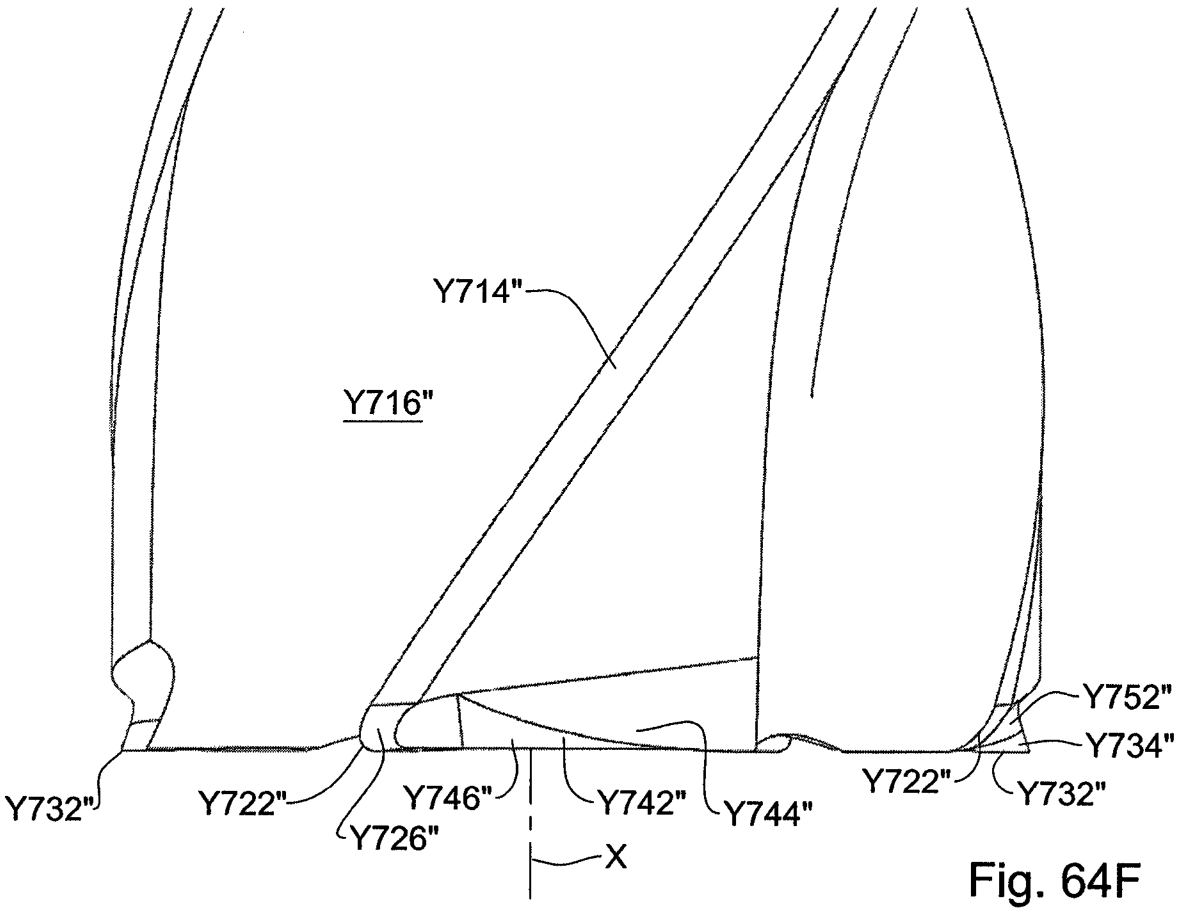


Fig. 64F

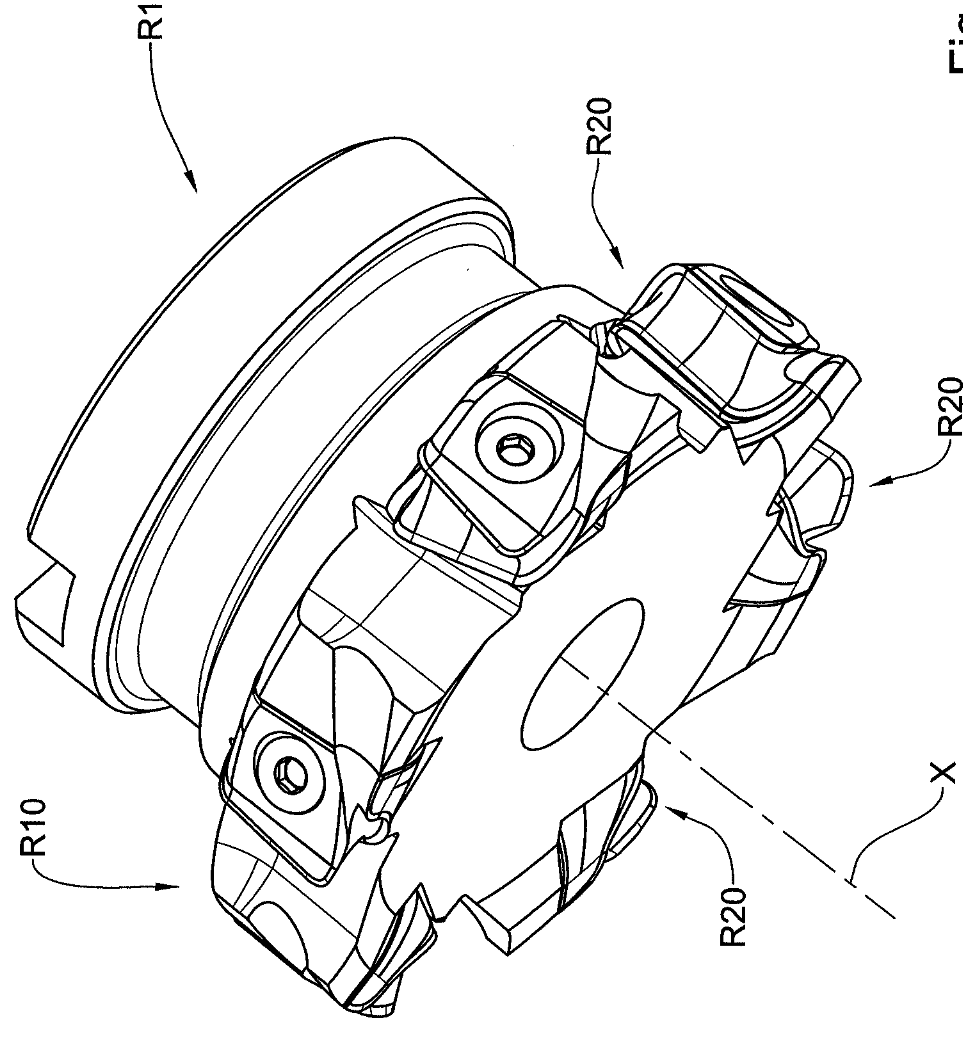


Fig. 65A

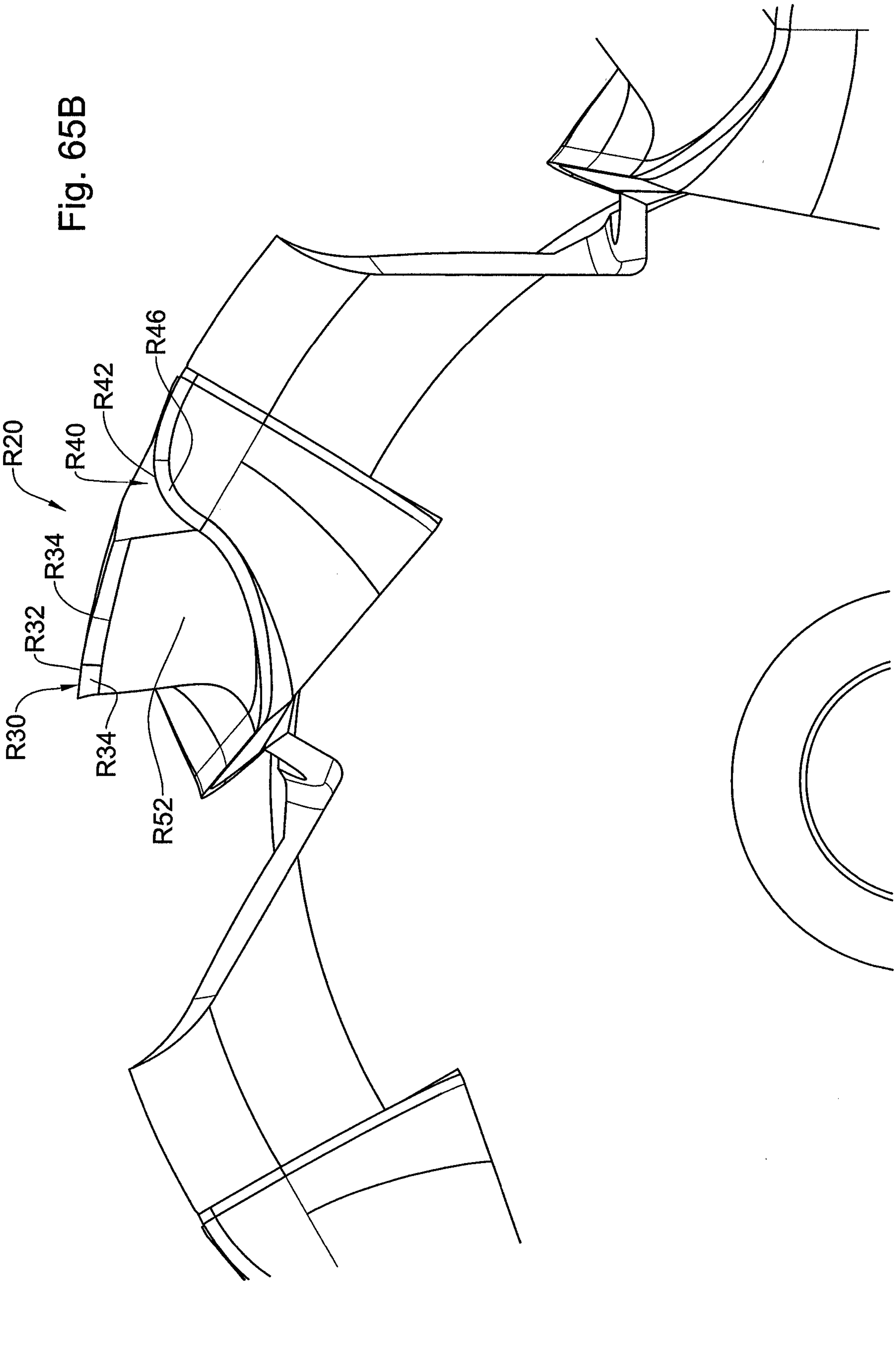


Fig. 65B

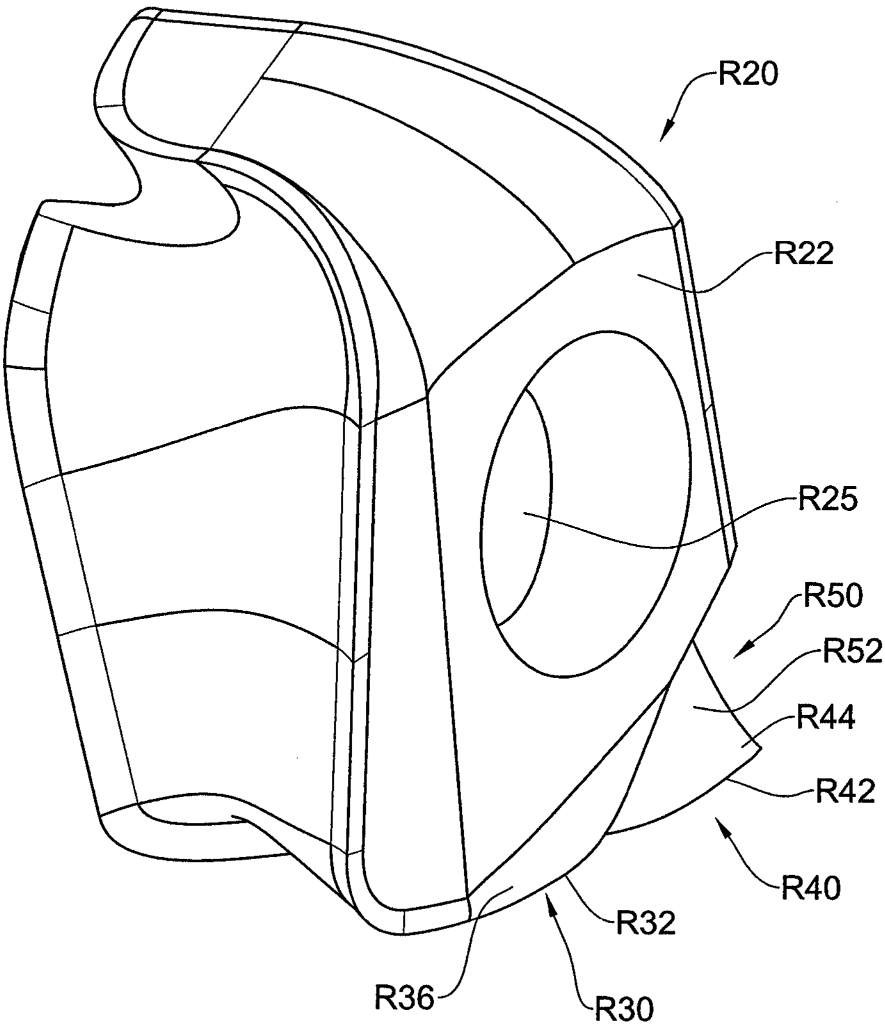


Fig. 65C

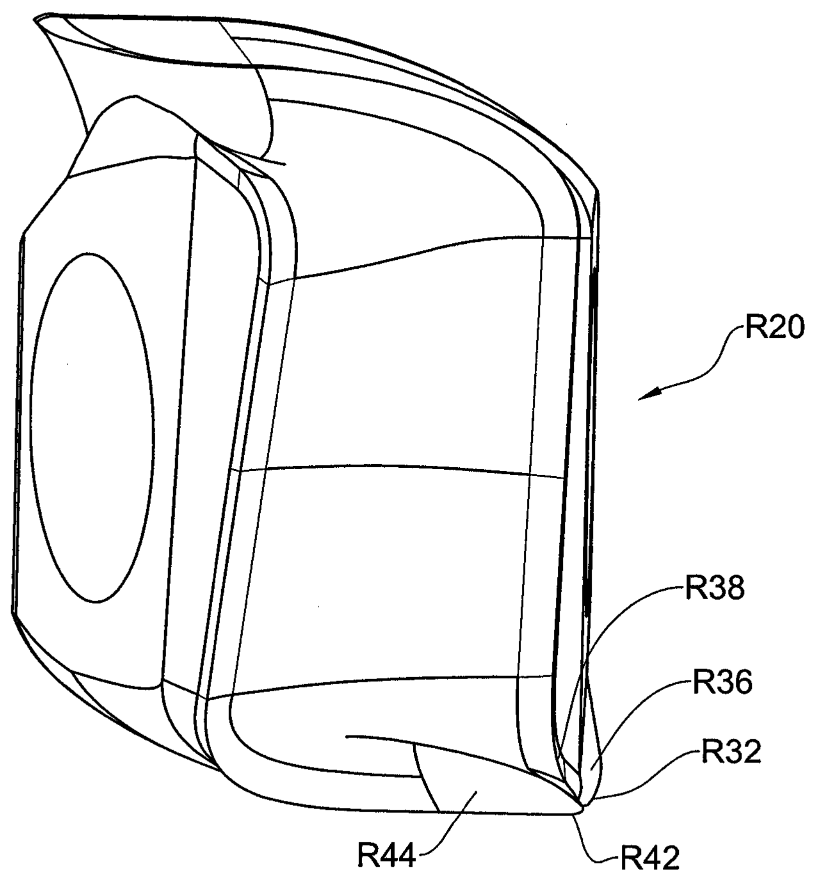


Fig. 65D

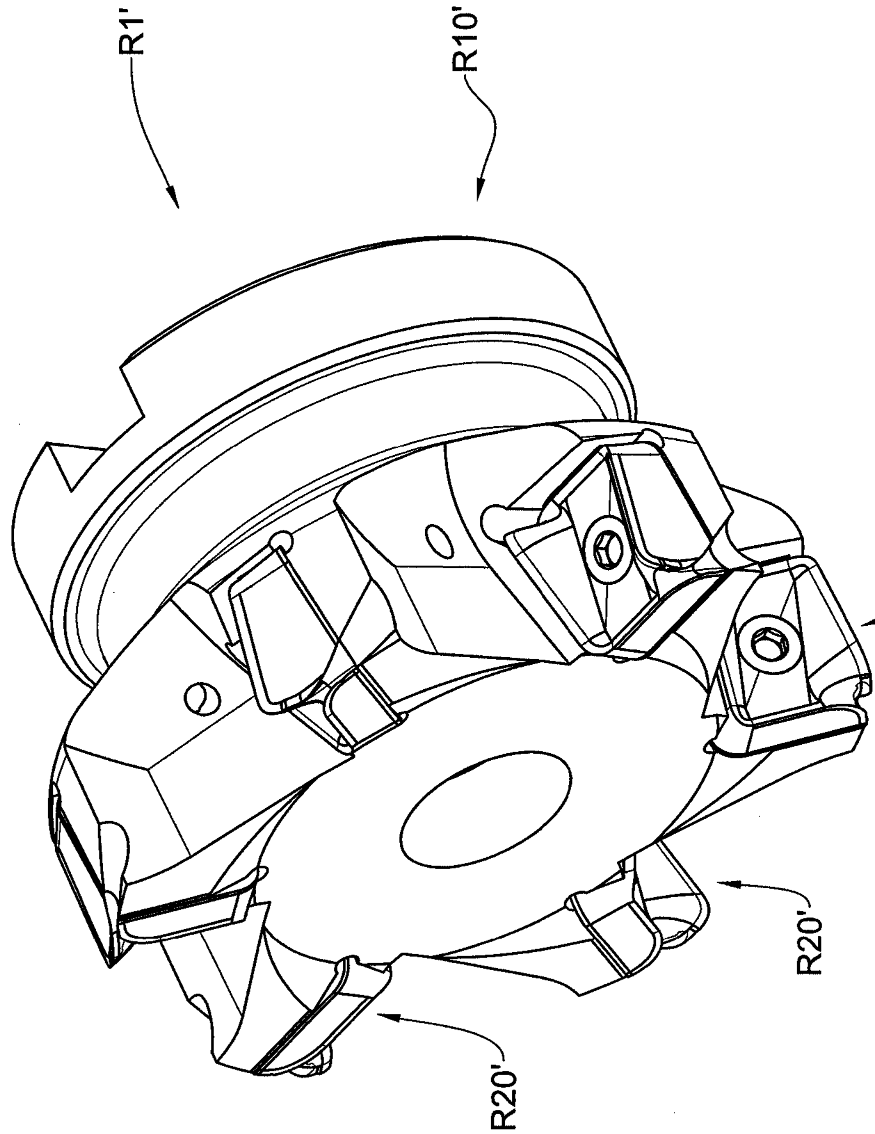


