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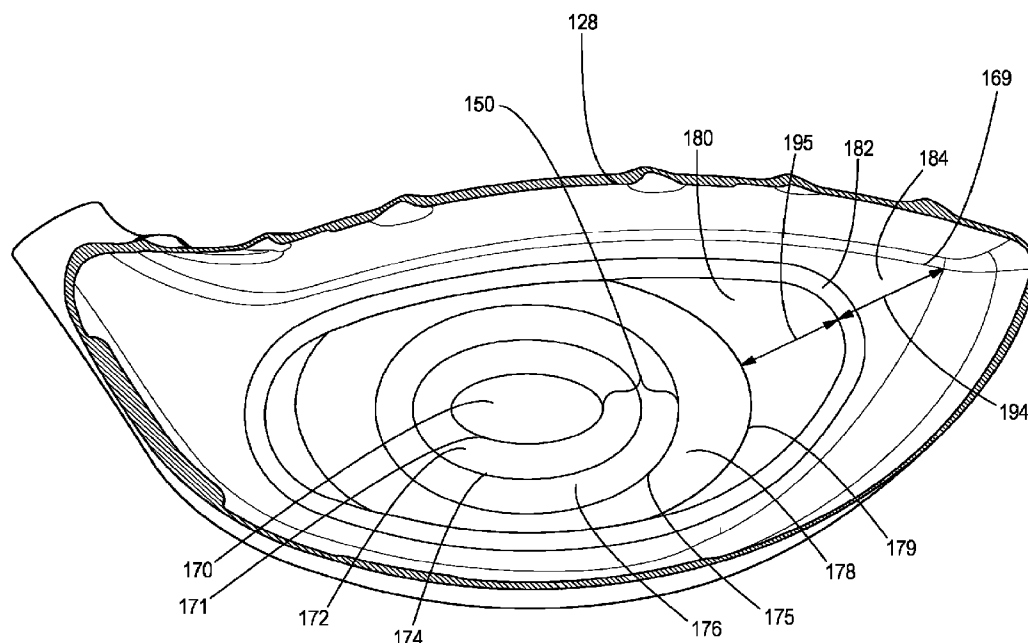


FIG. 1

(57) Abstract: Embodiments of golf club heads comprising a club face with a variable thickness profile to increase face deflection and ball speed for a given CT are described herein. The variable thickness profile comprises a central region, the central transition, the hinge, the inner transition, and the hinge outer peak creating a variable face thickness with a topography that evokes the shape of a speaker woofer to produce non-linear bending, thereby producing greater strike face deflection and resulting ball speed for a given CT value. The variable face thickness profiles can further comprise a non-linear bending region comprising a first peak, a valley, and a second peak to non-linearly bend at other locations on the strike face thereby, producing greater strike face deflection and resulting ball speed for a given CT value.



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GOLF CLUB HEAD WITH A VARIABLE FACE THICKNESS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This claims the benefit of U.S. Provisional Patent Application No. 63/571,377, filed on March 28, 2024, and U.S. Provisional Patent Application No. 63/595,687, filed on November 2, 2023. The contents of all the above-described disclosures are incorporated fully herein by reference in their entirety.

TECHNICAL FIELD

[0002] This disclosure relates generally to golf clubs and, more particularly, to wood-type golf club heads comprising a variable face thickness topography.

BACKGROUND

[0003] Golf club designers seek to optimize performance characteristics of golf clubs, such as spin, directionality, ball speed, and characteristic time (CT). The United States Golf Association (USGA), however, implements regulations that limit certain of those performance characteristics. For example, the CT of a club head must not exceed limits defined by the USGA. To conform to current CT limits, however, current golf club designs reduce strike face deflection and ball speed. Limiting strike face deflection induces sub-optimal launch characteristics, thereby diminishing the feel or playability of a golf club head. Therefore, there is a need in the art for alternative wood-type club head designs that meet USGA regulations while increasing strike face deflection and ball speed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] FIG. 1 illustrates a rear view, in cross-section, of a golf club head having a strike face with a variable thickness.

[0005] FIG. 2A illustrates an enlarged rear view of the strike face for the FIG. 1 golf club head.

[0006] FIG. 2B illustrates an enlarged rear view of the strike face for the FIG. 1 golf club head.

[0007] FIG. 3 illustrates an enlarged rear view of the strike face for the FIG. 1 golf club head.

[0008] FIG. 4 illustrates an enlarged rear view of the strike face for the FIG. 1 golf club head.

[0009] FIG. 5A illustrates an enlarged side view, in a horizontal cross-section, of a strike face for the FIG. 1 golf club head.

[0010] FIG. 5B illustrates exaggerated graphical representation of a variable face thickness region according to FIG. 1.

[0011] FIG. 6A illustrates an enlarged side view, in a vertical cross-section, of a strike face for the FIG. 1 golf club head.

[0012] FIG. 6B illustrates an enlarged side view, in a vertical cross-section, of a strike face for the FIG. 1 golf club head.

[0013] FIG. 7 illustrates a rear view, in cross-section, of a golf club head having an alternative strike face with a variable thickness.

[0014] FIG. 8 illustrates an enlarged rear view of the strike face for the FIG. 7 golf club head.

[0015] FIG. 9 illustrates an enlarged rear view of the strike face for the FIG. 7 golf club head.

[0016] FIG. 10 illustrates an enlarged rear view of the strike face for the FIG. 7 golf club head.

[0017] FIG. 11 illustrates an enlarged side view, in a horizontal cross-section, of a strike face for the FIG. 1 golf club head.

[0018] FIG. 12A illustrates an enlarged side view, in a vertical cross-section, of a strike face for the FIG. 7 golf club head.

[0019] FIG. 12B illustrates an enlarged side view, in a vertical cross-section, of a strike face for the FIG. 7 golf club head.

[0020] FIG. 13A illustrates the enlarged side view of FIG. 6A.

[0021] FIG. 13B illustrates the enlarged side view of FIG. 12A.

[0022] FIG. 14A illustrates the enlarged side view of FIG. 5.

[0023] FIG. 14B illustrates the enlarged side view of FIG. 11.

[0024] FIG. 15 illustrates an external heel and rear side perspective view of a golf club head.

[0025] FIG. 16 illustrates an external top or crown view of the golf club head of FIG. 15.

[0026] FIG. 17 illustrates an external bottom or sole view of the golf club head of FIG. 15.

[0027] FIG. 18 illustrates an external front view of the golf club head of FIG. 15 in an address position.

[0028] FIG. 19 illustrates a rear, internal view of the faceplate having a variable face thickness of FIG. 15 in an address position.

[0029] FIG. 20 illustrates a cross sectional view of the golf club head of FIG. 15 having a weight assembly affixed to the club head.

[0030] FIG. 21 illustrates a cross sectional view of the golf club head of FIG. 15 without a weight assembly affixed to the club head.

[0031] FIG. 22 illustrates a rear internal view of the golf club head of FIG. 7 with a sole-to-faceplate bridge and a crown-to-faceplate bridge.

[0032] FIG. 23 illustrates a close-up view of the crown-to-faceplate bridge of FIG. 22.

[0033] FIG. 24 illustrates a rear, internal view of the golf club head of FIG. 1 with a sole-to-faceplate bridge.

[0034] FIG. 25 illustrates a close-up view of the sole-to-faceplate bridge of FIG. 24.

[0035] FIG. 26A illustrates a variable face thickness comprising a non-linear bending region.

[0036] FIG. 26B illustrates an exaggerated graphical representation of a non-linear bending region.

[0037] FIG. 27 illustrates a perspective view of a golf club head.

[0038] FIG. 28 illustrates a front view of a golf club head comprising various axis and planes, a lie angle, and other features.

[0039] FIG. 29 illustrates a toe-side view of a golf club comprising a loft angle.

[0040] FIG. 30 illustrates a rear perspective view of a golf club head comprising a crown insert and a sole insert.

[0041] FIG. 31 illustrates a rear perspective view of the golf club head of FIG. 30 comprising a crown opening and a sole opening.

[0042] FIG. 32 illustrates a rear perspective view of a golf club head comprising a central insert.

[0043] FIG. 33 illustrates a rear perspective view of the golf club head of FIG. 32 comprising a central opening.

[0044] FIG. 34 illustrates a cross-sectional view of a golf club head comprising a lightweight shaft-receiving structure.

[0045] FIG. 35 illustrates a cross-sectional view of the golf club head of FIG. 34 devoid of the shaft sleeve

[0046] FIG. 36 illustrates a golf club head comprising a hosel mass zone.

[0047] FIG. 37 illustrates a golf club head comprising a mass pad.

[0048] FIG. 38A illustrates an alternative embodiment of a variable face thickness comprising multiple non-linear bending regions spaced various distances from the central region.

[0049] FIG. 38B illustrates an alternative embodiment of a variable face thickness comprising multiple non-linear bending regions spaced various distances from the central region.

[0050] FIG. 38C illustrates an alternative embodiment of a variable face thickness comprising multiple non-linear bending regions spaced various distances from the central region.

[0051] FIG. 38D illustrates an alternative embodiment of a variable face thickness comprising multiple non-linear bending regions spaced various distances from the central region.

[0052] FIG. 38E illustrates an alternative embodiment of a variable face thickness comprising multiple non-linear bending regions spaced various distances from the central region.

[0053] FIG. 38F illustrates an alternative embodiment of a variable face thickness comprising multiple non-linear bending regions spaced various distances from the central region.

[0054] FIG. 38G illustrates an alternative embodiment of a variable face thickness comprising multiple non-linear bending regions spaced various distances from the central region.

[0055] FIG. 38H illustrates an alternative embodiment of a variable face thickness comprising multiple non-linear bending regions spaced various distances from the central region.

[0056] FIG. 38I illustrates an alternative embodiment of a variable face thickness comprising multiple non-linear bending regions spaced various distances from the central region.

[0057] FIG. 38J illustrates an alternative embodiment of a variable face thickness comprising multiple non-linear bending regions spaced various distances from the central region.

[0058] FIG. 38K illustrates an alternative embodiment of a variable face thickness comprising multiple non-linear bending regions spaced various distances from the central region.

[0059] FIG. 39 illustrates stress distributions across the strike faces of three different golf club heads.

DEFINITIONS

[0060] For simplicity and clarity of illustration, the drawing figures illustrate the general manner of construction, and descriptions and details of well-known features and techniques may be omitted to avoid unnecessarily obscuring the invention. Additionally, elements in the drawing figures are not necessarily drawn to scale. For example, the dimensions of some of the elements in the figures may be exaggerated relative to other elements to help improve understanding of embodiments of the present invention. The same reference numerals in different figures denotes the same elements.

[0061] The terms “first,” “second,” “third,” “fourth,” and the like in the description and in the claims, if any, are used for distinguishing between similar elements and not necessarily for

describing a particular sequential or chronological order. It is to be understood that the terms so used are interchangeable under appropriate circumstances such that the embodiments described herein are, for example, capable of operation in sequences other than those illustrated or otherwise described herein. Furthermore, the terms “include,” and “have,” and any variations thereof, are intended to cover a non-exclusive inclusion, such that a process, method, system, article, device, or apparatus that comprises a list of elements is not necessarily limited to those elements but may include other elements not expressly listed or inherent to such process, method, system, article, device, or apparatus.

[0062] The terms "left," "right," "front," "back," "top," "bottom," "over," "under," and the like in the description and in the claims, if any, are used for descriptive purposes and not necessarily for describing permanent relative positions. It is to be understood that the terms so used are interchangeable under appropriate circumstances such that the embodiments of the apparatus, methods, and/or articles of manufacture described herein are, for example, capable of operation in other orientations than those illustrated or otherwise described herein.

[0063] The term characteristic time “CT” is used herein to mean a measurement used to determine the amount of time, measured in microseconds (μs), that a golf ball contacts the club face at the moment of impact. The characteristic time is measured by impacting a specific spot on the striking surface several times using a small steel pendulum. The characteristic time measurement is for wood-type club heads such as drivers, fairway woods, or hybrids. A computer program measures the amount of time the steel pendulum contacts the club face at the moment of impact. CT values were based on the method outlined in the USGA’s Procedure for Measuring the Flexibility of a Golf Clubhead. For example, Section 2 of the USGA’s Procedure for Measuring the Flexibility of a Golf Clubhead (USGA-TPX3004, Rev. 2.0, April 9, 2019) (the “Protocol For Measuring The Flexibility of A Golf Club Head”).