Fig. 66A

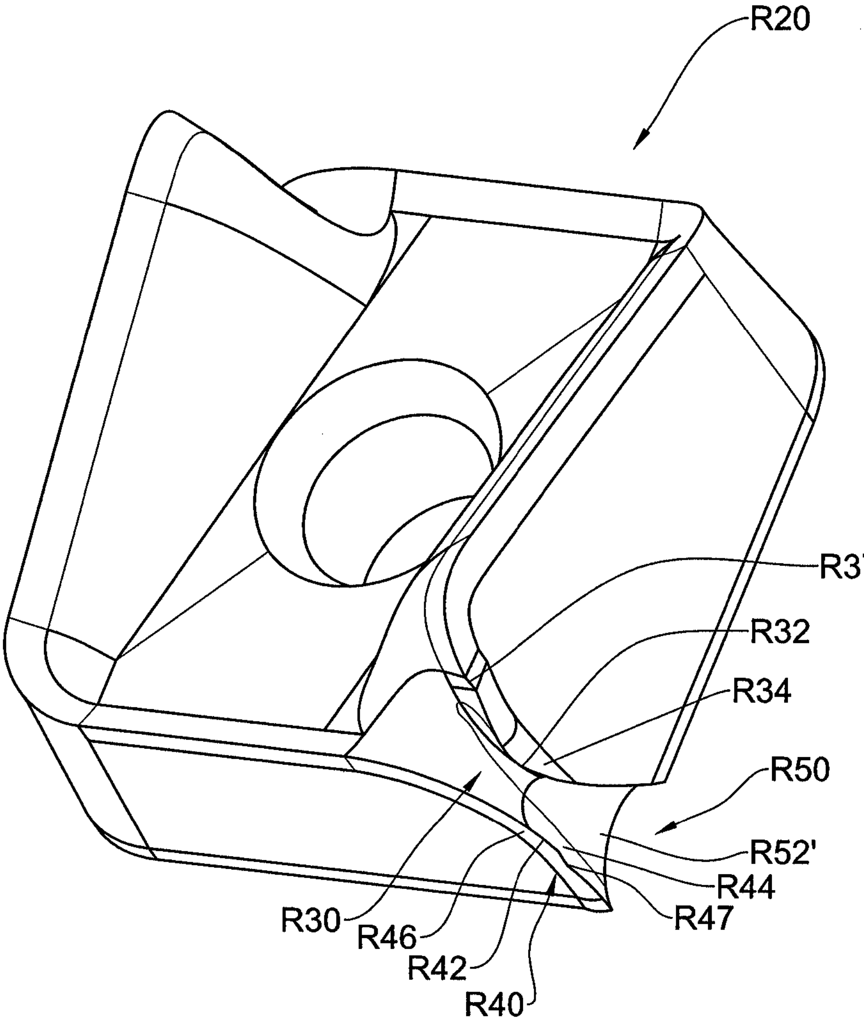


Fig. 66B

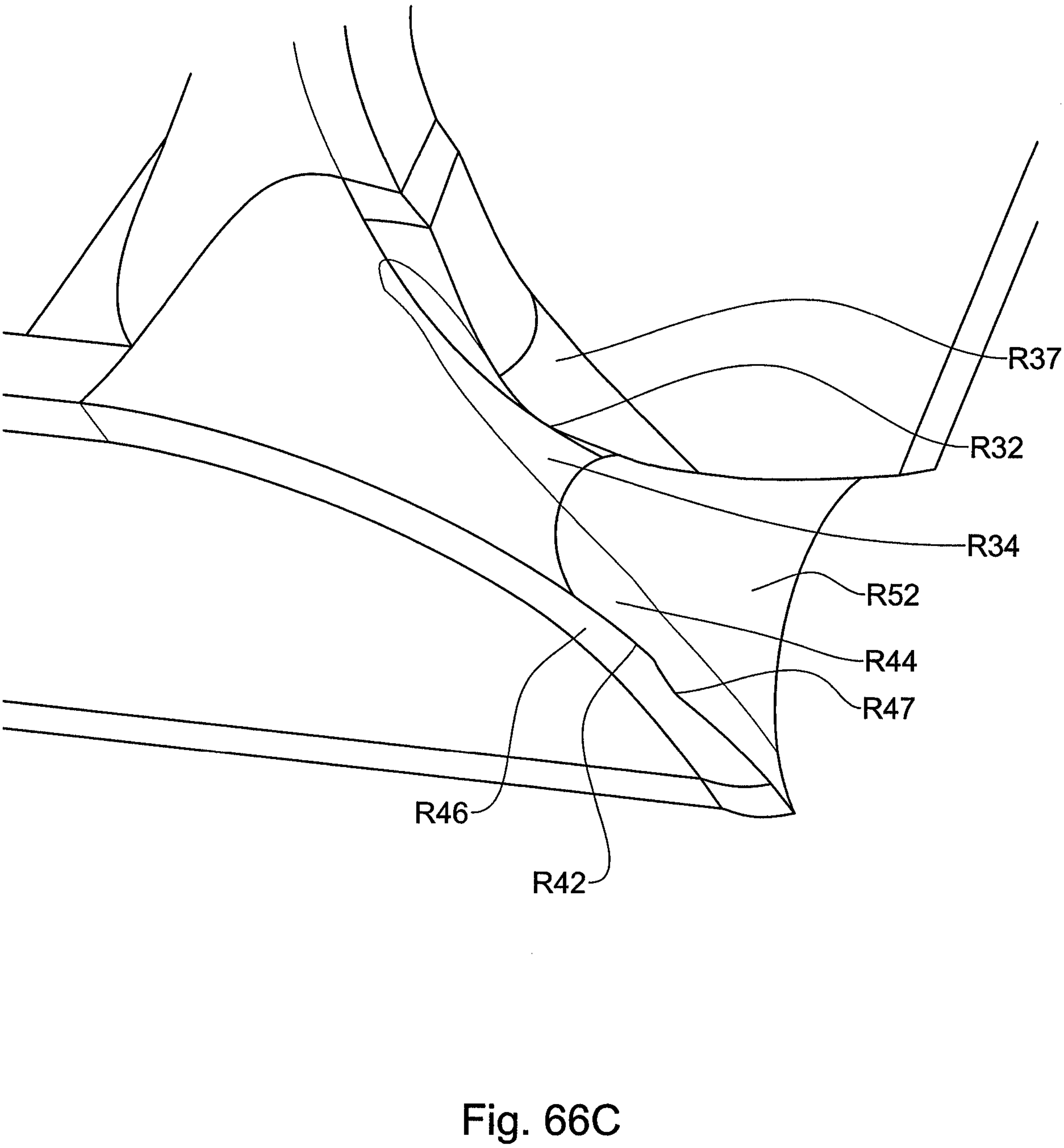


Fig. 66C

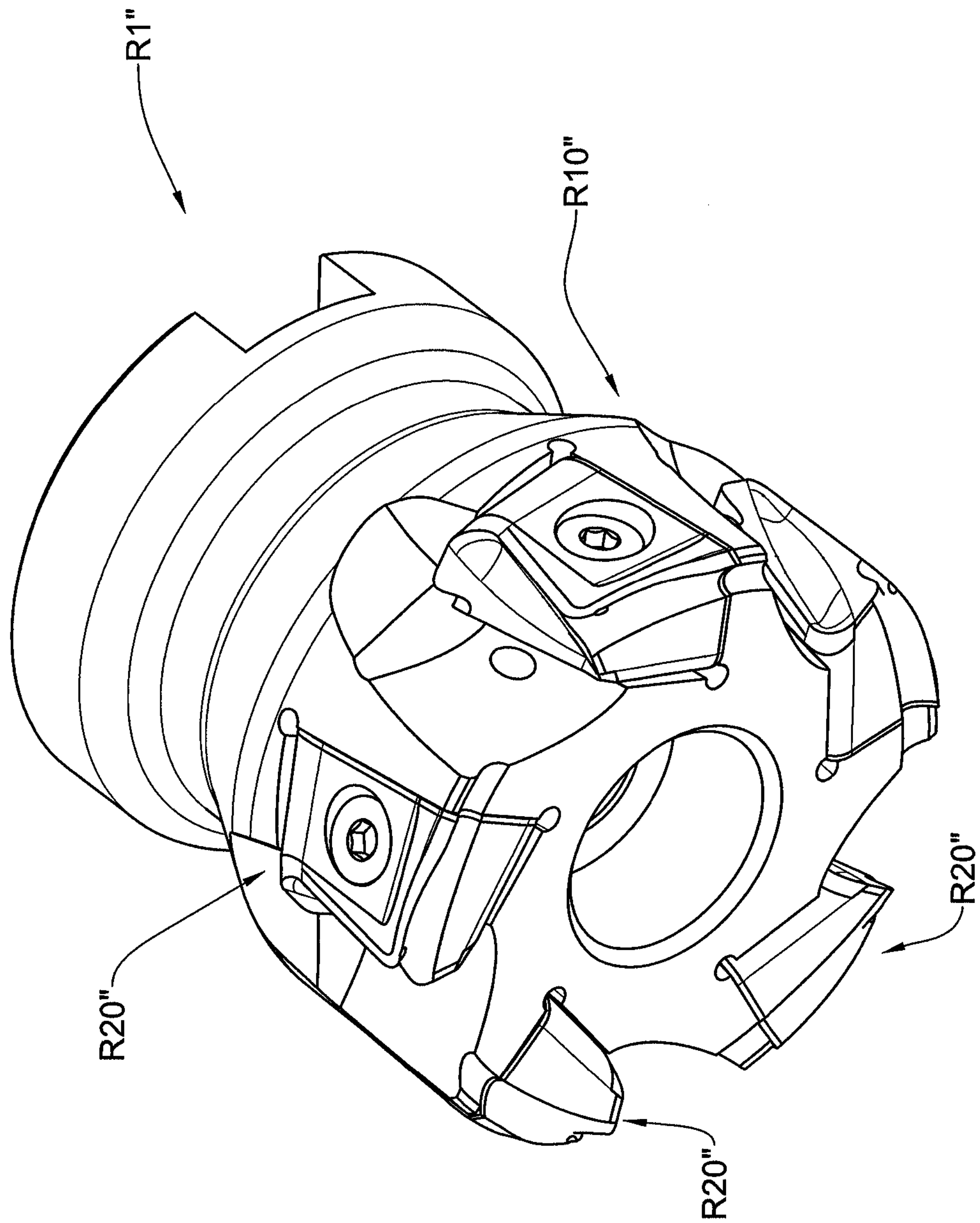


Fig. 67A

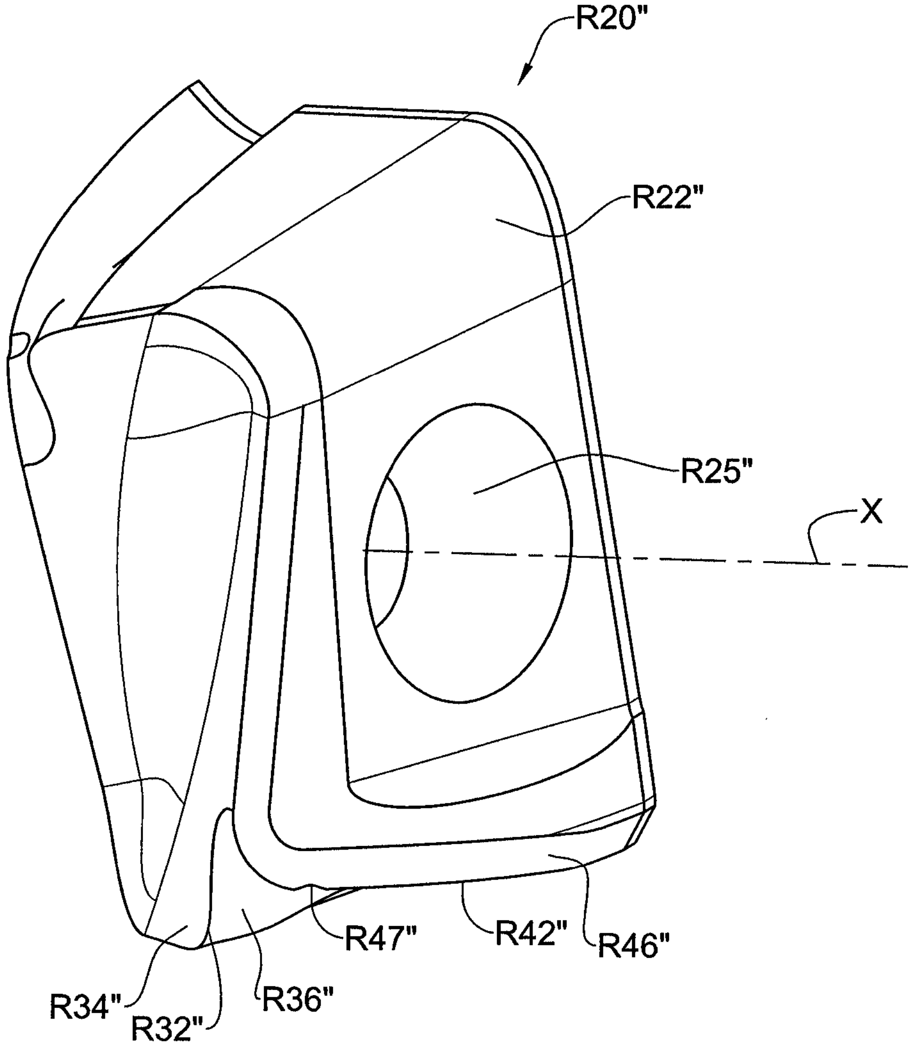


Fig. 67B

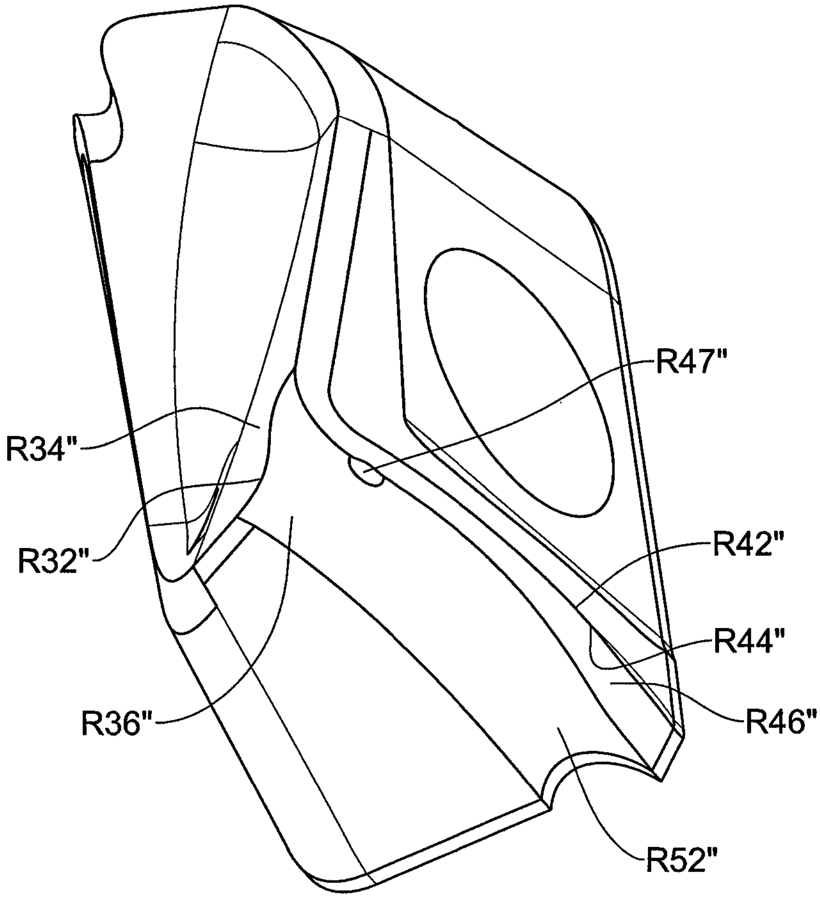


Fig. 67C

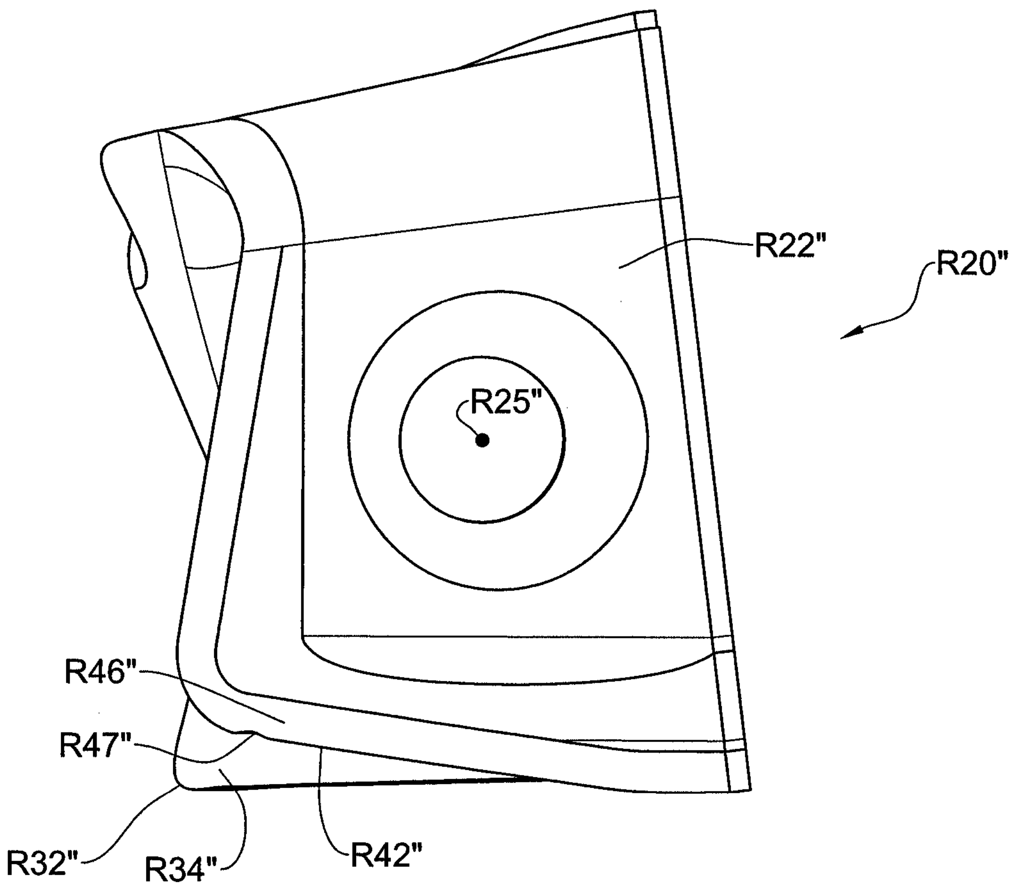


Fig. 67D

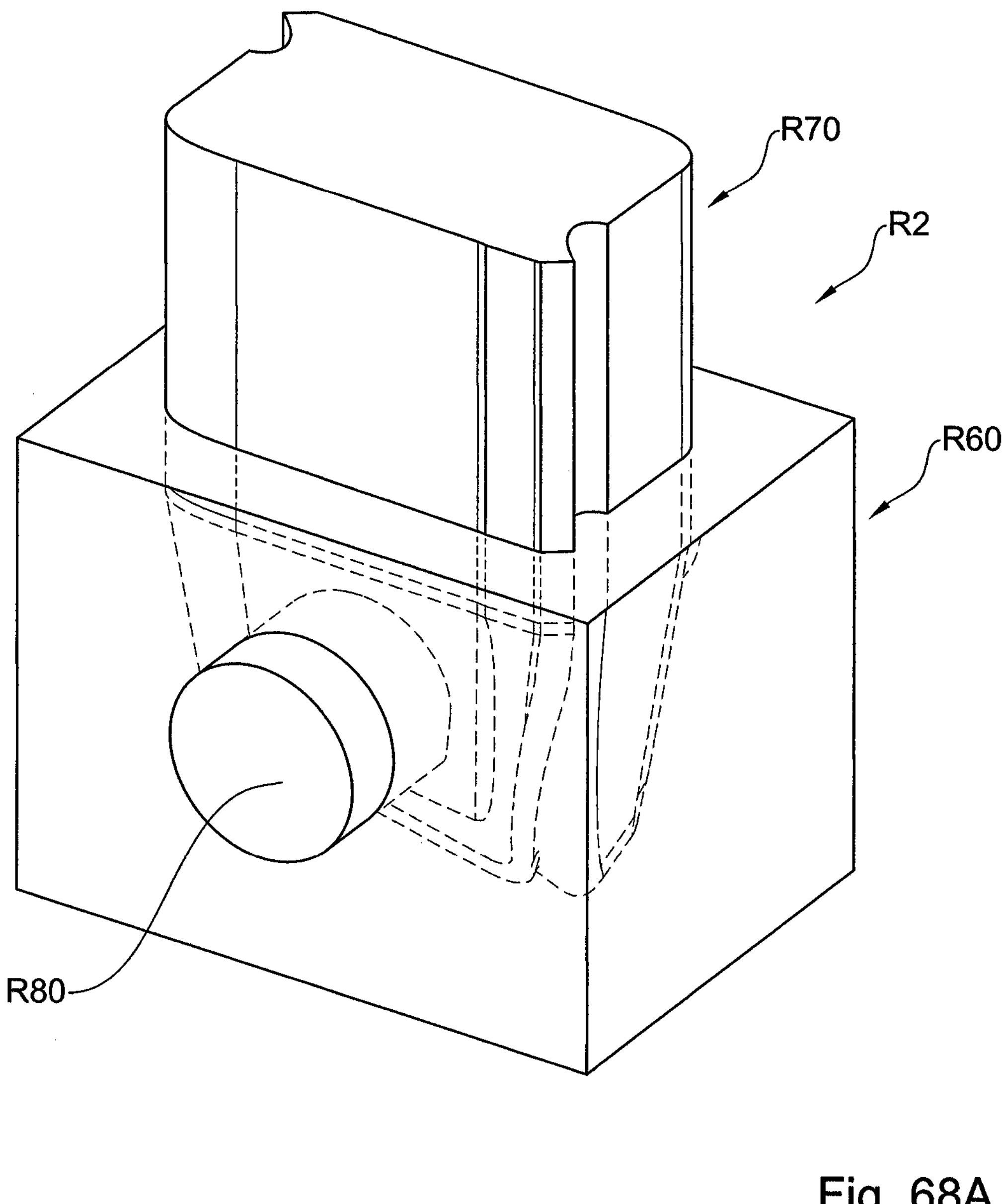


Fig. 68A

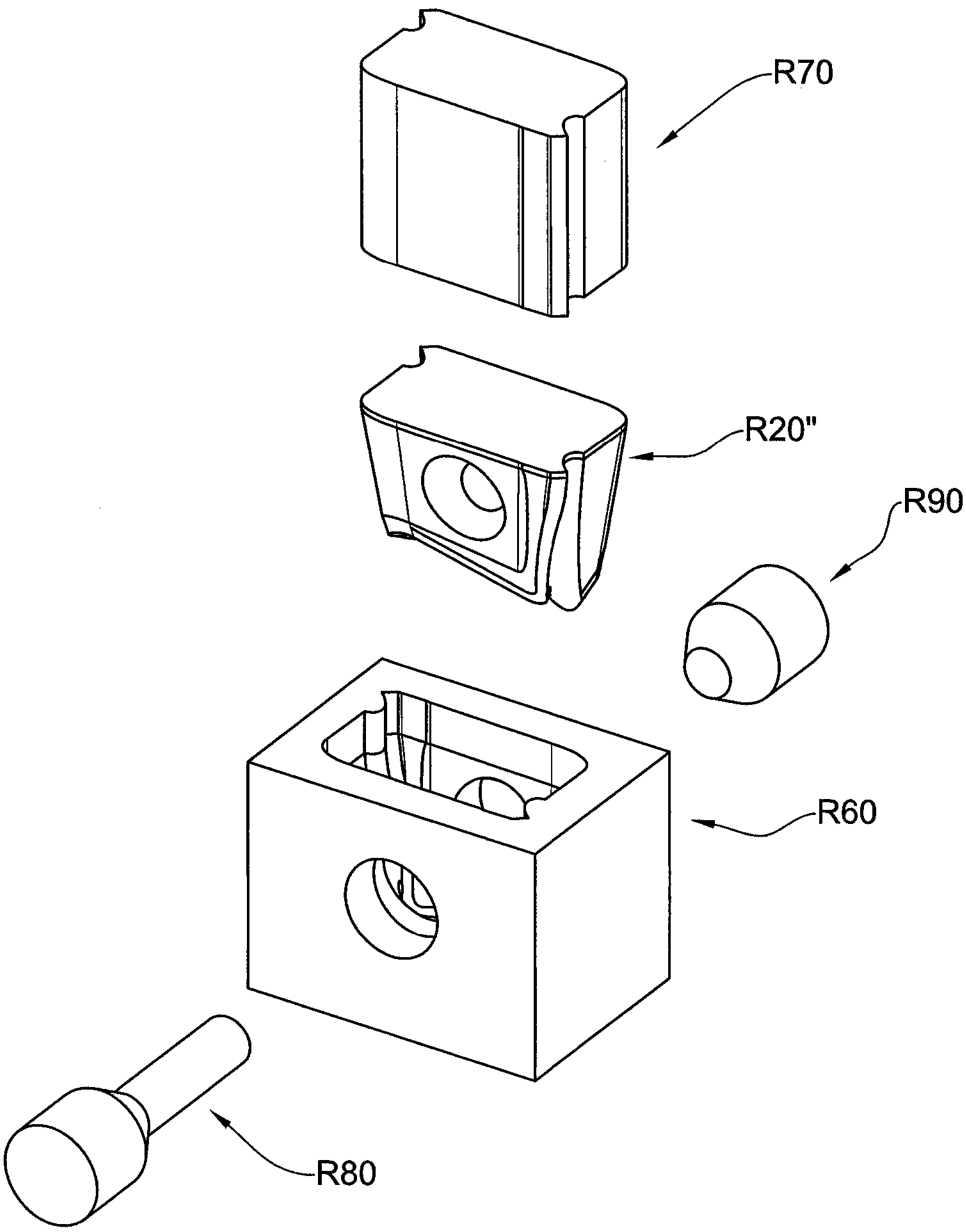


Fig. 68B

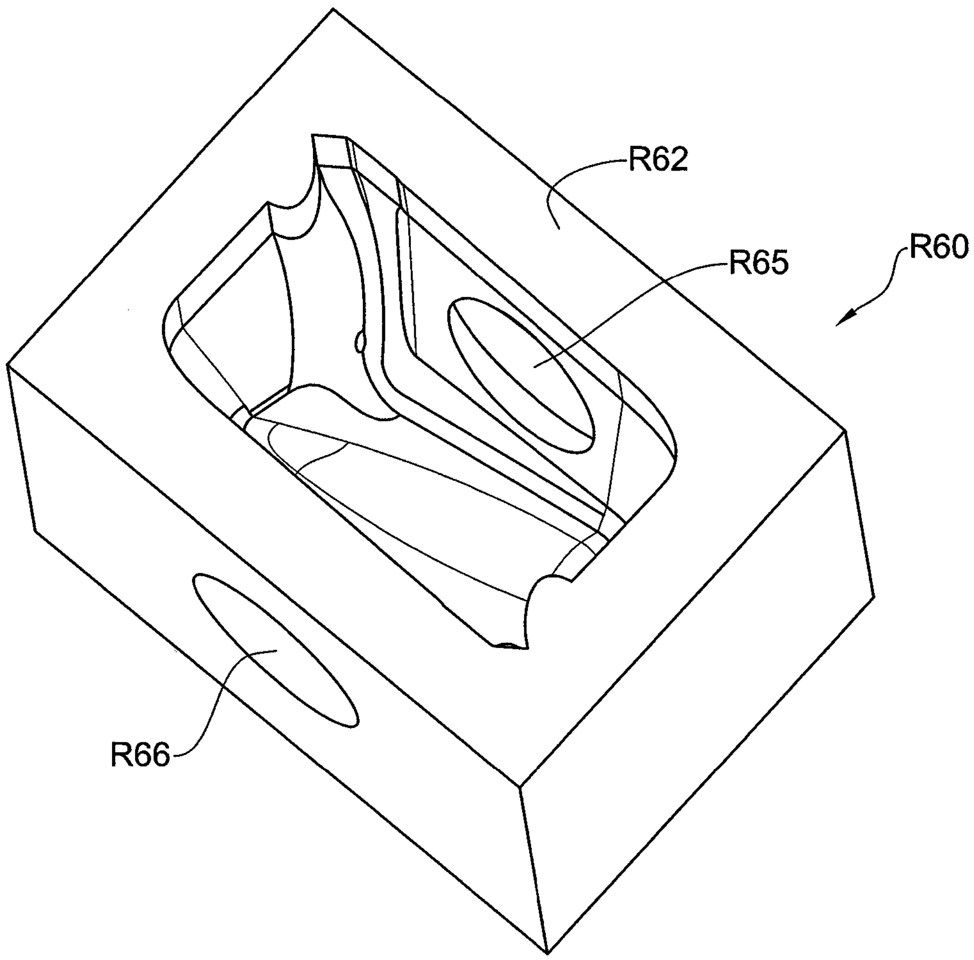


Fig. 68C

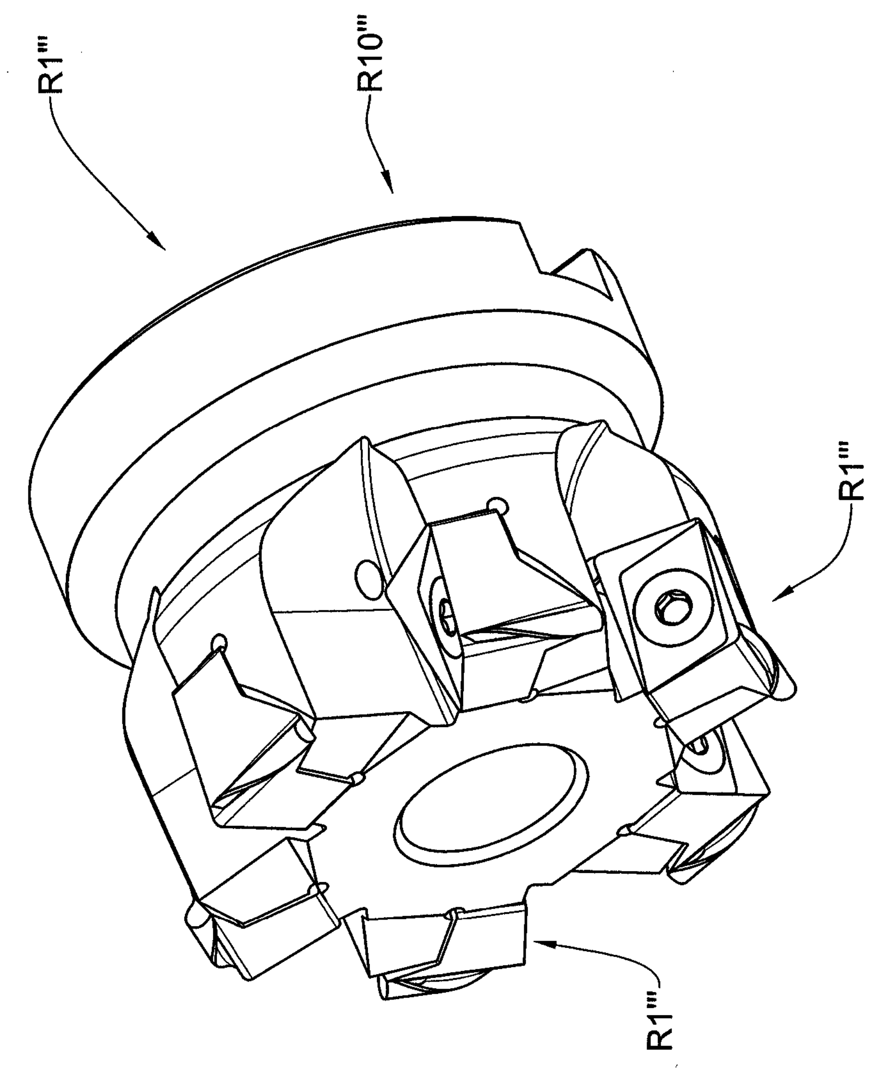


Fig. 69A

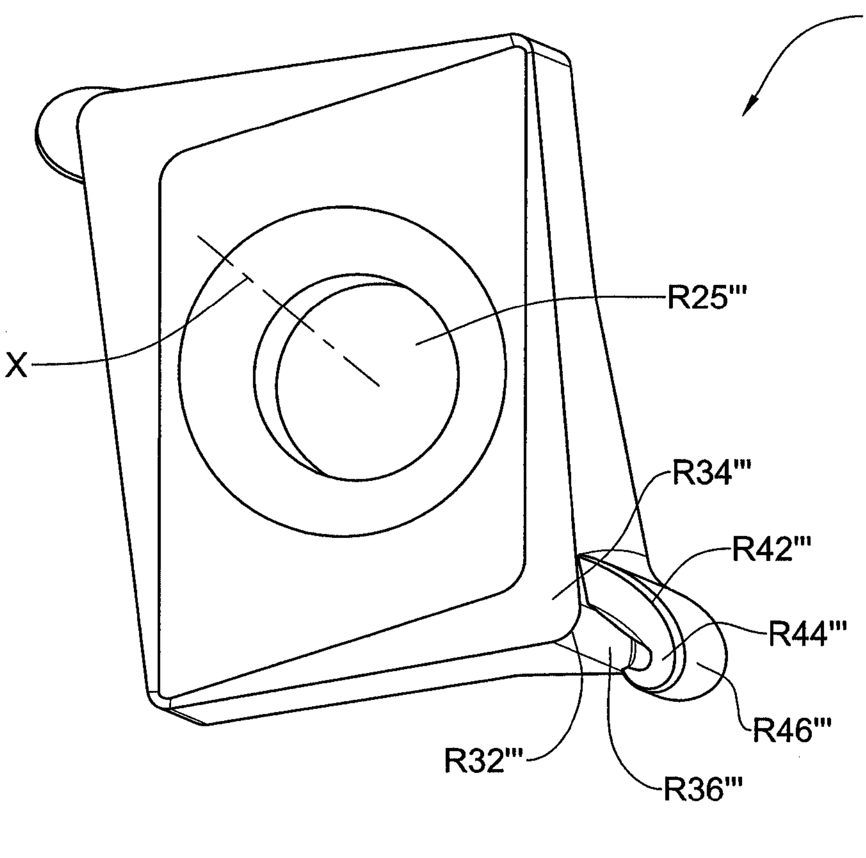