[0064] The term “low energy collision” as used herein is defined as a collision consisting of less than 1 joule, less than 5 joules, or less than 10 joules. The term “high energy collision” as used herein is defined as a collision consisting of more than 1 joule, more than 5 joules, or more than 10 joules.

[0065] The term “nonlinear bending” as used herein be a characteristic of a structure that when enduring a low energy collision reacts in a first behavior, but when enduring a high energy collision reacts in a second behavior. The second behavior results in an increase in deflection relative to the first behavior. In other words, the structure comprises significantly more deflection during a high energy collision compared to a low energy collision.

[0066] As used herein, “spline method” refers to a method to determine the location where the curvature of a surface changes. For example, the spline method can be used to determine where the surface curvature deviates from a bulge and roll curvature of the striking surface of a golf club head. The spline method can be implemented by imposing a spline onto the curved surface with an interval such that the spline indicates where a significant change in curvature begins.

[0067] The terms “couple,” “coupled,” “couples,” “coupling,” and the like, as used herein, should be broadly understood and refer to connecting two or more elements or signals, electrically, mechanically and/or otherwise.

[0068] The term “strike face,” as used herein, refers to a club head front surface that is configured to strike a golf ball. The term strike face can be used interchangeably with the “face.”

[0069] The term “strike face perimeter,” as used herein, can refer to an edge of the strike face. The strike face perimeter can be located along an outer edge of the strike face where the curvature deviates from a bulge and/or roll of the strike face.

[0070] The term “geometric centerpoint,” or “geometric center” of the strike face, as used herein, can refer to a geometric centerpoint of the strike face perimeter, and at a midpoint of the face height of the strike face. In the same or other examples, the geometric centerpoint also can be centered with respect to an engineered impact zone, which can be defined by a region of grooves on the strike face. As another approach, the geometric centerpoint of the strike face can be located in accordance with the definition of a golf governing body such as the United States Golf Association (USGA).

[0071] The term “ground plane,” as used herein, can refer to a reference plane associated with the surface on which a golf ball is placed. The ground plane can be a horizontal plane tangent to the sole at an address position.

[0072] The term “mid-plane,” as used herein, can refer to a reference plane extending through the geometric center point in a direction from the strike face to rear of the golf club head; wherein the mid-plane is perpendicular to the ground plane;

[0073] The term “loft plane,” as used herein, can refer to a reference plane that is tangent to the geometric center point of the strike face. A loft plane 15 is illustrated in FIG. 29.

[0074] The term “loft angle,” as used herein, can refer to an angle measured between the loft plane and the XY plane (defined below).

[0075] “Driver golf club heads” as used herein comprise a loft angle less than approximately 16 degrees, less than approximately 15 degrees, less than approximately 14 degrees, less than approximately 13 degrees, less than approximately 12 degrees, less than approximately 11 degrees, or less than approximately 10 degrees. Further, in many embodiments, “driver golf club heads” as used herein comprises a volume greater than approximately 400 cc, greater than approximately 425 cc, greater than approximately 445 cc, greater than approximately 450 cc, greater than approximately 455 cc, greater than approximately 460 cc, greater than approximately 475 cc, greater than approximately 500 cc, greater than approximately 525 cc, greater than approximately 550 cc, greater than approximately 575 cc, greater than approximately 600 cc, greater than approximately 625 cc, greater than approximately 650 cc, greater than approximately 675 cc, or greater than approximately 700 cc. In some embodiments, the volume of the driver can be approximately 400cc - 600cc, 425cc – 500cc, approximately 500cc - 600cc, approximately 500cc - 650cc, approximately 550cc - 700cc, approximately 600cc - 650cc, approximately 600cc - 700cc, or approximately 600cc - 800cc.

[0076] “Fairway wood golf club heads” as used herein comprise a loft angle less than approximately 35 degrees, less than approximately 34 degrees, less than approximately 33 degrees, less than approximately 32 degrees, less than approximately 31 degrees, or less than approximately 30 degrees. Further, in some embodiments, the loft angle of the fairway wood club heads can be greater than approximately 12 degrees, greater than approximately 13 degrees, greater than approximately 14 degrees, greater than approximately 15 degrees, greater than approximately 16 degrees, greater than approximately 17 degrees, greater than approximately 18 degrees, greater than approximately 19 degrees, or greater than approximately 20 degrees. For

example, in other embodiments, the loft angle of the fairway wood can be between 12 degrees and 35 degrees, between 15 degrees and 35 degrees, between 20 degrees and 35 degrees, or between 12 degrees and 30 degrees.

[0077] Further, “fairway wood golf club heads” as used herein comprises a volume less than approximately 400 cc, less than approximately 375 cc, less than approximately 350 cc, less than approximately 325 cc, less than approximately 300 cc, less than approximately 275 cc, less than approximately 250 cc, less than approximately 225 cc, or less than approximately 200 cc. In some embodiments, the volume of the fairway wood can be approximately 150cc - 200cc, approximately 150cc - 250cc, approximately 150cc - 300cc, approximately 150cc - 350cc, approximately 150cc - 400cc, approximately 300cc - 400cc, approximately 325cc - 400cc, approximately 350cc - 400cc, approximately 250cc - 400cc, approximately 250 - 350 cc, or approximately 275-375 cc.

[0078] “Hybrid golf club heads” as used herein comprise a loft angle less than approximately 40 degrees, less than approximately 39 degrees, less than approximately 38 degrees, less than approximately 37 degrees, less than approximately 36 degrees, less than approximately 35 degrees, less than approximately 34 degrees, less than approximately 33 degrees, less than approximately 32 degrees, less than approximately 31 degrees, or less than approximately 30 degrees. Further, in many embodiments, the loft angle of the hybrid can be greater than approximately 16 degrees, greater than approximately 17 degrees, greater than approximately 18 degrees, greater than approximately 19 degrees, greater than approximately 20 degrees, greater than approximately 21 degrees, greater than approximately 22 degrees, greater than approximately 23 degrees, greater than approximately 24 degrees, or greater than approximately 25 degrees.

[0079] Further, “hybrid golf club heads” as used herein comprise a volume less than approximately 200 cc, less than approximately 175 cc, less than approximately 150 cc, less than approximately 125 cc, less than approximately 100 cc, or less than approximately 75 cc. In some embodiments, the volume of the hybrid can be approximately 100cc - 150cc, approximately 75cc - 150cc, approximately 100cc - 125cc, or approximately 75cc - 125cc.

[0080] The term “face height,” as used herein, can refer to a distance measured parallel to loft plane between a top end of the strike face perimeter and a bottom end of the strike face perimeter.

[0081] The term “lie angle,” as used herein, can refer to an angle between a hosel axis 30, extending through the hosel, and the ground plane. The lie angle 25 is measured from a front view.

[0082] The “depth” of the golf club head, as used herein, can be defined as a front-to-rear dimension of the golf club head.

[0083] The “height” of the golf club head, as used herein, can be defined as a top rail-to sole dimension of the golf club head. In some embodiments, the height of the club head can be measured according to a golf governing body such as the United States Golf Association (USGA).

[0084] The “length” of the golf club head, as used herein, can be defined as a heel-to-toe dimension of the golf club head. In some embodiments, the length of the club head can be measured according to a golf governing body such as the United States Golf Association (USGA).

[0085] The term “low energy collision” as used herein is defined as a collision consisting of less than 1 joule, less than 5 joules, or less than 10 joules. The term “high energy collision” as used herein is defined as a collision consisting of more than 1 joule, more than 5 joules, or more than 10 joules.

[0086] An “XYZ” coordinate system of the golf club head, as described herein, is based upon the geometric center of the strike face. The golf club head dimensions as described herein can be measured based on a coordinate system as defined below. The geometric center of the strike face defines a coordinate system having an origin located at the geometric center of the strike face. The coordinate system defines an X axis, a Y axis, and a Z axis. The X axis extends through the geometric center of the strike face in a direction from the heel to the toe of the fairway-type club head. The Y axis extends through the geometric center of the strike face in a direction from the crown to the sole of golf club head. The Y axis is perpendicular to the X axis. The Z axis extends

through the geometric center of the strike face in a direction from the front end to the rear end of the golf club head. The Z axis is perpendicular to both the X axis and the Y axis.

[0087] The term or phrase “center of gravity position” or “CG location” can refer to the location of the club head center of gravity (CG) with respect to the XYZ coordinate system, wherein the CG position is characterized by locations along the X-axis, the Y-axis, and the Z-axis. The term “CGx” can refer to the CG location along the X-axis, measured from the origin point. The term “CG height” can refer to the CG location along the Y-axis, measured from the origin point. The term “CGy” can be synonymous with the CG height. The term “CG depth” can refer to the CG location along the Z-axis, measured from the origin point. The term “CGz” can be synonymous with the CG depth.

[0088] The term or phrase “CG projection” or “CG projection point” can refer to the location where the CG is projected on the strike face, wherein the projection is taken normal to the loft plane.

[0089] The XYZ coordinate system of the golf club head, as described herein defines an XY plane extending through the X axis 40 and the Y axis 50. The coordinate system defines XZ plane extending through the X axis and the Z axis. The coordinate system further defines a YZ plane extending through the Y axis and the Z axis. The XY plane, the XZ plane, and the YZ plane are all perpendicular to one another and intersect at the coordinate system origin located at the geometric center of the strike face. In these or other embodiments, the golf club head can be viewed from a front view when the strike face is viewed from a direction perpendicular to the XY plane. Further, in these or other embodiments, the golf club head can be viewed from a side view or side cross-sectional view when the heel is viewed from a direction perpendicular to the YZ plane.

[0090] The golf club head further comprises a coordinate system centered about the center of gravity. The coordinate system comprises an X'-axis, a Y'-axis, and a Z'-axis. The X'-axis extends in a heel-to-toe direction. The X'-axis is positive towards the heel and negative towards the toe. The Y'-axis extends in a sole-to-crown direction and is orthogonal to both the Z'-axis and the X'-axis. The Y'-axis is positive towards the crown and negative towards the sole. The Z-

axis extends front-to-rear, parallel to the ground plane and is orthogonal to both the X'-axis and the Y'-axis. The Z'-axis is positive towards the strike face and negative towards the rear.

[0091] The term or phrase “moment of inertia” (hereafter “MOI”) can refer to a value derived using the center of gravity (CG) location. The MOI can be calculated assuming the club head includes the body and the hosel structure. The term “ MOI_{xx} ” or “ I_{xx} ” can refer to the MOI measured about the X'-axis. The term “ MOI_{yy} ” or “ I_{yy} ” can refer to the MOI measured about the Y'-axis. The term “ MOI_{zz} ” or “ I_{zz} ” can refer to the MOI measured about the Z'-axis. The MOI values MOI_{xx} , MOI_{yy} , and MOI_{zz} determine how forgiving the club head is for off-center impacts with a golf ball.

DESCRIPTION

[0092] The wood-type golf club heads disclosed herein can comprise a strike face with a variable thickness (or “VFT”) that evokes the shape of a speaker woofer to produce non-linear bending, thereby producing greater strike face deflection and resulting ball speed for a given CT value. Specifically, the wood-type golf club head comprises a strike face with a topography including a center region, having a maximum thickness, surrounded by additional regions of different constant or varying thicknesses. Two of the regions are configured to produce a hinge-like response that increases strike face deflection and resulting ball speed while maintaining a CT at or below the USGA limit when compared to wood-type golf club heads without the VFT disclosed herein.

[0093] The embodiments disclosed herein can comprise a non-linear bending region spaced from, but fully surrounding, the central region perimeter. The non-linear bending region is disposed between a central region perimeter and a border perimeter. In some embodiments, the strike face can comprise multiple non-linear bending regions disposed between the central region and the border perimeter. Each of the non-linear bending regions comprise a first peak, a valley, and a second peak. The first peak, corresponding to a first localized maximum thickness, fully surrounds and is spaced a first distance from the central region perimeter. The valley, corresponding to a localized minimum thickness, fully surrounds and is spaced a second distance from the central region perimeter. The valley further fully surrounds and is spaced from the first peak. The second peak, corresponding to a second localized maximum thickness, fully surrounds

and is spaced a second distance from the central region perimeter. The second peak further fully surrounds and is spaced from the valley. Thus, the valley is disposed between the first peak and the second peak to create a hinge. The first peak comprises a first thickness, the valley comprises a second thickness, and the second peak comprises a third thickness. The second thickness is less than both the first thickness and the third thickness to create a hinge that non-linearly bends.

I. General Description

[0094] FIGS. 1-6B illustrate a golf club head 100 (or club head) having a body and a strike face 106 that define a substantially closed/hollow interior volume. The body comprises a crown 102, a sole 104 opposite the crown 102, a heel 116, a toe 112 opposite the heel 116, a front, and a rear opposite the front. The body can further include a skirt or trailing edge located between and adjoining the crown 102 and the sole 104, the skirt extending from near the heel 116 to near the toe 112.

[0095] The strike face 106 can comprise a variable face thickness (or variable thickness profile) that includes thin regions surrounding a thicker center region. The combination of the center region and the surrounding thin region produces greater strike face deflection and greater ball speeds, for a given CT of the strike face 106. The strike face 106 can further comprise an interior strike face perimeter 169 defined where the bulge and roll of the strike face 106 terminate on the interior surface of the strike face 106.

[0096] The strike face 106 can comprise a striking surface and a rear surface opposite the striking surface. The strike face 106 is configured to impact a golf ball along the striking surface. The striking surface further defines a face center or geometric center. In some embodiments, the face center can be located at a geometric center point of a face perimeter. In another approach, the face center of the striking surface can be located in accordance with the definition of a golf governing body such as the USGA.

[0097] Referring to FIG. 1, the club face perimeter can be located along an outer edge of the striking surface, where the curvature of the striking surface deviates from the bulge and roll curvature. The striking surface and rear surface comprise a striking surface area (or strike face surface area) and a rear surface area, respectively. The striking surface area and rear surface area

are measured within the boundary of the club face perimeter. In one approach, the spline method, as described above, can be used to determine the location of the outer edge where the curvature deviates from the bulge and roll of the striking surface.

[0098] Further, a club face height can be measured parallel to a loft plane extending between a top end of the face perimeter and a bottom end of the face perimeter. The top end of the face perimeter is located near the crown 102 and the bottom end of the face perimeter is located near the sole 104.

[0099] The club head defines the loft plane tangent to the face center of the striking surface. The club head defines a ground plane 10 tangent to the sole 104 when the club head is at an address position. The face center of the striking surface defines an origin for a coordinate system having an x-axis, a y-axis, and a z-axis. The x-axis is a horizontal axis that extends through the face center in a direction extending from near the heel 116 to near the toe 112 parallel to the ground plane 10. The y-axis is a vertical axis that extends through the face center in a direction extending from near the sole 104 to near the crown 102 perpendicular to the ground plane 10. The y-axis is perpendicular to the x-axis. The z-axis is a horizontal axis that extends through the face center in a direction extending from near the front to near the rear parallel to the ground plane 10. The z-axis is perpendicular to the x-axis and the y-axis. The x-axis extends in a positive direction toward the heel 116. The y-axis extends in a positive direction toward the crown 102. The z-axis extends in a positive direction toward the rear.

[0100] The club head further comprises a center of gravity (CG). In some embodiments, the center of gravity is located within the coordinate system defined above. The center of gravity can have a location on the x-axis (CGx), the y-axis (CGy), and the z-axis (CGz). The center of gravity further defines an origin of coordinate system having a CG x-axis, a CG y-axis, and a CG z-axis. The CG x-axis extends through the CG from near the heel 116 to near the toe 112. The CG y-axis extends through a CG 1000 from near the crown 102 to near the sole 104, the CG y-axis is perpendicular to the CG x-axis. The CG z-axis extends through the CG from near the front to near the rear, perpendicular to both the CG x-axis and the CG y-axis.

[0101] The golf clubs described herein can comprise a CGx between -0.2 inch and 0.3 inch. In some embodiments, the CGx can be between -0.20 and -0.15 inches, between -0.15 and -0.10

inches, between -0.10 and -0.05 inches, between -0.05 and 0.00 inches, between 0.00 and 0.05 inches, between 0.05 and 0.10 inches, between 0.10 and 0.15 inches, between 0.15 and 0.20 inches, between 0.20 and 0.25 inches, or between 0.25 and 0.30 inches.

[0102] The golf clubs described herein can comprise a CGy between -0.35 inch and 0.35 inch. In some embodiments, the CGy can be between -0.35 and -0.30 inches, between -0.30 and -0.25 inches, between -0.25 and -0.20 inches, between -0.20 and -0.15 inches, between -0.15 and -0.10 inches, between -0.10 and -0.05 inches, between -0.05 and 0.00 inches, between 0.00 and 0.05 inches, between 0.05 and 0.10 inches, between 0.10 and 0.15 inches, between 0.15 and 0.20 inches, between 0.20 and 0.25 inches, between 0.25 and 0.30 inches, or between 0.30 and 0.35 inches.

[0103] The golf clubs described herein can comprise a CGz between -2 inches to -0.05 inch. In some embodiments, the CGz can be between -2.00 and -1.75 inches, between -1.75 and -1.50 inches, between -1.50 and -1.25 inches, between -1.25 and -1.00 inches, between -1.00 and -0.75 inches, between -0.75 and -0.50 inches, between -0.50 and -0.25 inches, or between -0.25 and -0.05 inches.

[0104] The golf clubs described herein can comprise a MOI_{xx} between 100 kg·mm² and 600 kg·mm². In some embodiments, the MOI_{xx} can be between 100 kg·mm² and 150 kg·mm², between 150 kg·mm² and 200 kg·mm², between 200 kg·mm² and 250 kg·mm², between 250 kg·mm² and 300 kg·mm², between 300 kg·mm² and 350 kg·mm², between 350 kg·mm² and 400 kg·mm², between 400 kg·mm² and 450 kg·mm², between 450 kg·mm² and 500 kg·mm², between 500 kg·mm² and 550 kg·mm², or between 550 kg·mm² and 600 kg·mm².

[0105] The golf clubs described herein can comprise a MOI_{yy} between 100 kg·mm² and 600 kg·mm². In some embodiments, the MOI_{yy} can be between 100 kg·mm² and 150 kg·mm², between 150 kg·mm² and 200 kg·mm², between 200 kg·mm² and 250 kg·mm², between 250 kg·mm² and 300 kg·mm², between 300 kg·mm² and 350 kg·mm², between 350 kg·mm² and 400 kg·mm², between 400 kg·mm² and 450 kg·mm², between 450 kg·mm² and 500 kg·mm², between 500 kg·mm² and 550 kg·mm², or between 550 kg·mm² and 600 kg·mm².

[0106] The golf clubs described herein can comprise a MOI_{zz} between 100 kg·mm² and 450 kg·mm². In some embodiments, the MOI_{zz} can be between 100 kg·mm² and 150 kg·mm², between 150 kg·mm² and 200 kg·mm², between 200 kg·mm² and 250 kg·mm², between 250 kg·mm² and 300 kg·mm², between 300 kg·mm² and 350 kg·mm², between 350 kg·mm² and 400 kg·mm², or between 400 kg·mm² and 450 kg·mm².

II. Variable Face Thickness

[0107] The present embodiments are directed to wood-type golf club heads comprising strike faces with variable thickness profiles having a central region surrounded by a non-linear bending region to adjust stiffness, displacement upon impact with a golf ball, and increase strike face deflection and resulting ball speed for a given CT. The club faces described in this disclosure maintain CT within the United States Golf Association (USGA) regulations while improving ball speed and strike face deflection. Alternative embodiments of a variable face thickness are shown in FIGS. 7-14B

[0108] To maintain CT the strike face 106 or club face comprises a variable thickness profile having strategically positioned regions that are relatively uniformly thick, relatively uniformly thin, and transitioned from thick to thin or vice versa. The thickness of the club face can be measured from the striking surface to the rear surface in a direction perpendicular to the loft plane. An average strike face thickness defines the mean thickness value across the entirety of the strike face 106. FIGS. 1-2 illustrate a first embodiment of the variable thickness profile of the strike face 106. Specifically, the variable thickness profile can include an outer periphery 184, a border perimeter 182, a thin periphery 180, an outer transition 178, an inner transition 176, a hinge 174, a central transition 172, and a central region 170. A hinge region 150 comprises the central transition 172, the hinge 174, and the inner transition promotes non-linear bending of the strike face 106. The variable thickness profile of the club face increases the deflection of the strike face 106 upon impact with a golf ball, thereby increasing ball speed. The variable thickness profile also allows the golf club head to remain within the CT regulations of the USGA.

A. Outer Periphery

[0109] The outer periphery 184 can have a thickness sufficient to maintain structural integrity of the strike face 106 upon impact with a golf ball while allowing regions of the strike face 106 closer to the geometric face center 1010 to be significantly thinner. The outer periphery 184 of the strike face 106 defines the region nearest the club face perimeter, furthest from the geometric center. The outer periphery 184 extends inwards from the club face perimeter, towards the geometric center. The outer perimeter can further comprise a first peripheral width 194 measured radially between an inner edge of the outer periphery 184 to the club face perimeter. The first peripheral width 194 can vary along the club face perimeter. In some embodiments, the first peripheral width 194 can be greater at portions nearest the crown 102 and the toe 112. In other embodiments, the first peripheral width 194 can be substantially constant along the club face perimeter.

[0110] Further, the outer periphery 184, according to some embodiments, comprises an outer periphery thickness $t5$. The outer periphery thickness $t5$ can be measured from the striking surface to the rear surface in a direction perpendicular to the loft plane at areas within the outer periphery 184. In some embodiments, the outer periphery thickness $t5$ is constant. In other embodiments, the outer periphery thickness $t5$ is constant in the toe 112 and the heel 116 regions of the strike face 106. In other embodiments, the outer periphery thickness $t5$ is greater at the toe 112 than at the heel 116. In other embodiments, the outer periphery thickness $t5$ is greater at the heel 116 than at the toe 112.

[0111] The outer periphery thickness $t5$ can be greater than or equal to 0.05 inch, greater than or equal to 0.06 inch, greater than or equal to 0.065 inch, greater than or equal to 0.07 inch, greater than or equal to 0.08 inch, or greater than or equal to 0.09 inch. In other embodiments, the outer periphery thickness $t5$ can range from 0.05 to 0.125 inch. In some embodiments, the outer periphery thickness $t5$ can range from 0.05 to 0.075 inch, or 0.075 to 0.10 inch. In further embodiments, the outer periphery thickness $t5$ can range from 0.09 inch to 0.11 inch. In some embodiments, the outer periphery thickness $t5$ can range from 0.05 to 0.06 inch, 0.06 to 0.07 inch, 0.07 to 0.08 inch, 0.08 to 0.09 inch, or 0.09 to 0.10 inch. For example, the outer periphery thickness $t5$ can be approximately 0.05, 0.055, 0.06, 0.063, 0.065, 0.07, 0.075, 0.08, 0.085, 0.09, 0.095, 0.100, 0.105, 0.110, 0.115, 0.120, or 0.125 inch. In another example, the outer periphery

thickness t_5 can be 0.0999 inch. The outer periphery 184 abuts the border perimeter 182. In some embodiments, the outer periphery thickness t_5 is sufficient to maintain structural integrity upon impact with a golf ball while allowing regions closer to the geometric face center 1010, discussed in more detail below, to be significantly thinner.

B. Border Perimeter

[0112] The border perimeter 182 comprises a region along the innermost margin 184A of the outer periphery 184. In some embodiments, the border perimeter 182 can define the region where the face plate is welded to the golf club body. In other embodiments, the border perimeter 182 can define a transition between the outer periphery 184 and either the thin periphery 180, the outer transition 178 or both the thin periphery 180 and the outer transition 178. In such embodiments, the border perimeter 182 can include one or more rounded or curved surfaces adjacent the innermost margin of the outer periphery 184. Further, the border perimeter 182 can define a border perimeter thickness t_9 . The border perimeter thickness t_9 can be measured from the striking surface to the rear surface in a direction perpendicular to the loft plane at areas within the border perimeter 182. In some embodiments, the border perimeter thickness t_9 can be constant. In other embodiments, the border perimeter thickness t_9 can vary.