Fig. 69B

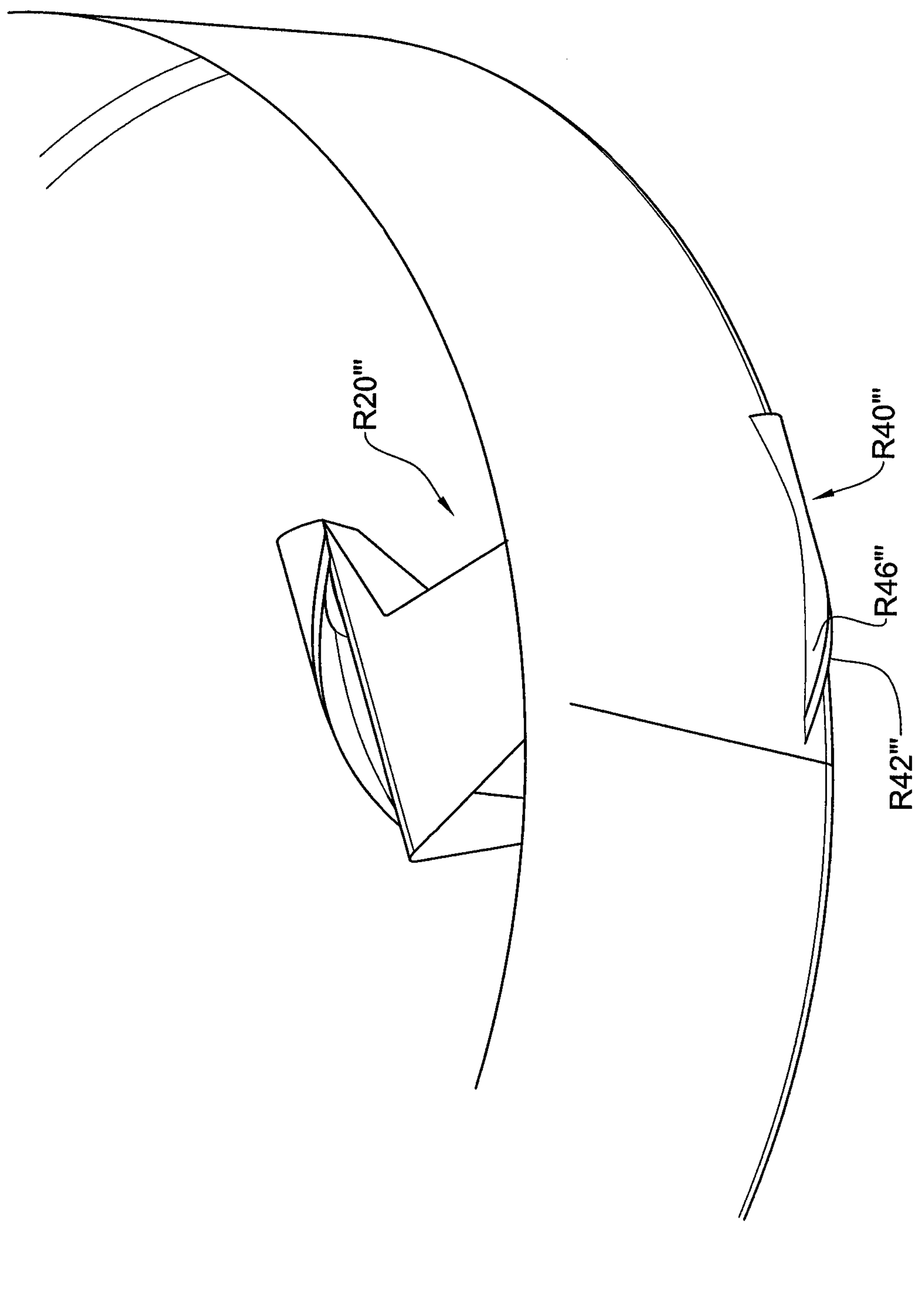


Fig. 69C

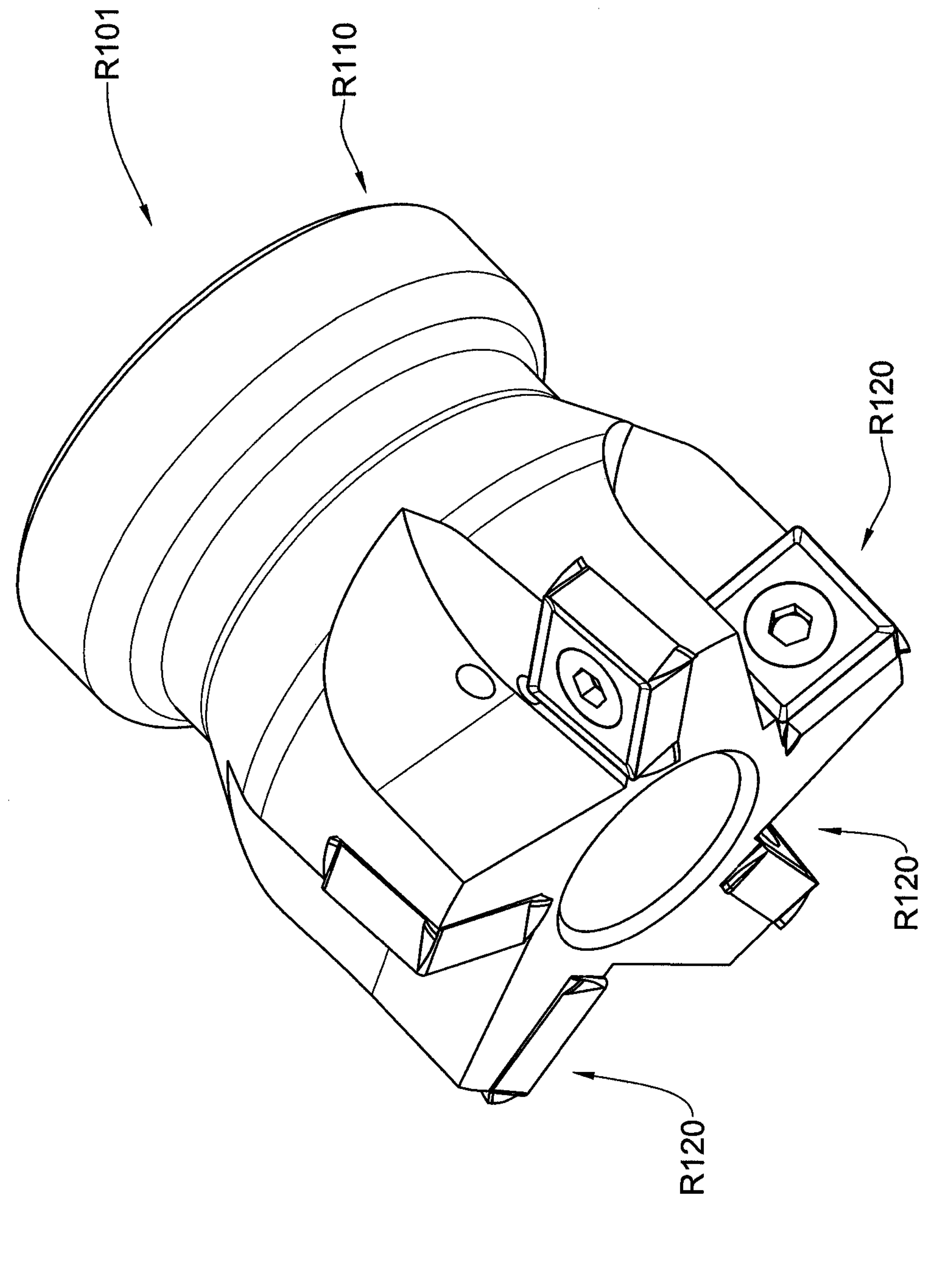


Fig. 70A

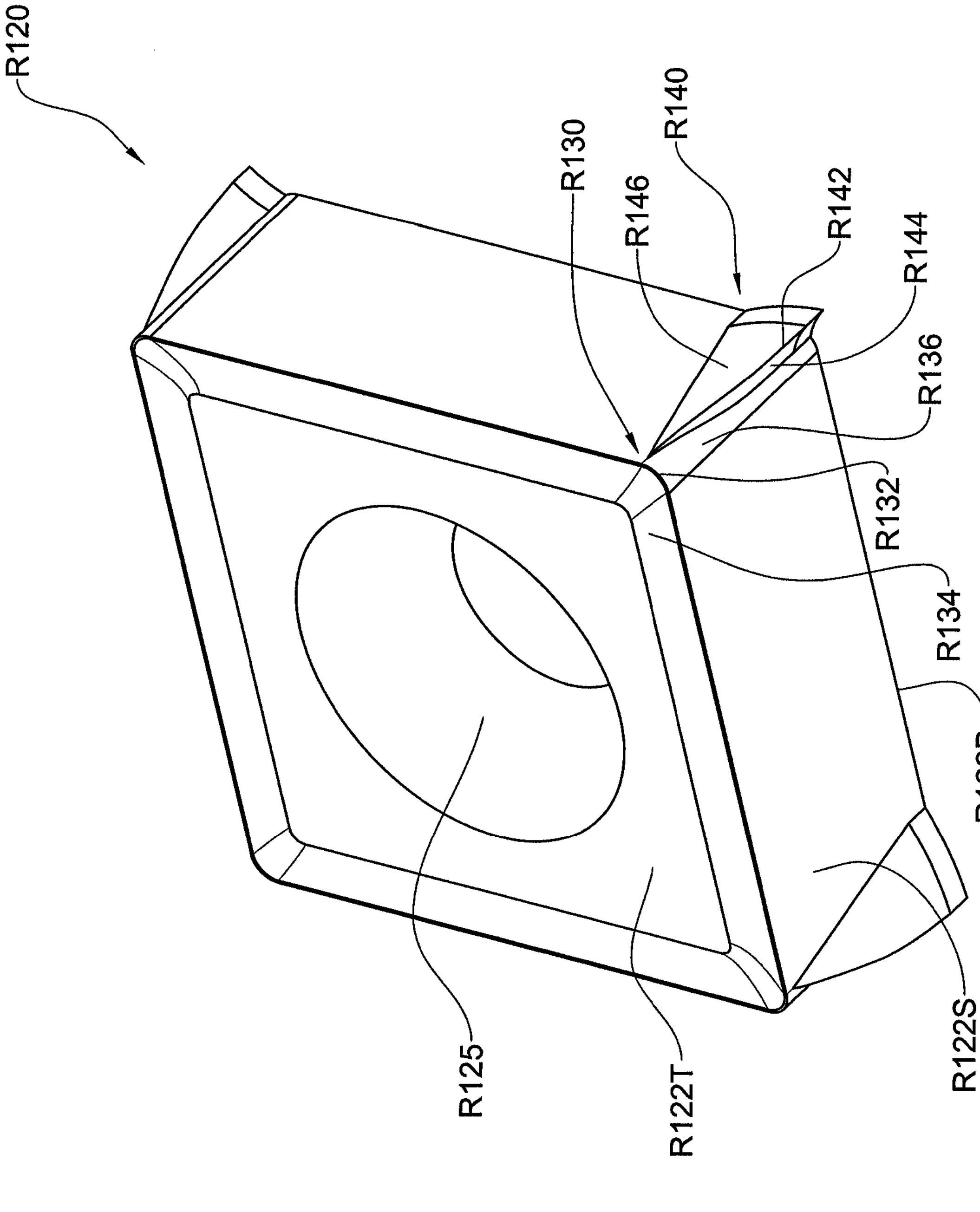

R120
R130
R140
R146
R142
R144
R136
R132
R134
R122B
R122S
R125
R122T

Fig. 70B

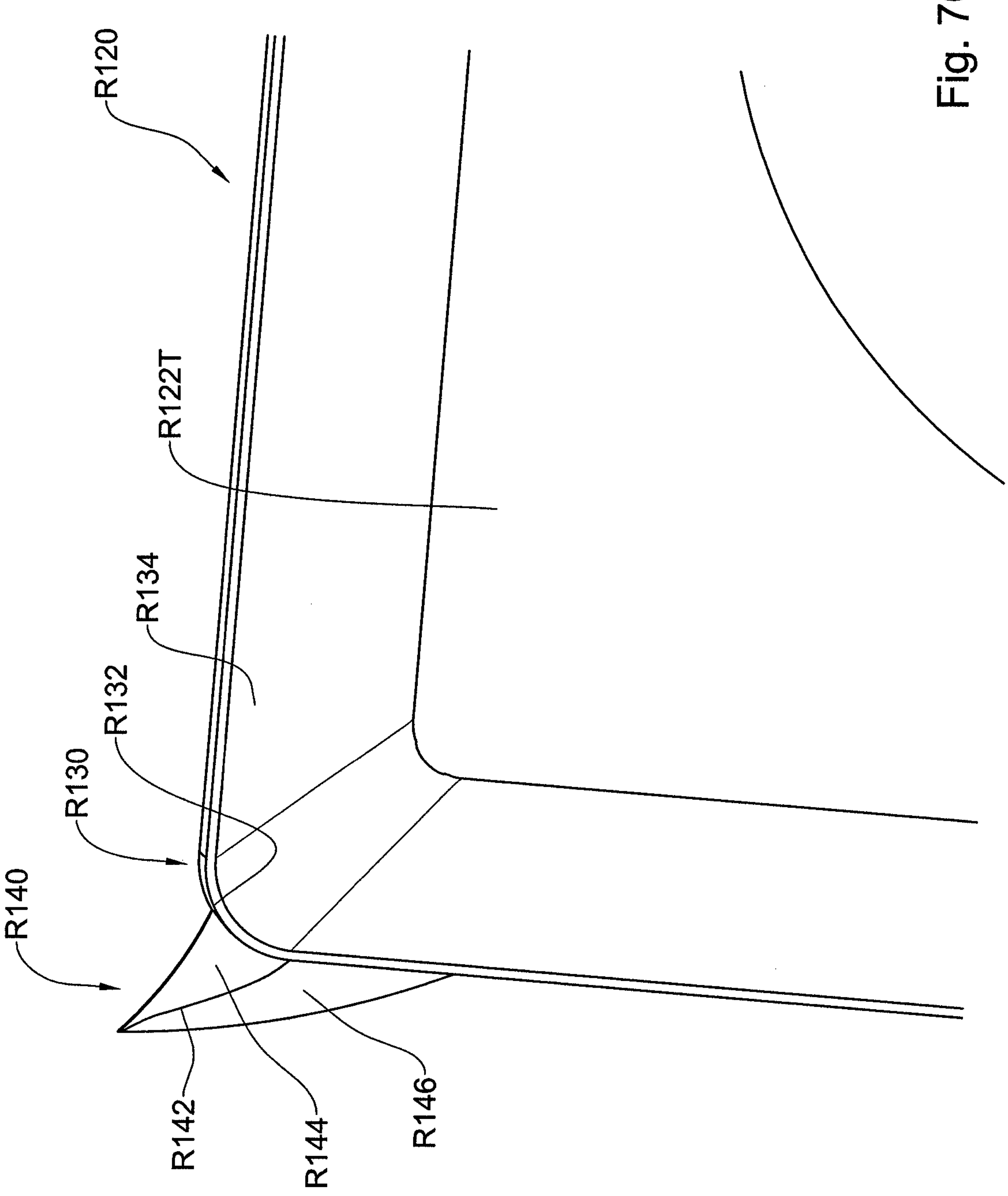


Fig. 70C

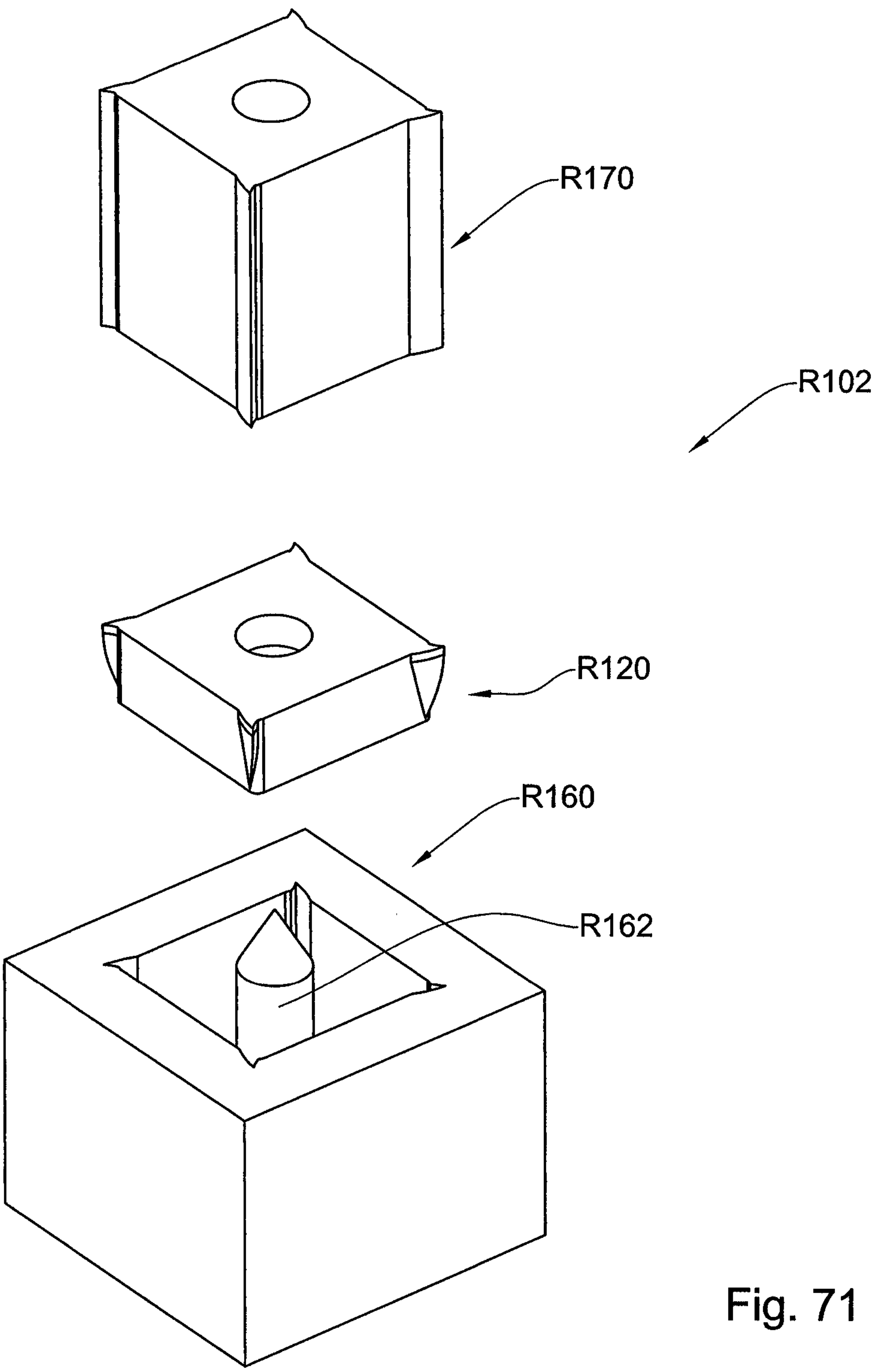


Fig. 71

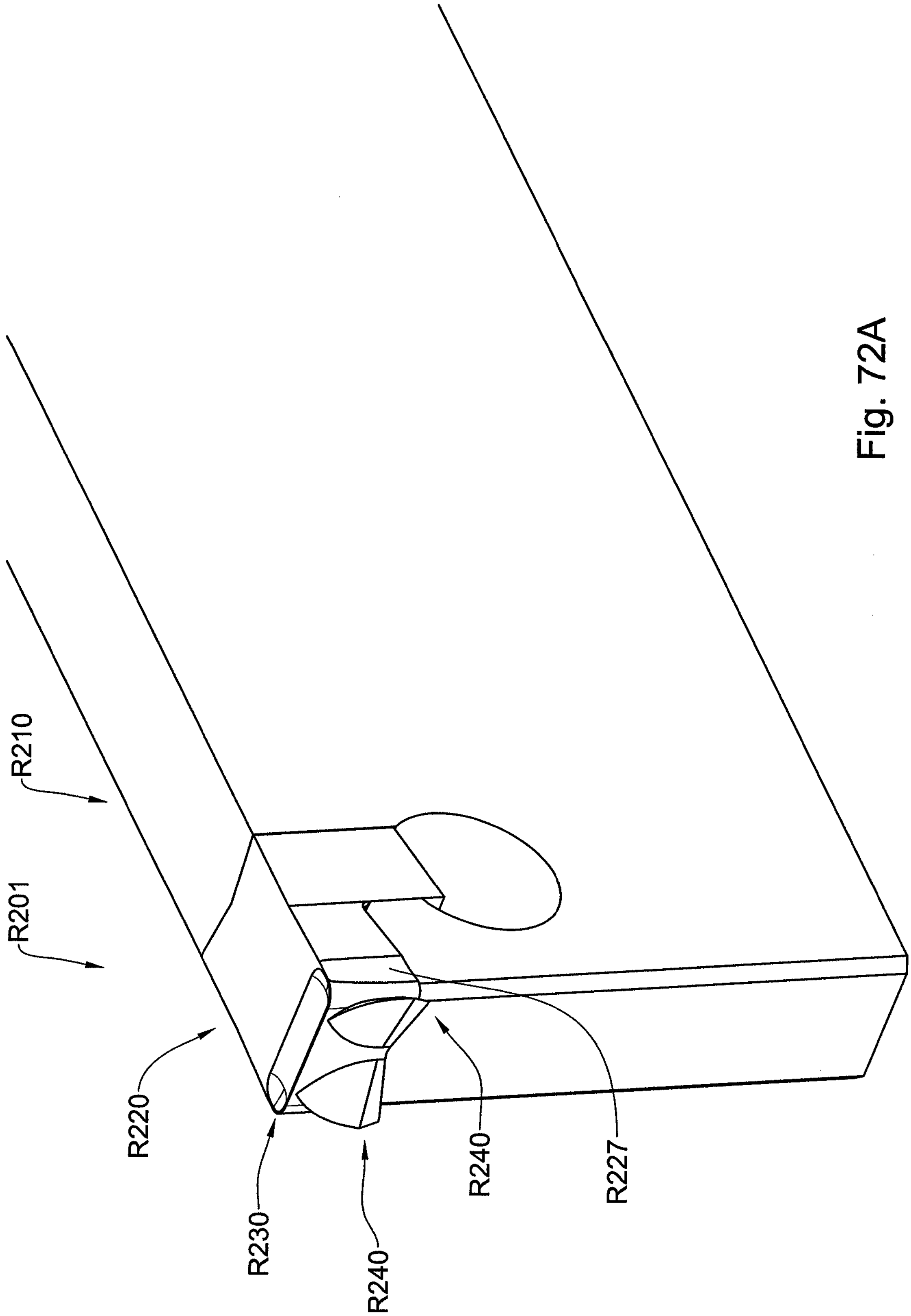


Fig. 72A

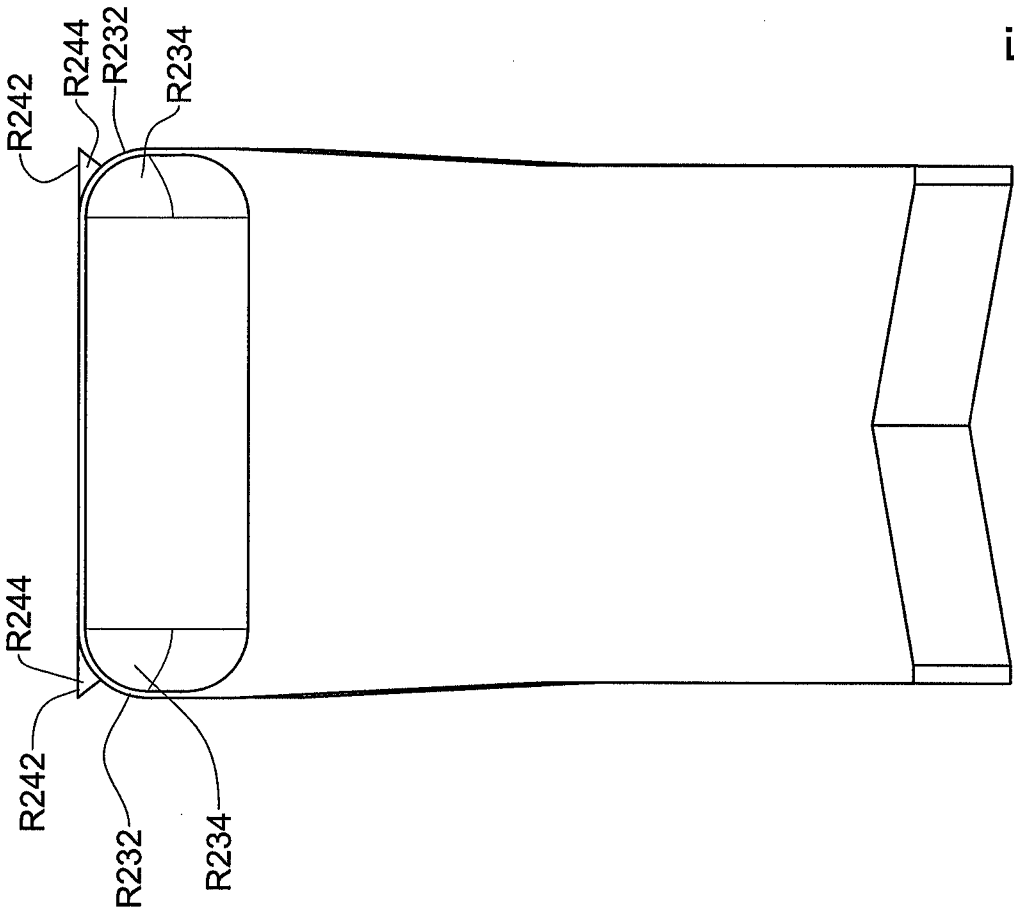


Fig. 72B

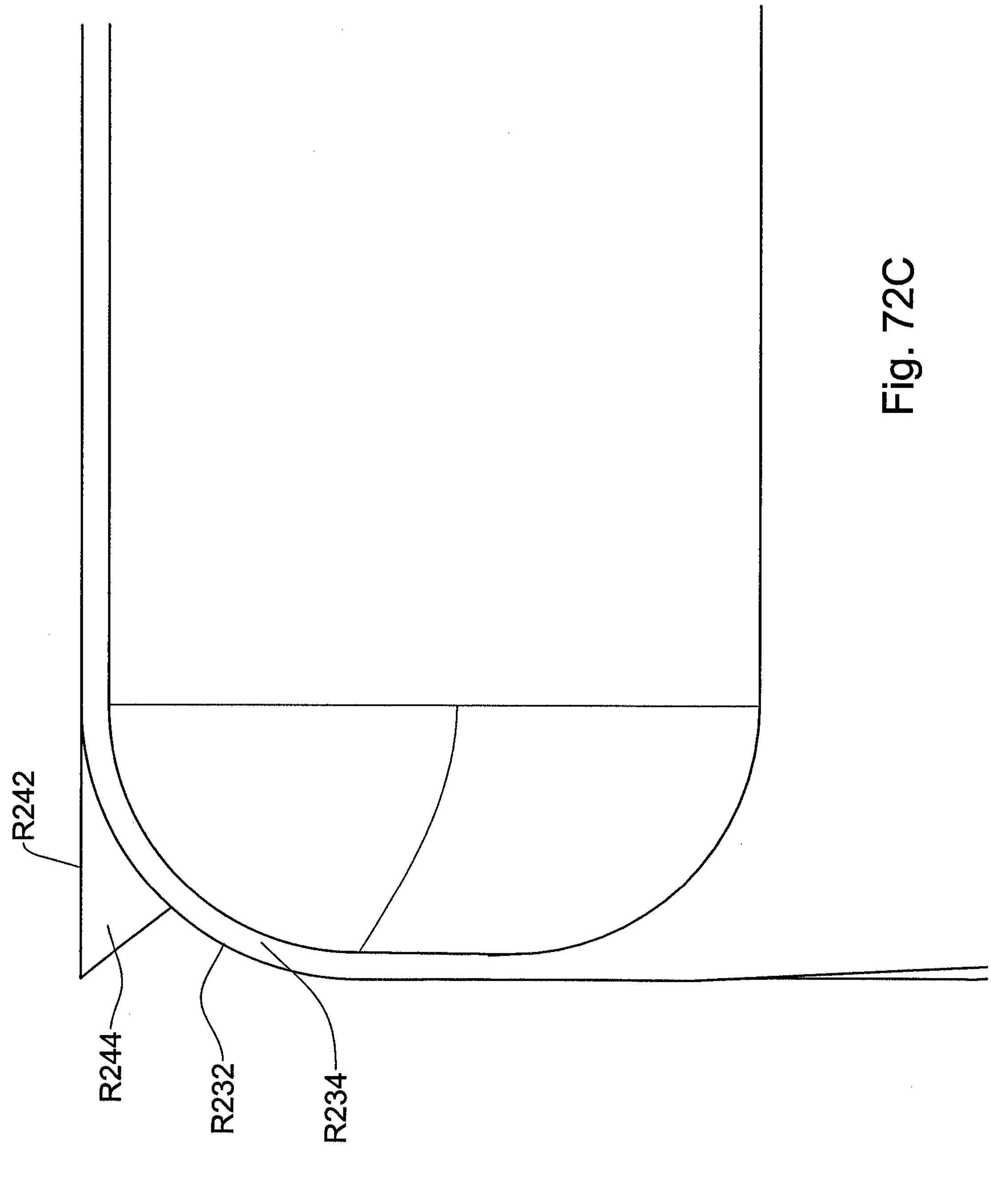


Fig. 72C

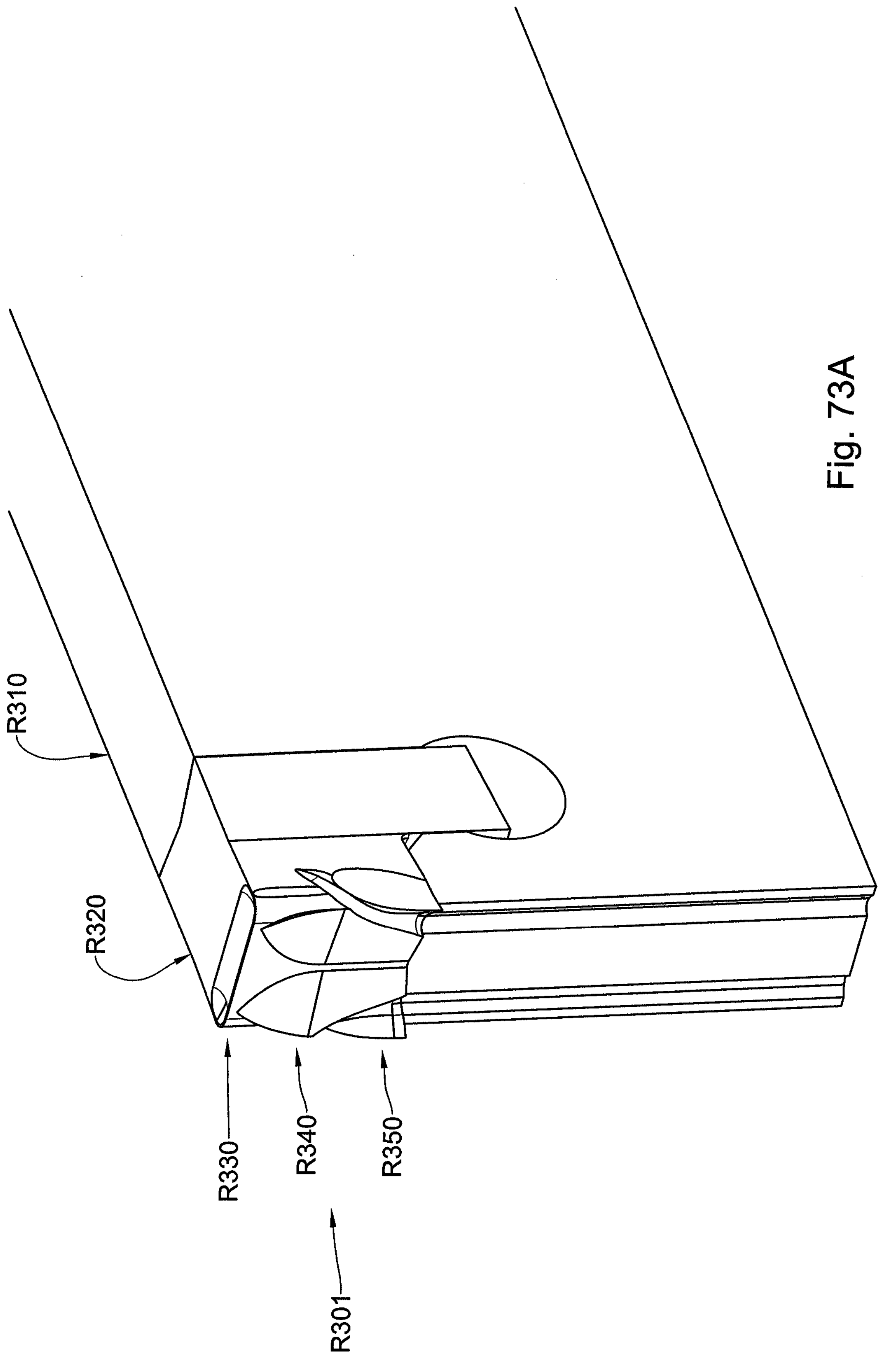


Fig. 73A