[0113] The border perimeter thickness t_9 can be greater than or equal to 0.05 inch, greater than or equal to 0.06 inch, greater than or equal to 0.065 inch, greater than or equal to 0.07 inch, greater than or equal to 0.08 inch, or greater than or equal to 0.09 inch. In another embodiment, the border perimeter thickness t_9 can range from 0.05 to 0.125 inch. In some embodiments, the border perimeter thickness t_9 can range from 0.05 to 0.075 inch, or 0.075 to 0.10 inch. In some embodiments, the border perimeter thickness t_9 can range from 0.05 to 0.06 inch, 0.06 to 0.07 inch, 0.07 to 0.08 inch, 0.08 to 0.09 inch, 0.09 to 0.10 inch, 0.10 to 0.11 inch, or 0.11 to 0.125 inch. For example, the border perimeter thickness t_9 can be approximately 0.05, 0.055, 0.06, 0.063, 0.065, 0.07, 0.075, 0.08, 0.085, 0.09, 0.095, 0.100, 0.105, 0.110, 0.115, 0.120, or 0.125 inch. In some embodiments, the border perimeter thickness t_9 can range from 0.078 inch to 0.10 inch.

[0114] The border perimeter 182 can abut the thin periphery 180 and/or the outer transition 178. In some embodiments, the border perimeter 182 can abut the outer transition 178 at a portion

nearest the crown 102. In some embodiments, the outer transition 178 can abut greater than 10%, 15%, 20%, 25%, 30%, 35%, or 40% of the border perimeter 182. In other embodiments, the outer transition 178 can abut 20% of the border perimeter 182.

C. Thin Periphery

[0115] The thin periphery 180 of the strike face 106 defines the region that is generally surrounded by the outer periphery 184 that can extend between the border perimeter 182 and the outer transition 178. The thin periphery 180 extends inwards from the outer periphery 184, towards the geometric face center 1010. The thin periphery 180 can further comprise a second peripheral width 195 between the border perimeter 182 and the inner edge of the thin periphery 180. The second peripheral width 195 can vary along the border perimeter 182. The thin periphery can further comprise an outer edge 179A that abuts the border perimeter 182. In some embodiments, the second peripheral width 195 can be greater at portions nearest the crown 102 and the toe 112. In other embodiments, the thin periphery 180 is omitted at portions of the crown 102, in which case the second peripheral width 195 is zero. In even further embodiments, the second peripheral width 195 can be substantially constant along the border perimeter 182.

[0116] The thin periphery 180 comprises a thin periphery thickness t_4 . The thin periphery thickness t_4 can be measured from the striking surface to the rear surface in a direction perpendicular to the loft plane at areas within the thin periphery 180. In some embodiments, the thin periphery thickness t_4 can be constant. Relative to adjacent transitions and regions, further described below, the thin periphery can comprise the thinnest region of the strike face according to many embodiments. The thin periphery thickness t_4 can be greater than or equal to 0.05 inch, greater than or equal to 0.06 inch, greater than or equal to 0.065 inch, greater than or equal to 0.07 inch, greater than or equal to 0.08 inch, or greater than or equal to 0.09 inch. In other embodiments, the thin periphery thickness t_4 can range from 0.05 to 0.10 inch. In some embodiments, the thin periphery thickness t_4 can range from 0.05 to 0.075 inch, or 0.075 to 0.10 inch. In some embodiments, the thin periphery thickness t_4 can range from 0.05 to 0.06 inch, 0.06 to 0.07 inch, 0.07 to 0.08 inch, 0.08 to 0.09 inch, or 0.09 to 0.10 inch. For example, the thin periphery thickness t_4 can be approximately 0.05, 0.055, 0.06, 0.063, 0.065, 0.07, 0.075, 0.08,

0.085, 0.09, 0.095, or 0.10 inch. In another example, the thin periphery thickness t_4 can be 0.078 inch.

D. Outer Transition

[0117] The outer transition 178 of the strike face 106 is a region of varying thickness that extends from the thin periphery 180 to the inner transition 176. In some embodiments, as illustrated in FIG. 3, the outer transition 178 directly abuts regions of the border perimeter 182, such as portions nearest the crown 102. The outer transition 178 further comprises a first radial width 196 measured radially between an innermost portion of the outer transition 178, further defined by a hinge outer peak 175, to an outer transition outer edge 179. In some embodiments, the first radial width 196 is greater along the horizontal axis than the vertical axis of the strike face 106, giving the outer transition 178 an elliptical shape, as illustrated in FIGS. 1-2. In other embodiments, the first radial width 196 can be substantially constant. The first radial width 196 can be or range between 0.050 inch and 1.0 inch. In even further embodiments, the first radial width 196 can be or range between 0.150 inch and 0.250 inch. In some embodiments, the first radial width 196 can be constant at or range between 0.050 to 0.10 inch, 0.10 to 0.20 inch, 0.20 inch to 0.30 inch, 0.30 inch to 0.40 inch, 0.40 inch to 0.50 inch, 0.50 inch to 0.60 inch, 0.60 inch to 0.70 inch, 0.70 inch to 0.75 inch, 0.75 inch to 0.80 inch, 0.80 inch to 0.85 inch, 0.85 inch to 0.90 inch, 0.90 inch to 0.95 inch, or 0.95 inch to 1.0 inch. In another example, the first radial width 196 can be constant at about 0.20 inch. In a further embodiment, the first radial width 196 can be substantially 0.300 inch. In another embodiment, the first radial width 196 can be substantially 0.150 inch.

[0118] Referring to FIGS. 1-6B, the outer transition 178 can comprise an outer transition thickness t_8 . The outer transition thickness t_8 can be measured from the striking surface to the rear surface in a direction perpendicular to the loft plane at areas within the outer transition 178. In some embodiments, the outer transition thickness t_8 can vary. In some embodiments the outer transition thickness t_8 continuously increases as it extends towards the geometric face center 1010. In some embodiments, illustrated in FIGS. 1-6B, the outer transition thickness t_8 is greatest at portions nearest the geometric face center 1010. In some embodiments, the outer transition thickness t_8 is between 0.05 inch to 0.15 inch. In some embodiments, the outer

transition thickness t_8 is 0.05 to 0.075 inch, 0.075 to 0.10 inch, or 0.10 inch to 0.12 inch. In some embodiments, the outer transition thickness t_8 is 0.05 to 0.06 inch, 0.06 to 0.07 inch, 0.07 to 0.08 inch, 0.08 to 0.09 inch, 0.09 to 0.10 inch, 0.10 inch to 0.11 inch, 0.11 inch to 0.12 inch, 0.12 inch to 0.13 inch, 0.13 inch to 0.14 inch, or 0.14 inch to 0.15 inch. In another example, the outer transition thickness t_8 is between 0.078 inch to 0.10224 inch.

E. Inner Transition

[0119] The inner transition 176 of the strike face 106 is a region of varying thickness that extends from the outer transition 178 to the central transition 172, abutting the hinge 174. The inner transition 176 further comprises a second radial width 197 measured radially between an innermost margin of the inner transition 176 to the an outermost margin of the inner transition 176. In some embodiments, the second radial width 197 is greater along the horizontal axis than the vertical axis of the strike face 106. In other embodiments, the second radial width 197 can be substantially constant. The second radial width 197 can be or range between 0.050 inch and 1.0 inch. In even further embodiments, the second radial width 197 can be or range between 0.150 inch and 0.250 inch. In some embodiments, the second radial width 197 can be constant at or range between 0.050 to 0.10 inch, 0.10 to 0.20 inch, 0.20 inch to 0.30 inch, 0.30 inch to 0.40 inch, 0.40 inch to 0.50 inch, 0.50 inch to 0.60 inch, 0.60 inch to 0.70 inch, 0.70 inch to 0.75 inch, 0.75 inch to 0.80 inch, 0.80 inch to 0.85 inch, 0.85 inch to 0.90 inch, 0.90 inch to 0.95 inch, or 0.95 inch to 1.0 inch. In another example, the second radial width 197 can be constant at about 0.20 inch. In a further embodiment, the second radial width 197 can be substantially 0.300 inch. In another embodiment, the second radial width 197 can be substantially 0.150 inch.

[0120] Referring to FIGS. 1-6B, the inner transition 176 can comprise an inner transition thickness t_7 . The inner transition thickness t_7 can be measured from the striking surface to the rear surface in a direction perpendicular to the loft plane at areas within the inner transition 176. In some embodiments, the inner transition thickness t_7 varies. In some embodiments the inner transition thickness t_7 continuously decreases as it extends towards the geometric face center 1010. As illustrated in FIGS. 1-2, the inner transition thickness t_7 is greater at portions nearest the outer transition 178. In some embodiments, the inner transition thickness t_7 is between 0.05 inch to 0.12 inch. In some embodiments, the inner transition thickness t_7 is between 0.05 to

0.075 inch, 0.075 to 0.10 inch, or 0.10 inch to 0.12 inch. In some embodiments, the inner transition thickness t_7 is between 0.05 to 0.06 inch, 0.06 to 0.07 inch, 0.07 to 0.08 inch, 0.08 to 0.09 inch, 0.09 to 0.10 inch, 0.10 inch to 0.11 inch, or 0.11 inch to 0.12 inch. In another example, the inner transition thickness t_7 is between 0.100093 inch to 0.10224 inch.

[0121] The outer transition 178 and the inner transition 176 meet at the hinge outer peak 175 having a transition thickness t_3 . The transition thickness t_3 comprises the maximum thicknesses of both the outer transition 178 and the inner transition 176.

F. Hinge

[0122] The hinge 174 is located where the inner transition 176 meets the central transition 172 meets the central transition 172, and corresponds to a local minimum thickness of the inner transition 176 and central transition 172 regions. The hinge 174 corresponds to a valley in between two peaks. The hinge 174 extends continuously around and completely surrounds the central region 170. The hinge 174 may have a shape, when viewed from the rear as shown in FIG. 1, that is circular, oval, gibbous, arcuate, rectilinear, symmetrical, asymmetrical, or combinations thereof. In many embodiments, the hinge 174 comprises a rounded transition surface between the inner transition 176 and the central transition 172. In further embodiments, the hinge 174 can comprise a hinge width 198 with reference to FIG 2B. The hinge width 198 can be measured radially between an outermost margin of the hinge 174 and an innermost margin of the hinge 174. In some embodiments, the hinge width 198 can be substantially constant. In other embodiments, the hinge width 198 can vary around the hinge 174. The hinge width 198 can be constant or vary between 0.001 inch and X inch. Furthermore, the hinge 174 can comprise a maximum length and a maximum height, defined below in relation to the central region 170.

[0123] Further, the hinge 174 can comprise a hinge thickness t_2 measured from the striking surface to the rear surface in a direction perpendicular to the loft plane at areas within the hinge 174. In some embodiments, illustrated in FIGS. 1-2, the hinge thickness can be constant. In some embodiments, less than or equal to 0.01 inch, less than or equal to 0.12 inch, less than or equal to 0.11 inch, less than or equal to 0.10 inch, less than or equal to 0.09 inch, or less than or equal to 0.08 inch. In other embodiments, the hinge thickness t_2 can range from 0.05 to 0.12 inch. In

other embodiments, the hinge thickness t_2 can range from 0.01 to 0.05 inch, or 0.075 to 0.10 inch. For example, the hinge thickness t_2 can be 0.0125 inch to 0.025 inch, 0.025 inch to 0.0375 inch, 0.0375 inch to 0.050 inch, 0.050 inch to 0.0625 inch, 0.0625 inch to 0.075 inch, 0.075 inch to 0.0875 inch, 0.0875 inch to 0.100 inch, or 0.100 inch to 0.120 inch. In one example, the hinge thickness t_2 can be 0.094 inch. In another example, the hinge thickness t_2 can be 0.091 inch. The relationship between the thicknesses, t_1 , t_2 , and t_3 create ring proximate the central region 170 such that the hinge is formed and creates a variable face thickness that non-linearly bends.