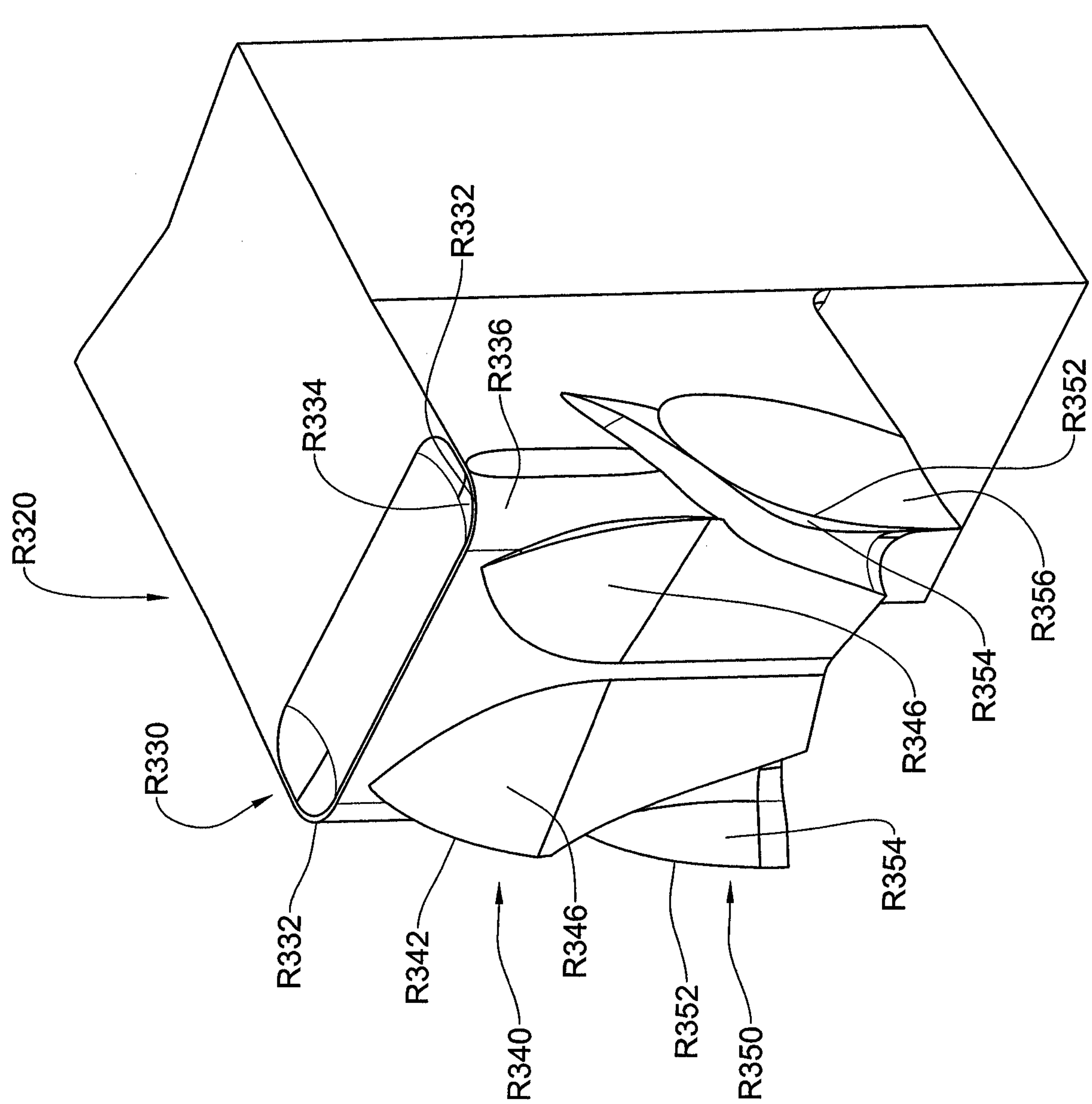

R320
R330
R332
R334
R332
R336
R352
R356
R354
R346
R354
R342
R346
R352
R332
R340
R350

Fig. 73B

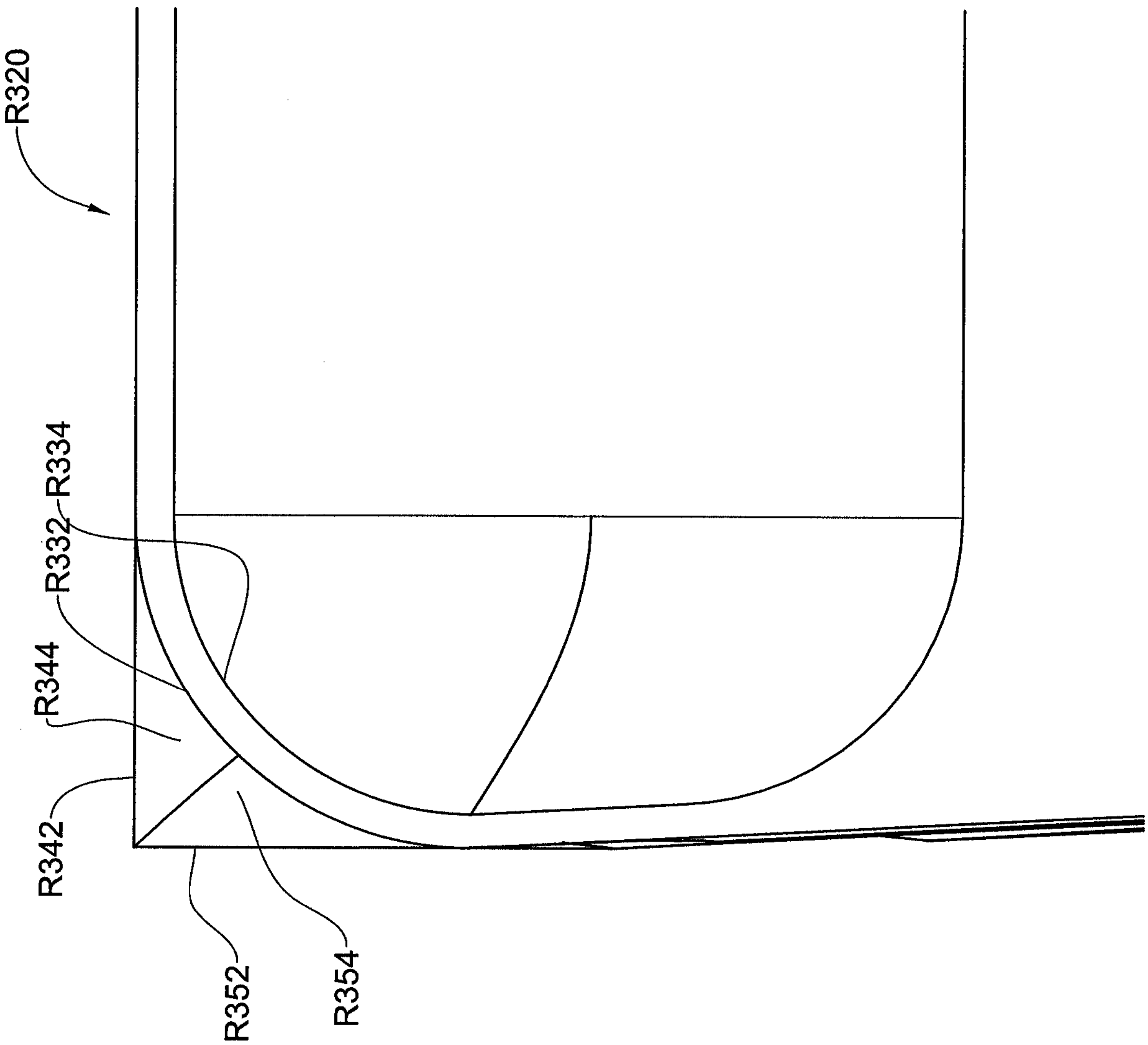


Fig. 73C

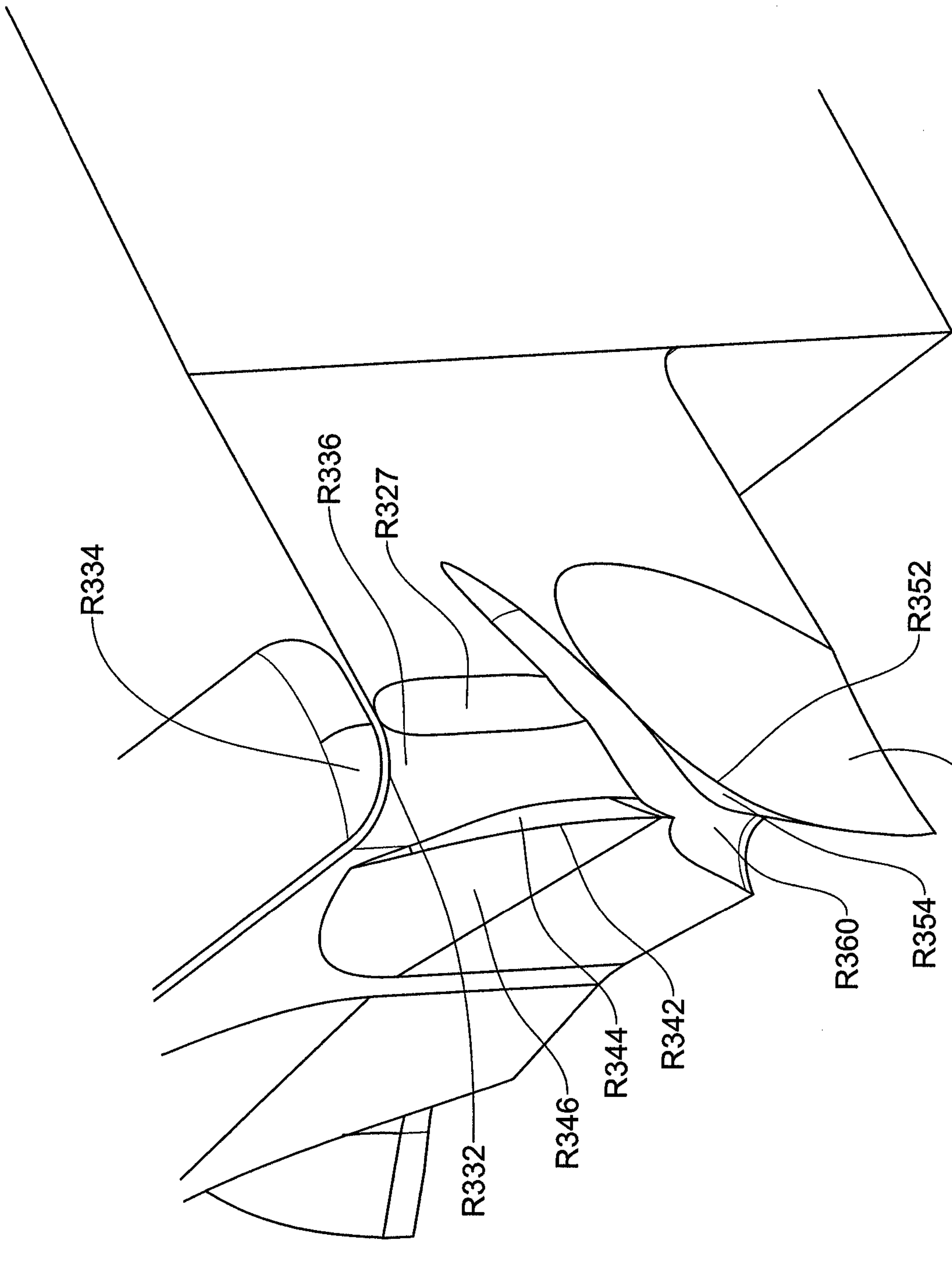


Fig. 73D

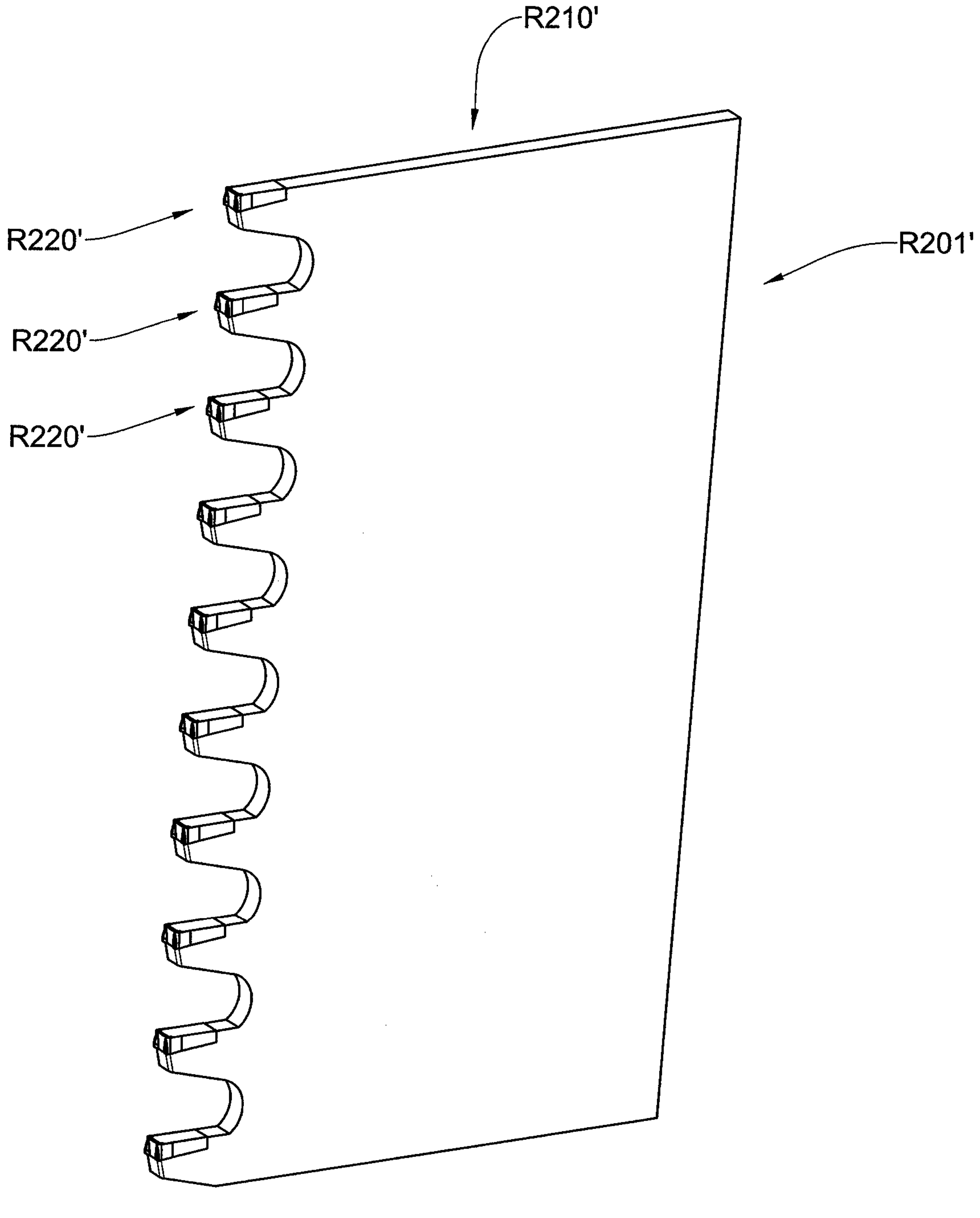


Fig. 74A

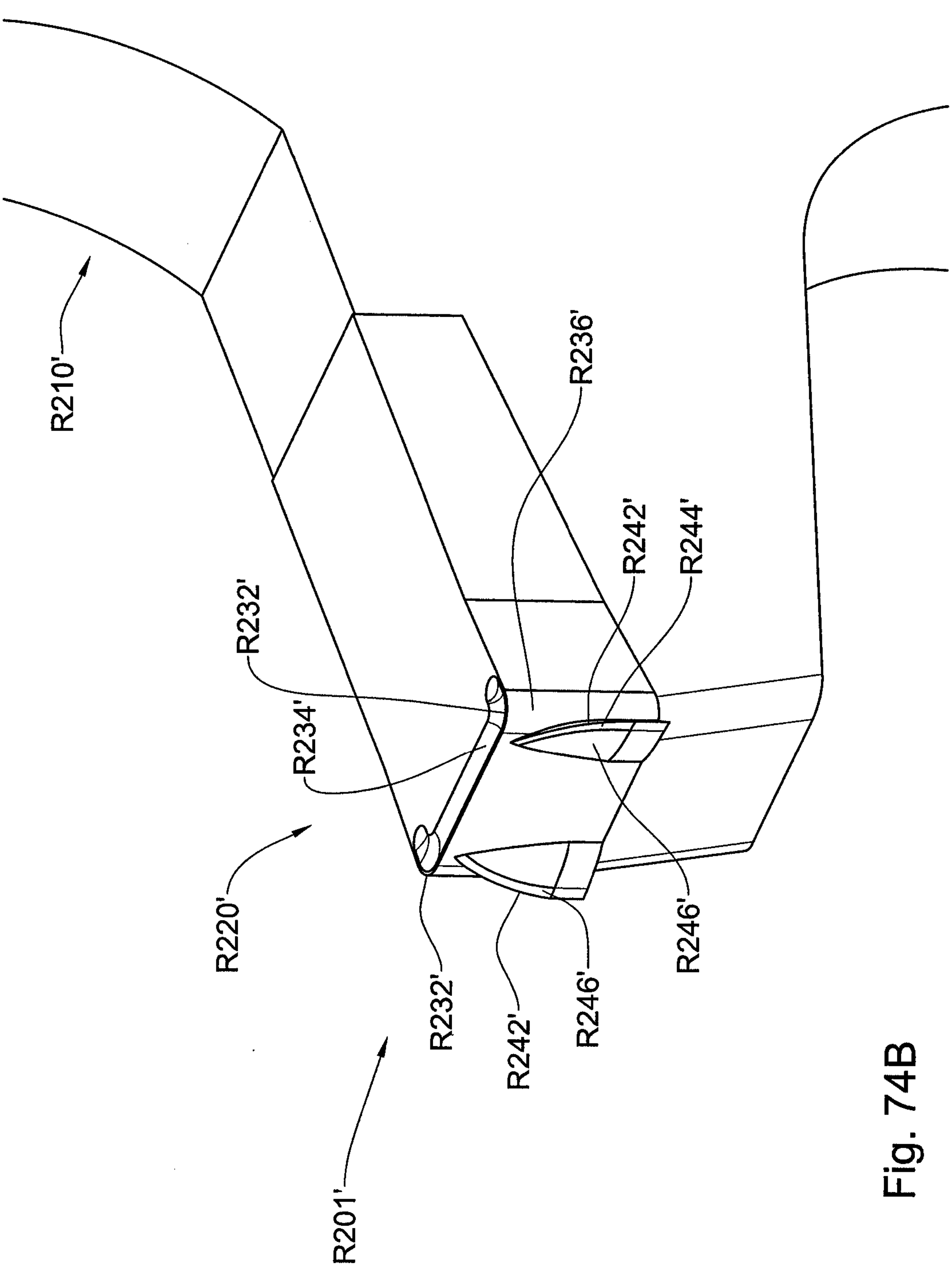


Fig. 74B

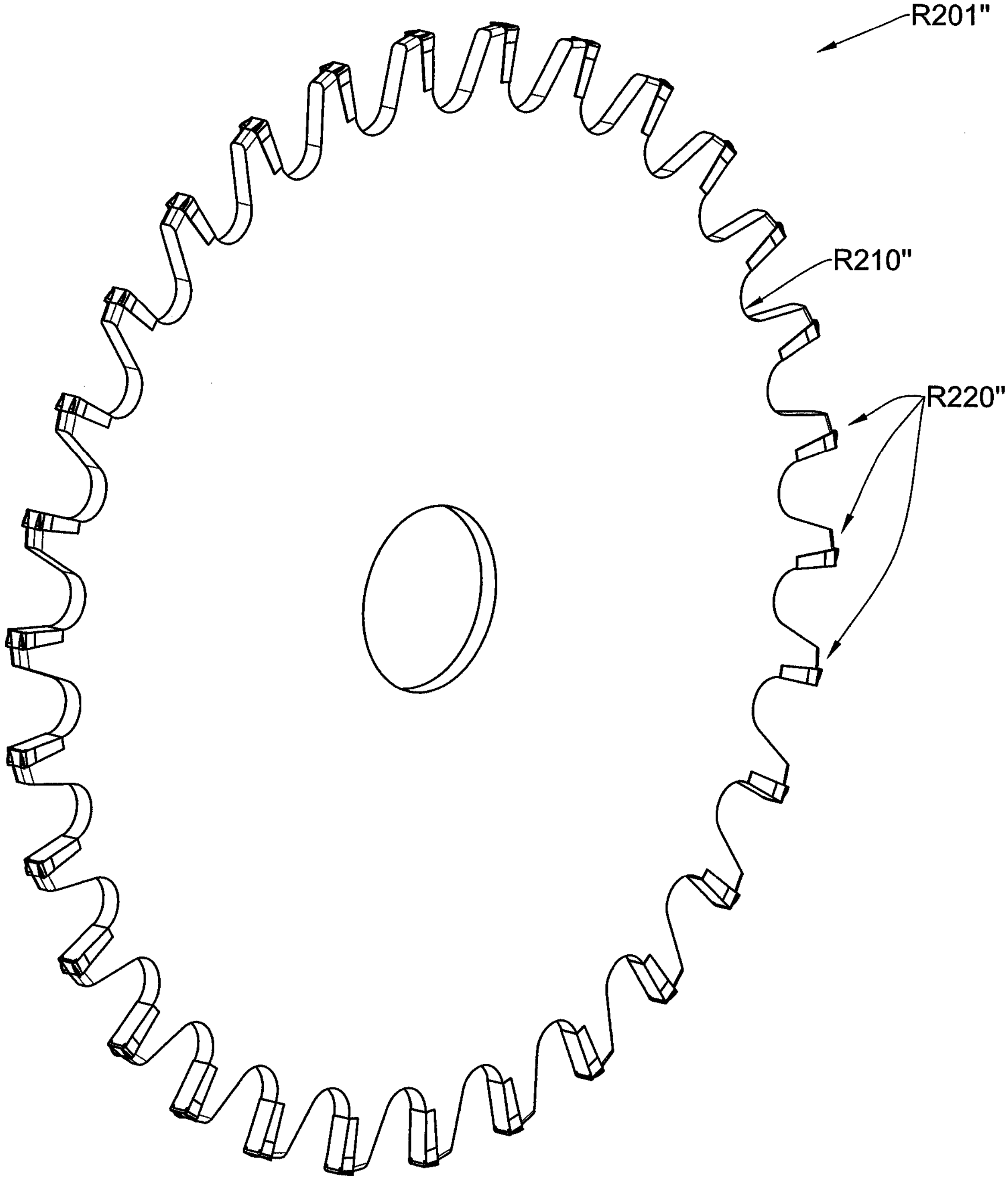


Fig. 75A

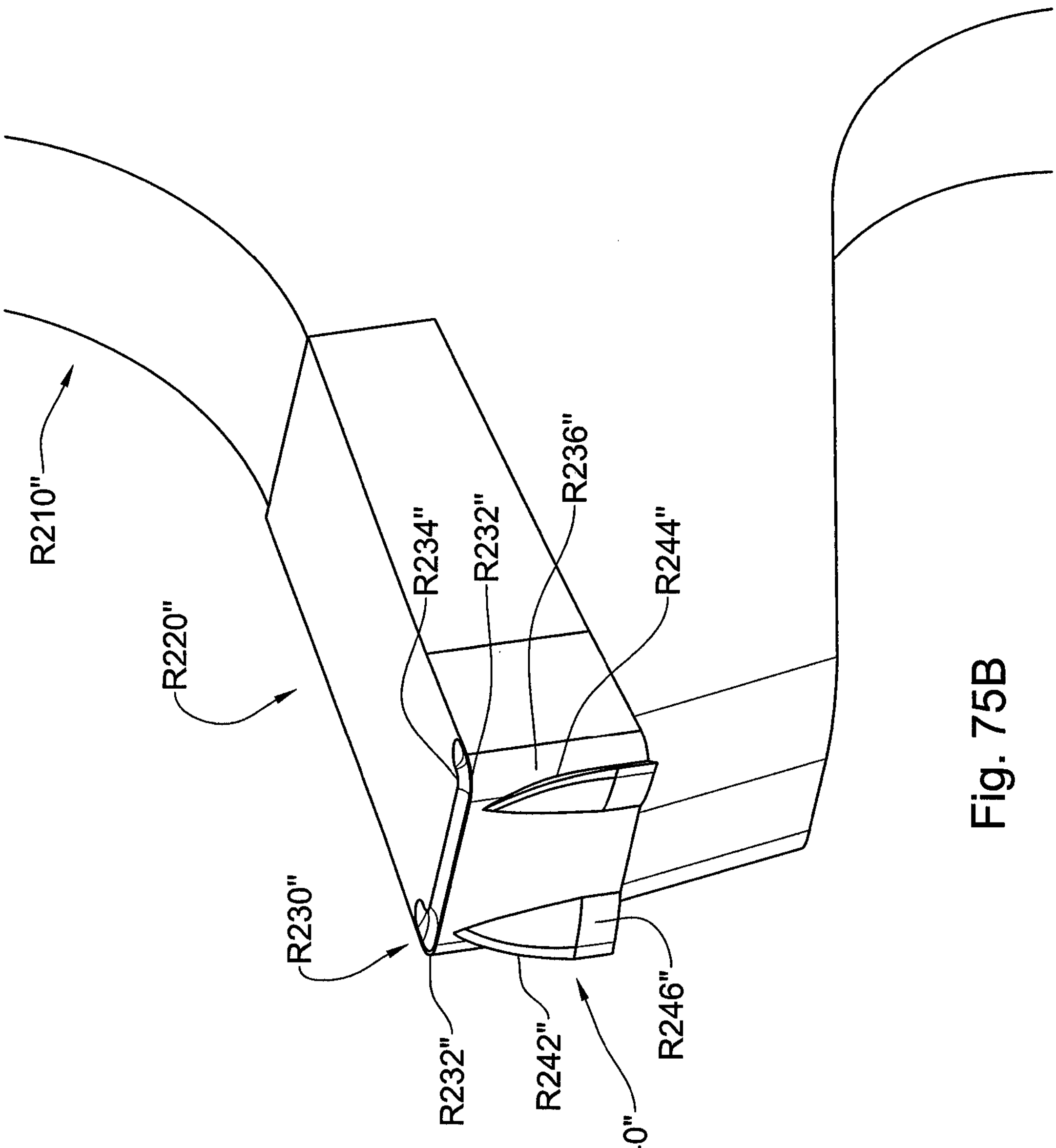


Fig. 75B

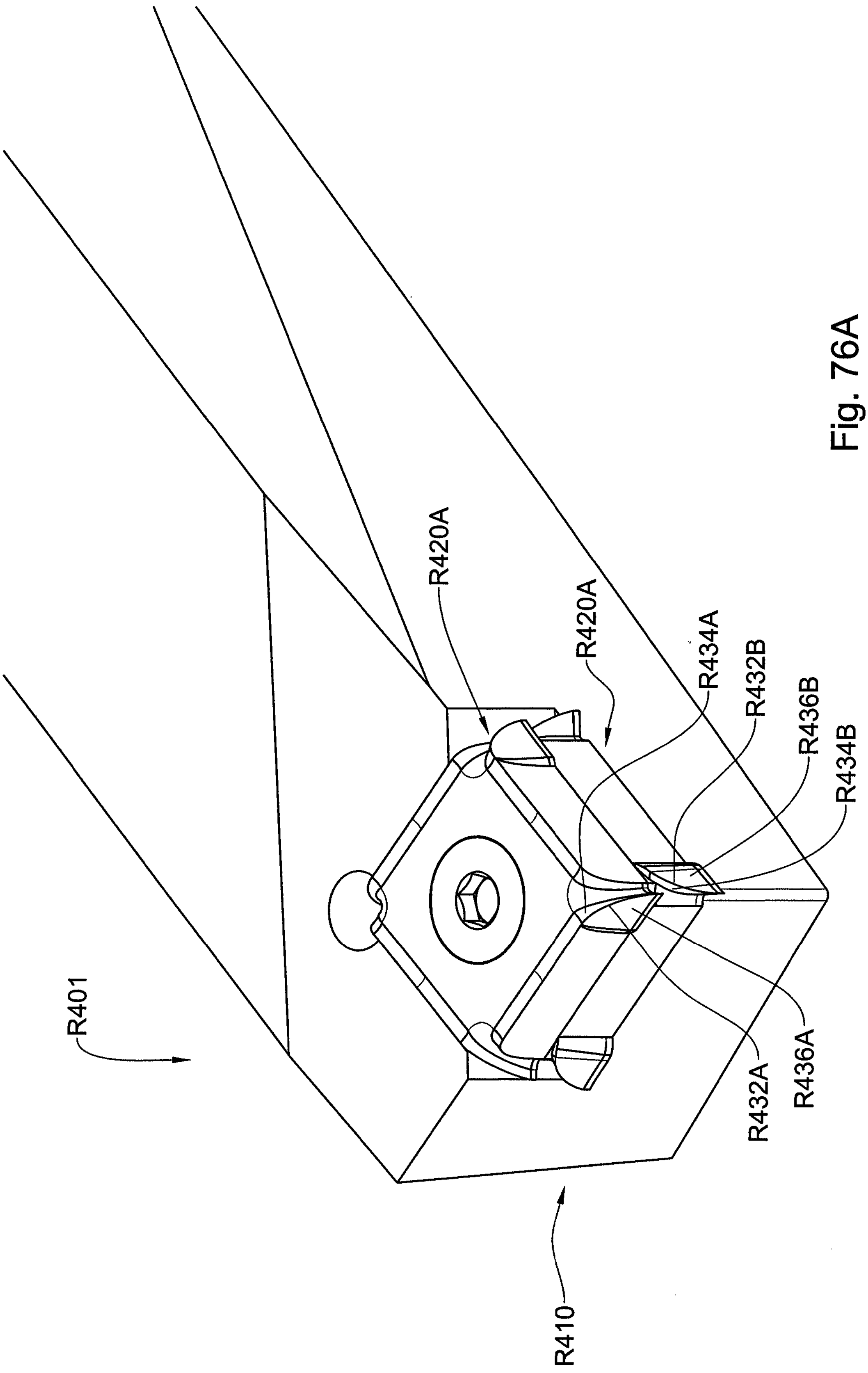
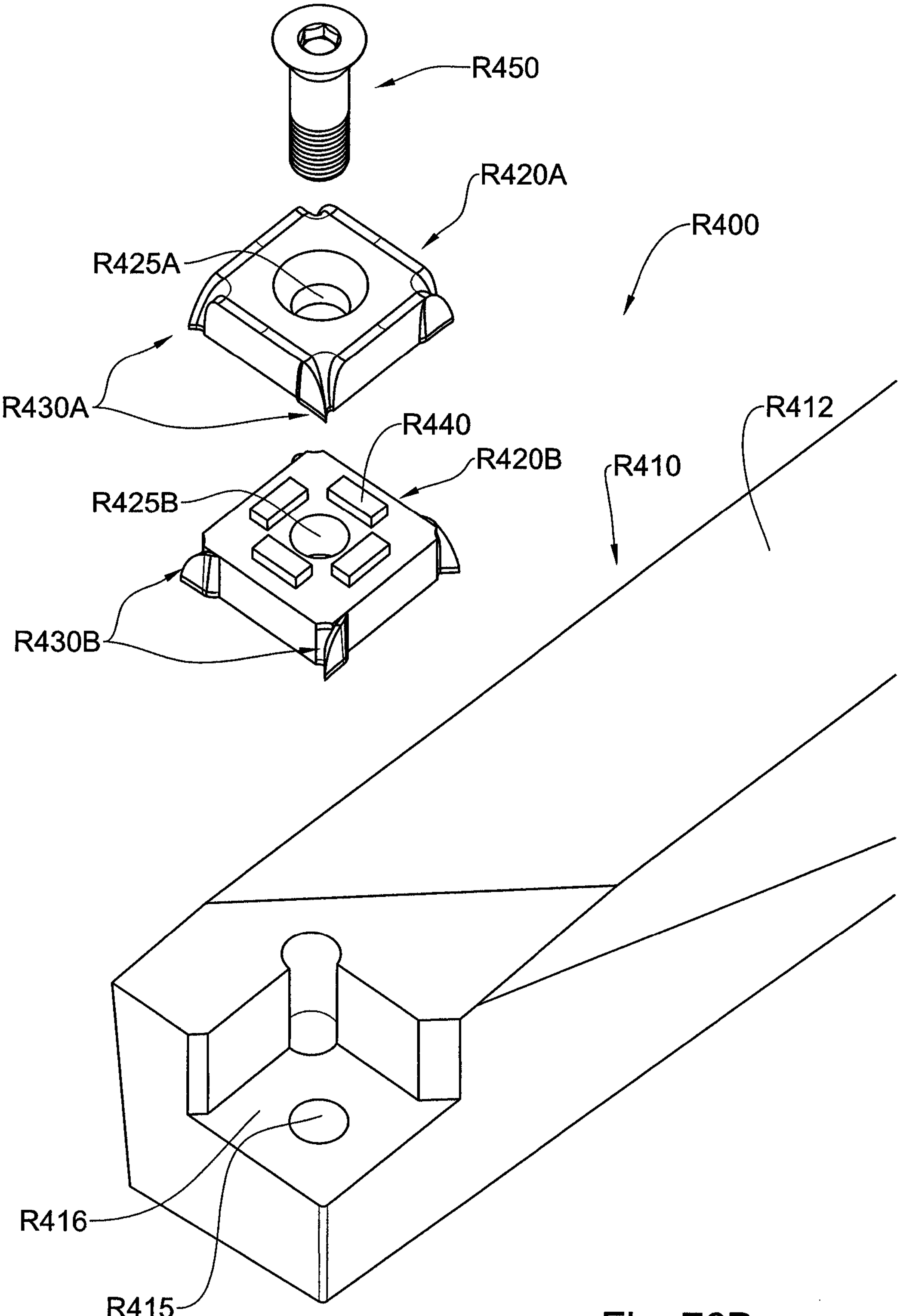


Fig. 76A


R450