[0124] In some embodiments, the hinge defines a local minimum strike face thickness. In other embodiments, the hinge defines a global minimum strike face thickness, as illustrated in FIGS. 1-2. The minimum strike face thickness acts as a pinch point region around the central transition 172. The pinch point region acts as a hinge, creating greater stresses along the hinge 174 and increasing internal energy of the strike face 106. Increasing the strike face 106 internal energy produces greater strike face 106 deflection and increases ball speed. Further, as the strike face 106 deflection increases, more stress is placed on the club head body (i.e., the crown 102 and the sole 104). Greater stresses at these regions increases the internal energy of the club head body, which can also improve ball speed and launch characteristics.

G. Central Transition

[0125] The central transition 172 of the strike face 106 is a region of varying thickness that extends from the hinge 174 to the central region 170. Referring to FIGS. 1-2, the central transition 172 can comprise a central transition thickness t_6 . The inner transition thickness t_7 can be measured from the striking surface to the rear surface in a direction perpendicular to the loft plane at areas within the central transition 172. In some embodiments, the central transition thickness t_6 varies. In some embodiments, illustrated in FIGS. 1-2, the central transition thickness t_6 is greatest at portions nearest the central region 170. In some embodiments, the central transition thickness t_6 is between 0.09 inch to 0.16 inch. In some embodiments, the central transition thickness t_6 is between 0.09 to 0.1 inch, 0.1 to 0.11 inch, 0.11 inch to 0.12 inch, 0.12 inch to 0.13 inch, 0.13 inch to 0.14 inch, 0.14 inch to 0.15 inch, or 0.15 inch to 0.16 inch. In some embodiments, the central transition thickness t_6 is between 0.05 to 0.06 inch, 0.06 to 0.07 inch, 0.07 to 0.08 inch, 0.08 to 0.09 inch, 0.09 inch to 0.10 inch, 0.10 inch to 0.11 inch, or 0.11

inch to 0.12 inch. In another example, the central transition thickness t_6 is between 0.100093 inch to 0.148 inch.

[0126] The central transition 172 comprises a central transition width 191 measured radially from an outermost margin of the central region to an innermost margin of the central transition. In some embodiments, the central transition width 191 can be substantially constant. In other embodiments, the central transition width 191 varies. In further embodiments, the central transition width 191 is between 0.050 inch and 1.0 inch. In even further embodiments, the central transition width 191 is between 0.250 inch and 0.350 inch. In some embodiments, the central transition width 191 is between 0.050 to 0.10 inch, 0.10 to 0.20 inch, 0.20 inch to 0.30 inch, 0.30 inch to 0.40 inch, 0.40 inch to 0.50 inch, 0.50 inch to 0.60 inch, 0.60 inch to 0.70 inch, 0.70 inch to 0.75 inch, 0.75 inch to 0.80 inch, 0.80 inch to 0.85 inch, 0.85 inch to 0.90 inch, 0.90 inch to 0.95 inch, or 0.95 inch to 1.0 inch. In another example, the central transition width 191 is about 0.20 inch. In a further embodiment, the central transition width 191 is substantially 0.300 inch. In another embodiment, the central transition width 191 is substantially 0.150 inch.

H. Central Region

[0127] The central region 170 of the strike face 106 defines the innermost region furthest from the interior strike face perimeter 169. The central region 170 further defines a central region perimeter 171 that defines a border between the central region 170 and the central transition 172. The central region 170 comprises a central region thickness t_1 that can be constant. In other embodiments, the central region thickness t_1 can vary. In some embodiments, the central region 170 comprises a maximum thickness of the club face.

[0128] In some embodiments, the central region thickness t_1 defines a maximum strike face thickness, as illustrated in FIGS. 1-2. The maximum strike face thickness of the central region 170 increases the average strike face thickness, which allows surrounding regions to be thinner without negatively impacting strike face durability. The central region thickness t_1 and the hinge thickness cooperate to decrease strike face weight, relative to prior art, increasing discretionary mass and improving forgiveness and feel. Further, the central region 170 allows the CT to adhere

to the regulations of the USGA, while also improving the strike face 106 deflection and ball speed.

[0129] The central region thickness t_1 can be less than or equal to 0.17 inch, less than or equal to 0.10 inch, less than or equal to 0.09 inch, or less than or equal to 0.08 inch. In other embodiments, the central region thickness t_1 is between 0.10 to 0.16 inch. In even further embodiments, the central region thickness t_1 is between 0.120 inch to 0.150 inch. In other embodiments, the central region thickness t_1 is between 0.05 to 0.075 inch, or 0.075 to 0.10 inch. For example, the central region thickness t_1 is 0.10 inch to 0.11 inch, 0.11 inch to 0.12 inch, 0.12 inch to 0.13 inch, 0.13 inch to 0.14 inch, 0.14 inch to 0.15 inch, 0.15 inch to 0.16 inch, or 0.16 inch to 0.17 inch. In one example, the central region thickness t_1 is 0.148 inch. In another example, the central region thickness t_1 is 0.125 inch. In another embodiment, the central region thickness t_1 is 0.137 inch. The relationship between the thicknesses, t_1 , t_2 , and t_3 create the hinge 174 to create a variable face thickness that non-linearly bends. To form the hinge 174, t_2 is less than t_1 and t_3 thereby creating a first peak, a valley, and a second peak. The hinge 174 comprising this thickness relationship will not deflect as much in low energy impacts and deflect more in high energy impacts thereby creating a structure that bends in a non-linear manor.

[0130] An alternative thickness characteristic of the central region 170 can be described relative to any combination of the aforementioned regions. Particularly, a perpendicular distance from the central region 170 to the hinge 174 (“Depth A”) and a perpendicular distance from the central region 170 to a junction between the inner and outer transitions (“Depth B”) can characterize the relationship between the variable thickness regions of the strike face. Depth A can be less than or equal to 0.070 inch, less than or equal to 0.040 inch, or less than or equal to 0.025 inch. Additionally, Depth B can be less than or equal to 0.60 inch, less than or equal to 0.030 inch, or less than or equal to 0.020 inch.

[0131] The central region 170 of the strike face 106 can comprise a percentage of the strike face rear surface area. The central region 170 can comprise greater than 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, or 70% of the rear surface area. In other embodiments, the central region 170 can comprise 30% to 75% of the rear surface area. In other embodiments, the central region 170 can comprise 30% to 50%, or 50% to 75% of the rear surface area. In other embodiments still,

the central region 170 can comprise 30% to 55%, 40 to 65%, or 50 to 75% of the rear surface area. For example, the central region 170 can comprise 30, 35, 40, 45, 50, 55, 60, 65, 70, or 75% of the rear surface area.

[0132] In many embodiments, the central region 170 is located proximate to the geometric face center 1010. In some embodiments, the central region 170 comprises a central region geometric center 163 that aligns with the geometric face center 1010 in the loft plane. In other embodiments, the central region geometric center 163 is offset from the geometric face center 1010 when viewed in the loft plane. In further embodiments, the central region geometric center 163 is offset a y-axis distance and/or an x-axis distance from the geometric face center 1010. Particularly, the central region geometric center 163 can be offset from the geometric face center 1010 a y-distance between 0.00 inch and 1.50 inches. Further, the central region geometric center 163 can be offset from the geometric face center 1010 an x-distance between 0.00 inch and 1.50 inches.

[0133] When viewed from a rear of the strike face, the central region 170 can comprise symmetrical, non-symmetrical, arcuate, or rectilinear shapes, as well as combinations thereof. For example, the central region 170 may have a circular shape, an ovular shape, an ellipsoidal shape, an oblong-ellipse shape, egg shape, ellipse with circular ends shape, a square shape, a triangular shape, a rectangular shape, or any other suitable shape. The shape of the central region 170 may be selected to normalize CT across the strike face.

[0134] In the exemplary embodiment, the central region 170 comprises a generally elliptical shape. The elliptical geometry of the central region 170 can be generally defined by maximum lengths along its major axis 161 and minor axis 162. Namely, the major axis 161 extends along a maximum width 189 of the central region 170, and the minor axis 162 extends along a maximum height 190 of the central region 170. In the exemplary embodiment, the major axis 161 is substantially parallel to the club head y-axis and the minor axis 162 is substantially parallel to the club head x-axis. In other embodiments, the central region 170 is tilted relative to the x-axis, such that a central region offset angle is formed between the club head x-axis and the major axis 161. The central region offset angle can be positive or negative relative to the x-axis. Specifically, the central region 170 can be tilted in a toe-down or toe-up orientation. In some

embodiments, the central region offset angle can be between 0 and +/-25 degrees. In other embodiments, the central region offset angle in a toe-up or toe-down orientation can be less than approximately 25 degrees, less than approximately 20 degrees, less than approximately 15 degrees, less than approximately 10 degrees, less than approximately 8 degrees, less than approximately 6 degrees, less than approximately 5 degrees, less than approximately 4 degrees, less than approximately 3 degrees, less than approximately 2 degrees, or less than approximately 1 degrees.

[0135] The central region 170 comprises a first side 165 (also referred to as a toe side) and a second side 166 (also referred to as a heel side). The first side 165 and the second side 166 of the central region 170 are separated by the minor axis 162. The first side 165 is positioned between the minor axis 162 and the toe portion, and the second side 166 is positioned between the minor axis 162 and the heel portion. As such, the central region 170 comprises a first side length 185 (or “toe side length”) and a second side length 186 (or “heel side length”) measured along the major axis 161. In some embodiments, the first side length 185 is equivalent (or substantially similar) to the second side length 186.

[0136] In many embodiments, the combined first side length 185 and second side length 186 can be greater than approximately 0.75 inch, greater than approximately 0.80 inch, greater than approximately 0.85 inch, greater than approximately 0.90 inch, greater than approximately 0.95 inch, or greater than approximately 1.0 inch. In other embodiments, the combined first side length 185 and second side length 186 can be approximately 0.89 inch, 1.0 inch, 1.1 inches, 1.2 inches, 1.3 inches, or 1.4 inches. In some embodiments, the combined first side length 185 and second side length 186 can be between 0.75 inch and 0.80 inch.

[0137] The central region 170 further comprises a top side 167 and a bottom side 168. The top side 167 and bottom side 168 of the central region 170 are separated by the major axis 161. As such, the central region 170 further comprises a top-side length 187 measured along the minor axis 162 from the center of the central region 170 toward the top, and a bottom side length 188 measured along the minor axis 162 from the center of the central region 170 toward the bottom. In this embodiment, the top-side length 187 and the bottom side length 188 are equivalent (or substantially similar) in length.

[0138] In the illustrated embodiment, the combined length of the top-side length 187 and the bottom side length 188 can be approximately 0.40 inches. In other embodiments, the top-side length 187 and/or the bottom side length 188 can be between 0.05 and 1.0 inches. For example, in some embodiments, the top-side length 187 and/or the bottom side length 188 can be between 0.05 and 0.25, 0.15 and 0.35, 0.25 and 0.45, 0.35 and 0.55, 0.45 and 0.65, 0.55 and 0.75, 0.65 and 0.85, or 0.75 and 0.1 inches.

[0139] Subsequently, the size, shape, and orientation of the aforementioned hinge 174 is dependent upon the size and shape of the central region 170 and central transition 172. In the exemplary embodiment, the hinge maximum length and height are defined by the elliptical geometry of the central region 170 and the substantially constant central transition width. Subsequently, the summation of the central transition width and the central region top-side or bottom-side length is effectively half of the maximum hinge height. Similarly, the summation of the central transition width and the central region first or second side length is effectively half of the maximum hinge length.

[0140] In other embodiments, the size and shape of the hinge 174 is similar, yet proportionally different to the central region 170. In these embodiments, the central transition width is not constant over the perimeter of the central transition 172. In many embodiments, the size and shape of the hinge 174 can be between 5% and 50% larger in scale than that of the central region 170. In further embodiments, the hinge 174 can be between 5-10%, 10-15%, 15-20%, 20-25%, 25-30%, 30-35%, 35-40%, 40-45%, or 45-50% larger than the central region 170.

[0141] The size and shape of the central region 170, along with its relationship with the hinge 174, allows for CT normalization across the strike face. Generally, CT can vary across the face of a golf club. A specifically designed VFT can act to better normalize CT over the entirety of the face, which results in less ball speed loss on mishits. Alternatively, a specifically designed VFT can normalize CT over the strike face by limiting hot spots or strike locations that achieve drastically higher ball speeds compared to ideal impact locations. Retaining consistent ball speed on mishits allows players to maintain distance expectations and results on off-center strikes. Therefore, normalized CT across the face is desirable to golfers, and the central region 170 better achieves this.