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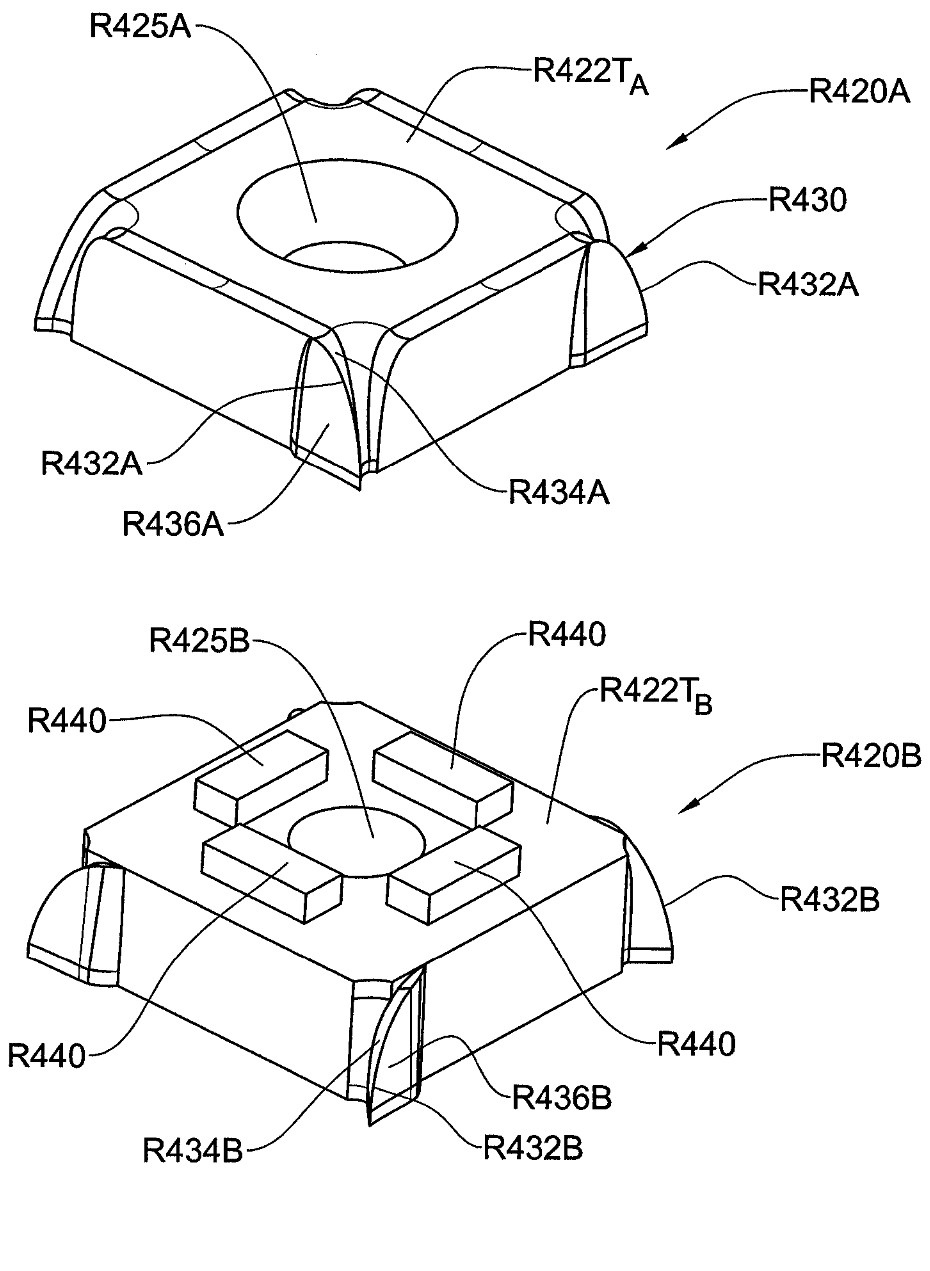
R400
R425A
R430A
R440
R412
R420B
R410
R425B
R430B
R416
R415

Fig. 76B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R422T_A
R420A
R430
R432A
R432A
R434A
R436A
R425B
R440
R440
R422T_B
R420B
R432B
R440
R440
R436B
R434B
R432B

Fig. 76C