[0142] The combination of the central region 170, the central transition 172, the hinge 174, the inner transition 176, and the hinge outer peak 179 creates a variable face thickness with a topography that evokes the shape of a speaker woofer to produce non-linear bending, thereby producing greater strike face deflection and resulting ball speed for a given CT value.

I. Non-Linear Bending Region

[0143] The embodiments disclosed herein can further comprise a non-linear bending region 950 spaced from but fully surrounding a central region 970 and a central region perimeter 971, illustrated in FIG. 26A. The non-linear bending region 950 is disposed between the central region perimeter 971 and a border perimeter 982. In some embodiments a variable face thickness profile can comprise multiple non-linear bending regions 950 disposed between the central region 970 and the border perimeter 982. Each of the non-linear bending regions 950 comprise a first peak 951, a valley 952, and a second peak 953. These non-linear bending regions 950 create a structure that provides more strike face deflection and ball speed for a given CT.

[0144] The region between the central region 970 and the first peak 951 can be defined as an intermediate region 992. In some embodiments the intermediate region 992 can increase or decrease in thickness. In some embodiments, the intermediate region 992 can comprise a constant thickness and/or a varying thickness. The intermediate region 992 serves as a transition between the central region 970 and the non-linear bending region 950. The intermediate region 992 provides a region that can comprise a preferred thickness to maintain durability of the strike face 106 and normalize CT across the strike face 106.

[0145] The first peak 951 is the beginning of the non-linear bending region 950. The first peak 951, corresponding to a first localized maximum thickness, fully surrounds and is spaced a first distance from the central region perimeter 971. A first transition region 954, comprising a decreasing thickness, extends from the first peak 951 to the valley 952.

[0146] The valley 952, corresponding to a localized minimum thickness, fully surrounds and is spaced a second distance from the central region perimeter 971. The valley 952 serves as the hinge point of the non-linear bending region where upon high impact collisions the non-linear bending region 950 hinges about the valley 952. The valley 952 is similar to the hinge 174

disclosed above except that it can be located away from the central region 970 (*i.e.*, not directly surrounding the central region 970). In some embodiments, the valley 952 is spaced (measured radially) from the central region perimeter 971 a distance between 0.5 inch to 2 inches. The valley 952 further fully surrounds and is spaced from the first peak 951. Therefore, the valley 952 is outside of the first peak 951 relative to the geometric face center 1010 or the central region geometric center 963.

[0147] The second peak 953 is the end of the non-linear bending region 950. The second peak 953, corresponding to a second localized maximum thickness, fully surrounds and is spaced a second distance from the central region perimeter 971. A second transition region 955, comprising an increase in thickness, extends radially from the valley 952 to the second peak 953. The second peak 953 further fully surrounds and is spaced from the valley 952. Therefore, the second peak 953 is outside of the valley 952 relative to the geometric face center 1010 or the central region geometric center 963.

[0148] Since the valley 952 surrounds and is outside of the first peak 951, and the second peak 953 surrounds and is outside of the valley 952, the valley 952 is therefore disposed between the first peak 951 and the second peak 953 to create a hinge 974 in the valley 952. In other words, the first peak 951 is surrounded by the valley 952 such that the valley 952 is outside of the first peak 951, and the valley 952 is surrounded by the second peak 953 such that the second peak is outside of the valley 952. This relationship between the first peak 951, the valley 952, and the second peak 953 creates a non-linear bending structure that has more face deflection strike face deflection and ball speed for a given CT.

[0149] The first peak 951 comprises a first thickness, the valley 952 comprises a second thickness, and the second peak 953 comprises a third thickness. The second thickness is less than both the first thickness and the third thickness to create the hinge 974 that non-linearly bends. Thereby creating a strike face that has more strike face deflection and ball speed for a given CT.

[0150] The non-linear bending region 950 can be surrounded by an outside region 993 that can extend to the strike face perimeter. The outside region can increase or decrease in thickness or remain constant. The outside region connects the non-linear bending region 950 to the interior strike face perimeter 969.

[0151] The first thickness can be inclusively between 0.050 inch and 0.75 inch. In some embodiments the first thickness can be inclusively between 0.050 inch to 0.100 inch, 0.100 inch to 0.150 inch, 0.150 inch to 0.200 inch, 0.200 inch to 0.250 inch, 0.250 inch to 0.300 inch, 0.300 inch to 0.350 inch, 0.350 inch to 0.400 inch, 0.400 inch to 0.450 inch, 0.450 inch to 0.500 inch, 0.500 inch to 0.550 inch, 0.550 inch to 0.600 inch, 0.600 inch to 0.650 inch, 0.650 inch to 0.700 inch, or 0.700 inch to 0.750 inch. In some embodiments the first thickness can be less than 0.75 inch, less than 0.70 inch, less than 0.65 inch, less than 0.60 inch, less than 0.55 inch, less than 0.50 inch, less than 0.45 inch, less than 0.40 inch, less than 0.35 inch, less than 0.30 inch, less than 0.25 inch, less than 0.20 inch, less than 0.15 inch, less than 0.10 inch, or less than 0.05 inch.

[0152] The second thickness can be between 0.05 to 0.12 inch. In some embodiments the second thickness can be between 0.05 inch to 0.06 inch, 0.06 inch to 0.07 inch, 0.07 inch to 0.08 inch, 0.08 inch to 0.09 inch, 0.09 inch to 0.10 inch, 0.10 inch to 0.11 inch, or 0.11 inch to 0.12 inch. In some embodiments the second thickness can be less than 0.12 inch, less than 0.11 inch, less than 0.10 inch, less than 0.09 inch, less than 0.08 inch, less than 0.07 inch, less than 0.06 inch, less than 0.05 inch.

[0153] The third thickness can be between 0.050 inch and 0.75 inch. In some embodiments the third thickness can be inclusively between 0.050 inch to 0.100 inch, 0.100 inch to 0.150 inch, 0.150 inch to 0.200 inch, 0.200 inch to 0.250 inch, 0.250 inch to 0.300 inch, 0.300 inch to 0.350 inch, 0.350 inch to 0.400 inch, 0.400 inch to 0.450 inch, 0.450 inch to 0.500 inch, 0.500 inch to 0.550 inch, 0.550 inch to 0.600 inch, 0.600 inch to 0.650 inch, 0.650 inch to 0.700 inch, or 0.700 inch to 0.750 inch. In some embodiments the third thickness can be less than 0.75 inch, less than 0.70 inch, less than 0.65 inch, less than 0.60 inch, less than 0.55 inch, less than 0.50 inch, less than 0.45 inch, less than 0.40 inch, less than 0.35 inch, less than 0.30 inch, less than 0.25 inch, less than 0.20 inch, less than 0.15 inch, less than 0.10 inch, or less than 0.05 inch.

[0154] The first distance can be between 0.15 inch to 1.75 inch. In some embodiments, the first distance can be inclusively between 0.150 inch to 0.200 inch, 0.200 inch to 0.250 inch, 0.250 inch to 0.300 inch, 0.300 inch to 0.350 inch, 0.350 inch to 0.400 inch, 0.400 inch to 0.450 inch, 0.450 inch to 0.500 inch, 0.500 inch to 0.550 inch, 0.550 inch to 0.600 inch, 0.600 inch to 0.650 inch, 0.650 inch to 0.700 inch, 0.700 inch to 0.750 inch, 0.750 inch to 0.800 inch, 0.800 inch to

0.850 inch, 0.850 inch to 0.900 inch, 0.900 inch to 0.950 inch, 0.950 inch to 1.00 inch, 1.00 inch to 1.05 inch, 1.05 inch to 1.10 inch, 1.10 inch to 1.15 inch, 1.15 inch to 1.20 inch, 1.20 inch to 1.25 inch, 1.25 inch to 1.30 inch, 1.30 inch to 1.35 inch, 1.35 inch to 1.40 inch, 1.40 inch to 1.45 inch, 1.45 inch to 1.50 inch, 1.50 inch to 1.55 inch, 1.55 inch to 1.60 inch, 1.60 inch to 1.65 inch, 1.65 inch to 1.70 inch, or 1.70 inch to 1.75 inch. In some embodiments, the first distance can be less than 1.75 inch, less than 1.70 inch, less than 1.65 inch, less than 1.60 inch, less than 1.55 inch, less than 1.50 inch, less than 1.45 inch, less than 1.40 inch, less than 1.35 inch, less than 1.30 inch, less than 1.25 inch, less than 1.20 inch, less than 1.15 inch, less than 1.10 inch, less than 1.05 inch, less than 1.00 inch, less than 0.95 inch, less than 0.90 inch, less than 0.85 inch, less than 0.80 inch, less than 0.75 inch, less than 0.70 inch, less than 0.65 inch, less than 0.60 inch, less than 0.55 inch, less than 0.50 inch, less than 0.45 inch, less than 0.40 inch, less than 0.35 inch, less than 0.30 inch, less than 0.25 inch, less than 0.20 inch, or less than 0.15 inch.

[0155] The second distance can be between 0.2 inch to 2.0 inches. In some embodiments, the second distance can be inclusively between 0.200 inch to 0.250 inch, 0.250 inch to 0.300 inch, 0.300 inch to 0.350 inch, 0.350 inch to 0.400 inch, 0.400 inch to 0.450 inch, 0.450 inch to 0.500 inch, 0.500 inch to 0.550 inch, 0.550 inch to 0.600 inch, 0.600 inch to 0.650 inch, 0.650 inch to 0.700 inch, 0.700 inch to 0.750 inch, 0.750 inch to 0.800 inch, 0.800 inch to 0.850 inch, 0.850 inch to 0.900 inch, 0.900 inch to 0.950 inch, 0.950 inch to 1.00 inch, 1.00 inch to 1.05 inch, 1.05 inch to 1.10 inch, 1.10 inch to 1.15 inch, 1.15 inch to 1.20 inch, 1.20 inch to 1.25 inch, 1.25 inch to 1.30 inch, 1.30 inch to 1.35 inch, 1.35 inch to 1.40 inch, 1.40 inch to 1.45 inch, 1.45 inch to 1.50 inch, 1.50 inch to 1.55 inch, 1.55 inch to 1.60 inch, 1.60 inch to 1.65 inch, 1.65 inch to 1.70 inch, 1.70 inch to 1.75 inch, 1.75 inch to 1.80 inch, 1.80 inch to 1.85 inch, 1.85 inch to 1.90 inch, 1.90 inch to 1.95 inch, or 1.95 inch to 2.0 inch. In some embodiments, the second distance can be less than 2.0 inch, less than 1.95 inch, less than 1.90 inch, less than 1.85 inch, less than 1.80 inch, less than 1.75 inch, less than 1.70 inch, less than 1.65 inch, less than 1.60 inch, less than 1.55 inch, less than 1.50 inch, less than 1.45 inch, less than 1.40 inch, less than 1.35 inch, less than 1.30 inch, less than 1.25 inch, less than 1.20 inch, less than 1.15 inch, less than 1.10 inch, less than 1.05 inch, less than 1.00 inch, less than 0.95 inch, less than 0.90 inch, less than 0.85 inch, less than 0.80 inch, less than 0.75 inch, less than 0.70 inch, less than 0.65 inch, less than 0.60

inch, less than 0.55 inch, less than 0.50 inch, less than 0.45 inch, less than 0.40 inch, less than 0.35 inch, less than 0.30 inch, less than 0.25 inch, or less than 0.20 inch.

[0156] The third distance can be between 0.25 inch to 2.25 inches. In some embodiments, the third distance can be inclusively between 0.250 inch to 0.300 inch, 0.300 inch to 0.350 inch, 0.350 inch to 0.400 inch, 0.400 inch to 0.450 inch, 0.450 inch to 0.500 inch, 0.500 inch to 0.550 inch, 0.550 inch to 0.600 inch, 0.600 inch to 0.650 inch, 0.650 inch to 0.700 inch, 0.700 inch to 0.750 inch, 0.750 inch to 0.800 inch, 0.800 inch to 0.850 inch, 0.850 inch to 0.900 inch, 0.900 inch to 0.950 inch, 0.950 inch to 1.00 inch, 1.00 inch to 1.05 inch, 1.05 inch to 1.10 inch, 1.10 inch to 1.15 inch, 1.15 inch to 1.20 inch, 1.20 inch to 1.25 inch, 1.25 inch to 1.30 inch, 1.30 inch to 1.35 inch, 1.35 inch to 1.40 inch, 1.40 inch to 1.45 inch, 1.45 inch to 1.50 inch, 1.50 inch to 1.55 inch, 1.55 inch to 1.60 inch, 1.60 inch to 1.65 inch, 1.65 inch to 1.70 inch, 1.70 inch to 1.75 inch, 1.75 inch to 1.80 inch, 1.80 inch to 1.85 inch, 1.85 inch to 1.90 inch, 1.90 inch to 1.95 inch, 1.95 inch to 2.00 inch, 2.00 inch to 2.05 inch, 2.05 inch to 2.10 inch, 2.10 inch to 2.15 inch, 2.15 inch to 2.20 inch, or 2.20 inch to 2.25 inch. In some embodiments, the third distance can be less than 2.25 inch, less than 2.20 inch, less than 2.15 inch, less than 2.10 inch, less than 2.05 inch, less than 2.00 inch, less than 1.95 inch, less than 1.90 inch, less than 1.85 inch, less than 1.80 inch, less than 1.75 inch, less than 1.70 inch, less than 1.65 inch, less than 1.60 inch, less than 1.55 inch, less than 1.50 inch, less than 1.45 inch, less than 1.40 inch, less than 1.35 inch, less than 1.30 inch, less than 1.25 inch, less than 1.20 inch, less than 1.15 inch, less than 1.10 inch, less than 1.05 inch, less than 1.00 inch, less than 0.95 inch, less than 0.90 inch, less than 0.85 inch, less than 0.80 inch, less than 0.75 inch, less than 0.70 inch, less than 0.65 inch, less than 0.60 inch, less than 0.55 inch, less than 0.50 inch, less than 0.45 inch, less than 0.40 inch, less than 0.35 inch, less than 0.30 inch, less than 0.25 inch.

[0157] Various embodiments comprising multiple non-linear bending regions spaced different distances from the central region are illustrated in FIGS. 38A – 38K. These embodiments comprise various combinations of peaks 951A, 951B, 951A, 951B, 951C, 951D, 951E, 951F, and 951G, valleys 952A, 952B, 952C, 952D, 952E, 952F, and peaks 953A, 953B. In some of these embodiments the peaks 951 form the second peak of one non-linear bending region 950

and the first peak of another non-linear bending region 950. These non-linear bending regions 950 act the same as the non-linear bending regions 950 described above.

J. Rounds

[0158] In some embodiments, rounds provide smooth transitions between any combination of the previously mentioned regions to facilitate the manufacture of the VFT. The use of rounds allows the strike face to vary the thickness without seams or abrupt changes in thickness between the various regions disclosed herein.

III. Bridges

[0159] In some embodiments, the variable face thickness profiles disclosed herein can be used in combination with a crown-to-strike face bridge or a sole-to-strike face bridge. These bridges can be in a transition region between the strike face and the sole and a transition region between the strike face and the crown to selectively thicken regions of the transition regions. In doing so, the CT of the strike face can be controlled to remain within the limits as set forth by the USGA. The transition regions can be split into different portions to identify different areas that require the thickened crown-to strike face bridge or the sole-to-strike face bridge.

[0160] The crown 102 can be segmented (or split) into three distinct length portions (*i.e.*, a front portion 125, a middle portion 126, and a rear portion 127), measured in a front-to-rear direction from a rear 107 of the golf club head 100 to the strike face 106.

[0161] The front portion 125 of the crown 102 can be proximal to the strike face 106 and defined as the forward 1/6th portion (and/or having a length that is 1/6th) of the crown length. The rear portion 127 of the crown 102 is proximal to the rear 107 of the golf club head 100 and defined as being the rearward 2/6th portion (and/or having a length that is 2/6th) of the crown length. The middle portion 126 of the crown 102 is between the front portion 125 and the rear portion 127 and defined as being the middle 3/6th portion (and/or having a length that is 3/6th) of the crown length.

[0162] In this or other embodiments, the thickness of the crown 102 can vary from near the front portion 125 of the crown 102 to near the rear 107 of the crown 102 and/or from near the heel

portion of the crown 102 to near the toe portion of the crown 102, or in any direction along the crown 102 of the golf club head. As illustrated by FIGS. 6 and 7, in some embodiments, the thickness of the crown 102 can decrease from near the front end towards the rear end of the golf club head 100, measured from an inner crown surface 128 to an outer crown surface 129.

[0163] The sole 104 can be segmented (or split) into three distinct length portions (i.e. a front sole portion 130, a middle sole portion 131, and a rear sole portion 132), measured in a front-to-rear direction from the faceplate-to-rear of the golf club head.

[0164] The front sole portion 130 of the sole 104 can be proximal to the strike face 106 and the forward 1/3rd portion (and/or having a length that is 1/3rd) of the sole length. The rear sole portion 132 of the sole 104 is proximal to the rear 107 of the golf club head and defined as being the rearward 1/3rd portion (and/or having a length that is 1/3rd) of the sole length. The middle sole portion 131 of the sole is between the front sole portion 130 and the rear sole portion 132 and defined as being the middle 1/3rd portion (and/or having a length is 1/3rd) of the sole length.

[0165] In this or other embodiments, the thickness of the sole 104, measured from an inner sole surface 133 to an outer sole surface 134, can vary from near the front portion of the sole to near the rear end of the sole and/or from near the heel portion of the sole to near the toe portion of the sole, or in any direction along the sole of the golf club head. In some embodiments, the thickness of the sole 104 can decrease from near the front end towards the rear 107 of the golf club head 100.

K. Crown-to-strike face bridge

[0166] With continued reference to FIG. 8-11, the golf club head 100 further comprises a continuous transition region 119 spanning between the sole 104 and the crown 102. The continuous transition region 119 comprises a crown transition region 156 and a sole transition region 157. The crown transition region 156 can extend entirely or partially from a heel end 118 to a toe end 114, spanning between the strike face 106 and the crown 102. In some embodiments, the continuous transition region 119 surrounds the strike face entirely and is disposed between the strike face and the crown 102. The continuous transition region 119 comprises at least one crown-to-strike face bridge 108. The continuous transition region 119 is curved and devoid of

any sharp angles or points. In some embodiments, the radius of curvature of the continuous transition region 119 is between 0.15 inches and 0.80 inches. In some embodiments, the radius of curvature of the crown transition region 156 is between 0.30 inches and 0.80 inches. The portion of the crown-to-strike face bridge 108 that is within the continuous transition region 119 comprises a radius of curvature or variable radius of curvature to match that of the continuous transition region 119.

[0167] The at least one crown-to-strike face bridge 108 can be located near the strike face 106, entirely internally within the hollow body. The crown-to-strike face bridge 108 is located in locations between the heel 116 and the toe 112, near to or abutting the strike face 106, to make the strike face 106 more rigid near regions of higher CT. In some embodiments, the strike face 106 experiences greatest CT response between a mid-plane 158 (of the golf club head 100) and the toe end 114 nearest the crown 102, and between the mid-plane 158 and the heel end 118 nearest the sole 104. The crown-to-strike face bridge 108 can be positioned to decrease CT properties only within the desired regions. The crown-to-strike face bridge 108 can mimic a gusset like structure that strengthens/enlarges (or thickens) a specific portion of the transition region.

[0168] In some embodiments, the golf club head 100 can have a heel-side plane and a toe-side plane that are parallel to the mid-plane 158. For example, the heel-side plane can be located in a direction toward the heel 116 of the golf club head 100 and away from the mid-plane 158, and the toe-side plane can be located in a direction toward the toe of the golf club head 100 and away from the mid-plane 158. In some embodiments, the heel-side plane can be located a distance of 0.55 inch to 0.80 inch from the mid-plane in a heelward direction and the toe-side plane can be located a distance of 0.55 inch to 0.80 inch from the mid-plane in a toeward direction. For example, the heel-side plane can be located a distance of 0.55 inch, 0.56 inch, 0.57 inch, 0.58 inch, 0.59 inch, 0.60 inch, 0.61 inch, 0.62 inch, 0.63 inch, 0.64 inch, 0.65 inch, 0.66 inch, 0.67 inch, 0.68 inch, 0.69 inch, 0.70 inch, 0.71 inch, 0.72 inch, 0.73 inch, 0.74 inch, 0.75 inch, 0.76 inch, 0.77 inch, 0.78 inch, 0.79 inch, or 0.80 inch from the mid-plane 158. By way of example, the toe-side plane can be located a distance of 0.55 inch, 0.56 inch, 0.57 inch, 0.58 inch, 0.59 inch, 0.60 inch, 0.61 inch, 0.62 inch, 0.63 inch, 0.64 inch, 0.65 inch, 0.66 inch, 0.67 inch, 0.68

inch, 0.69 inch, 0.70 inch, 0.71 inch, 0.72 inch, 0.73 inch, 0.74 inch, 0.75 inch, 0.76 inch, 0.77 inch, 0.78 inch, 0.79 inch, or 0.80 inch from the mid-plane. In further embodiments, the crown-to-strike face bridge 108 can be bounded and entirely between the heel-side plane and the toe-side plane, but extending through the mid-plane 158.

[0169] The crown-to-strike face bridge 108 can be placed in a low stress and/or low displacement region of the golf club head 100 to locally reinforce portions of the crown 102 and the strike face 106 without impacting the performance of the golf club head 100 (i.e., ball speed). Locally reinforcing a crown portion and a strike face portion through a crown-to-strike face bridge 108 can decrease areas of high CT properties (without increasing the entire face thickness), while having a negligible effect on ball speed.

[0170] In some embodiments, the crown-to-strike face bridge 108 extends from the inner crown surface 128 to an inner rear surface of the strike face 106. As illustrated by FIGS 8-11, the crown-to-strike face bridge 108 is only present within the front portion 125 of the crown 102. Stated another way, the crown-to-strike face bridge 108 is not present within the middle portion 126 or the rear portion 127 of the crown 102, and instead is present only in the front portion of the crown 102.

[0171] The crown-to-strike face bridge 108 is integral with the continuous transition region 119, crown 102, and/or the sole 104. The crown-to-strike face bridge 108 is devoid of weld beads, adhesives, or any other known join method.

[0172] The crown-to-strike face bridge 108 locally thickens a specific region of the golf club head 100. The club head with the crown-to-strike face bridge 108 can have mass removed from other parts of the golf club head 100, allowing for an optimized mass-to-volume ratio (described above) to accommodate slow swing speeds. Reducing the mass-to-volume ratio can improve ball speed, trajectory, and distance.

[0173] In some embodiments, the mass of the crown-to-strike face bridge 108 is no greater than three grams. Minimizing the weight of the crown-to-strike face bridge 108 ensures that the above described mass/volume relationship is satisfied to improve club head characteristics, while reducing the likelihood of a golf club head having a CT value falling outside a designed

threshold value. In alternative embodiments, the mass of the crown-to-strike face bridge 108 can be between approximately 0.5 gram – approximately 1 gram, approximately 1 gram – approximately 2 grams, or approximately 2 grams – approximately 3 grams. In other embodiments, the mass of the crown-to-strike face bridge can be approximately 0.5 grams, approximately 1 gram, approximately 2 grams, or approximately 3 grams.

[0174] As best shown in in FIGS. 10 and 11, the golf club head 100 comprises at least one crown-to-strike face bridge 108 that intersects and extends beyond the mid-plane 158 in a direction toward the heel 116 and/or the toe 112 of the golf club head. The mid-plane 158 divides a width of the golf club head in a heel-to-toe direction, into two equal parts. The crown-to-strike face bridge 108 can be defined by at least a length, a width, and a thickness. The crown-to-strike face bridge length is measured in a heel-to-toe direction, perpendicular to the mid-plane 158. The crown-to-strike face bridge width is measured in a front-to-rear direction, parallel to the mid-plane. In some embodiments, a heel-to-toe center 159 divides the length of the crown-to-strike face bridge 108 into two equal parts. In the same or another embodiment, a front-to-rear center divides the width of the crown-to-strike face into two equal parts. Stated another way, at least one of the heel end 118 and/or the toe end 114 of the crown-to-strike face bridge 108 is partially distal to and/or spaced from the mid-plane intersection line. In alternative embodiments, the entire crown-to-strike face bridge 108 can be located between the mid-plane 158 and the heel end 118 or the toe end 114, but not intersecting the mid-plane.

[0175] In some embodiments, the crown-to-strike face bridge 108 is aligned such that the heel-to-toe center is coplanar with the mid-plane 158. In other embodiments, the crown-to-strike face bridge 108 is offset from the mid-plane 158. In some of these embodiments, the crown-to-strike face bridge center is offset from the mid-plane by between 0.5 inch and 1.0 inch. For example, the crown-to-strike face bridge center can be offset from the mid-plane 158 by 0.5 inch, 0.6 inch, 0.7 inch, 0.8 inch, 0.9 inch, or 1.0 inch. In other embodiments, the reinforcement region center is offset from the mid-plane by between 1.0 inch and 2.0 inches. For example, the reinforcement center can be offset from the mid-plane by 1.0 inch, 1.1 inch, 1.2 inch, 1.3 inch, 1.4 inch, 1.5 inch, 1.6 inch, 1.7 inch, 1.8 inch, 1.9 inch, or 2.0 inch.

[0176] The crown-to-strike face bridge length does not extend entirely from the heel end 118 to the toe end 114 of the golf club head. Instead, the crown-to-strike face bridge length extends along only a portion of the heel-to-toe length of the transition region in which it lies. In some embodiments, the crown-to-strike face bridge length can be between 0.75 inch and 4 inches. For example, the crown-to-strike face bridge length can be between 0.75 inch and 1 inch, 1 inch and 1.25 inches, 1.25 inches and 1.50 inches, 1.50 inches and 1.75 inches, 1.75 inches and 2 inches, 2 inches and 2.25 inches, 2.25 inches and 2.5 inches, 2.5 inches and 2.75 inches, 2.75 inches and 3 inches, 3 inches and 3.25 inches, 3.25 inches and 3.5 inches, 3.5 inches and 3.75 inches, or 3.75 inches and 4 inches. In alternative embodiments, the crown-to-strike face bridge length can be 0.75 inch, 1.0 inch, 1.25 inches, 1.50 inches, 1.75 inches, 2.0 inches, 2.25 inches, 2.5 inches, 3.0 inches, 3.25 inches, 3.5 inches, 3.75 inches, or 4.0 inches. In some embodiments, the crown-to-strike face bridge length can be between 15% and 85% of the length of the transition region from the heel end 118 to the toe end 114.

[0177] As described above, the crown-to-strike face bridge 108 lies at least partially within the continuous transition region 119. In some embodiments, the crown-to-strike face bridge width extends across the entire transition region front-to-rear width. In some embodiments, the crown-to-strike face bridge width extends across only a portion of the transition region front-to-rear width. In some of these embodiments and others, the crown-to-strike face bridge width extends beyond the transition region and onto either the crown or the sole 104. The crown-to-strike face bridge width can be between 50% and 100% of the transition region width. In some embodiments wherein the crown-to-strike face bridge extends beyond the transition region, the crown-to-strike face bridge width can be greater than the transition region width. In these embodiments, the crown-to-strike face bridge width can be up to 150% of crown-to-strike face bridge width.

[0178] The crown-to-strike face bridge width does not extend entirely from the strike face 106 to rear of the golf club head. In some embodiments, the crown-to-strike face bridge width can be between 0.40 inch and 0.80 inches. For example, the crown-to-strike face bridge width can be between 0.40 inch and 0.50 inch, 0.50 inch and 0.6 inches, 0.6 inches and 0.7 inches, or 0.7 inches and 0.80 inches. In some embodiments, the crown-to-strike face bridge width can be

approximately 0.40 inch, approximately 0.45 inch, approximately 0.50 inch, approximately 0.55 inch, approximately 0.60 inch, approximately 0.65 inch, approximately 0.70 inch, approximately 0.75 inch, or approximately 0.80 inch.

[0179] In some embodiments, the crown-to-strike face bridge 108 is integrally formed with at least the portions of the club head which it contacts (i.e., devoid of weld beads, adhesives, etc). Stated another way, the crown-to-strike face bridge 108, the transition region, and the portion of the crown to which the crown-to-strike face bridge 108 is coupled, comprise the same material or combination of materials.

[0180] In some embodiments, the crown-to-strike face bridge 108 has a generally projected rectangular shape when viewed from a top plane. In other embodiments, the crown-to-strike face bridge 108 can have one of the following shapes: oval, circle, trapezoidal, rounded rectangle, square, rounded square, or another polygon.

[0181] The crown-to-strike face bridge 108 can have a variable or constant thickness across the width and/or length. In some of these embodiments, the crown-to-strike face bridge 108 comprises a non-transitioned, constant thickness across both of its width and length. In other embodiments, the crown-to-strike face bridge 108 comprises a constant thickness across only one of the width or length, and a variable (or transitioned) thickness across the other of the width or length.

[0182] In some embodiments, the crown-to-strike face bridge 108 is thickest at its center. In these embodiments, the crown-to-strike face bridge thickness transitions circumferentially (or radially) from the center, and the center of the reinforcement region comprises a rounded or pointed peak. In other words, the crown-to-strike face bridge thickness reduces linearly or geometrically away from the center (of both the width and the length) in all directions. The transition rate will vary in some directions relative to others based on the crown-to-strike face bridge dimensions, such that the crown-to-strike face bridge thickness is the same at all edges of the crown-to-strike face bridge. The thickness can transition linearly, geometrically, or in a stepped formation toward its edges in a direction away from the center and toward the front, the rear, the heel end 118, and the toe end 114. The front, the rear, the heel end 118, and the toe end 114 edges of the crown-to-strike face bridge are shaped such that they transition substantially

continuously or seamlessly to the surrounding portions of the golf club head. In other words, the thickness of the crown-to-strike face bridge reduces to that of the surrounding golf club head at its perimeter edges to prevent forming a substantial lip or step that differentiates the reinforcement region from the surrounding club head.

[0183] In some embodiments, the crown-to-strike face bridge front-to-rear cross-sectional shape differs from the crown-to-strike face bridge heel-to-toe cross-sectional shape. In others of these embodiments, the crown-to-strike face bridge front-to-rear cross-sectional shape is similar to the crown-to-strike face bridge heel-to-toe cross-sectional shape. In some embodiments, the reinforcement region comprises a slightly curved cross-sectional shape.

L. Sole-to-Strike face Bridge

[0184] Many of the aforementioned features are able to be incorporated into the golf club head 100 by of implementing at least one sole-to-strike face bridge 110. The sole-to-strike face bridge 110 can be placed in a low stress and/or low displacement region of the clubhead to locally reinforce a sole 104 portion and strike face portion without impacting the performance of the clubhead (i.e., ball speed). Locally reinforcing a sole portion and a strike face portion through a sole-to-strike face bridge 110 can decrease areas of high CT characteristics (without increasing the entire face thickness), while having a negligible effect on ball speed. In some embodiments, the crown-to-strike face bridge 110 can mimic a gusset like structure in strengthening/enlarging a specific portion of the club head.

[0185] In some embodiments, the sole-to-strike face bridge 110 extends from the inner sole surface 133 of the sole to an inner rear surface of the strike face 106. As illustrated by FIGS. 12 and 13, the sole-to-strike face bridge 110 is only present within the front portion of the sole 104. Stated another way, the sole-to-strike face bridge 110 is not present within the middle sole portion 131 or the rear sole portion 132 of the sole 104, and instead is present only in the front sole portion 130 of the sole 104.

[0186] As described above, the golf club head 100 comprises the continuous transition region 119 spanning between the sole 104 and the crown 102. The continuous transition region 119 comprises the crown transition region 156 and the sole transition region 157. The sole transition

region 157 can extend entirely or partially from the heel end 118 to the toe end 114, spanning between the strike face 106 and the sole 104. In some embodiments, the continuous transition region 119 surrounds the strike face 106 entirely and is disposed between the strike face 106 and the sole 104. The continuous transition region 119 comprises at least one sole-to-strike face bridge 110. The continuous transition region 119 is curved and devoid of any sharp angles or points. In some embodiments, the radius of curvature of the continuous transition region 119 is between 0.15 inches and 0.80 inches. In some embodiments, the radius of curvature of the continuous transition region 119 is approximately 0.15 inch, 0.16 inch, 0.17 inch, 0.18 inch, 0.19 inch, 0.20 inch, 0.21 inch, 0.22 inch, 0.23 inch, 0.24 inch, 0.25 inch, 0.26 inch, 0.27 inch, 0.28 inch, 0.29 inch, 0.30 inch, 0.31 inch, 0.32 inch, 0.33 inch, 0.34 inch, 0.35 inch, 0.36 inch, 0.37 inch, 0.38 inch, 0.39 inch, 0.40 inch, 0.41 inch, 0.42 inch, 0.43 inch, 0.44 inch, 0.45 inch, 0.46 inch, 0.47 inch, 0.48 inch, 0.49 inch, 0.50 inch, 0.51 inch, 0.52 inch, 0.53 inch, 0.54 inch, 0.55 inch, 0.56 inch, 0.57 inch, 0.58 inch, 0.59 inch, 0.60 inch, 0.61 inch, 0.62 inch, 0.63 inch, 0.64 inch, 0.65 inch, 0.66 inch, 0.67 inch, 0.68 inch, 0.69 inch, 0.70 inch, 0.71 inch, 0.72 inch, 0.73 inch, 0.74 inch, 0.75 inch, 0.76 inch, 0.77 inch, 0.78 inch, 0.79 inch, or 0.80 inch. In some embodiments, the radius of curvature of the sole transition region 157 is between 0.30 inches and 0.80 inches. In some embodiments, the radius of curvature of the sole transition region 157 is approximately 0.30 inch, 0.31 inch, 0.32 inch, 0.33 inch, 0.34 inch, 0.35 inch, 0.36 inch, 0.37 inch, 0.38 inch, 0.39 inch, 0.40 inch, 0.41 inch, 0.42 inch, 0.43 inch, 0.44 inch, 0.45 inch, 0.46 inch, 0.47 inch, 0.48 inch, 0.49 inch, 0.50 inch, 0.51 inch, 0.52 inch, 0.53 inch, 0.54 inch, 0.55 inch, 0.56 inch, 0.57 inch, 0.58 inch, 0.59 inch, 0.60 inch, 0.61 inch, 0.62 inch, 0.63 inch, 0.64 inch, 0.65 inch, 0.66 inch, 0.67 inch, 0.68 inch, 0.69 inch, 0.70 inch, 0.71 inch, 0.72 inch, 0.73 inch, 0.74 inch, 0.75 inch, 0.76 inch, 0.77 inch, 0.78 inch, 0.79 inch, or 0.80 inch. The portion of the sole-to-strike face bridge 110 that is within the continuous transition region 119 comprises a radius of curvature or variable radius of curvature to match that of the continuous transition region 119.

[0187] The at least one sole-to-strike face bridge 110 can be located near the strike face 106, internally within the hollow body. The sole-to-strike face bridge 110 is located between the heel 116 and the toe 112, near to or abutting the strike face 106, to make the strike face 106 more rigid near regions of highest CT. In some embodiments, the strike face 106 experiences greatest

CT characteristics between the mid-plane 158 and the toe end 114 nearest the sole 104, and between the mid-plane 158 and the end nearest the sole 104. The sole-to-strike face bridge 110 can be positioned accordingly to decrease CT properties only within the necessary regions.

[0188] In some embodiments, the golf club head 100 can have a heel-side plane and a toe-side plane that are parallel to the mid-plane 158. For example, the heel-side plane can be located in a direction toward the heel 116 of the golf club head 100 and away from the mid-plane 158, and the toe-side plane can be located in a direction toward the toe of the golf club head 100 and away from the mid-plane 158. In some embodiments, the heel-side plane can be located a distance of 0.55 inch to 0.80 inch from the mid-plane in a heelward direction and the toe-side plane can be located a distance of 0.55 inch to 0.80 inch from the mid-plane in a toeward direction. For example, the heel-side plane and/or the toe-side plane can be located a distance of 0.55 inch, 0.56 inch, 0.57 inch, 0.58 inch, 0.59 inch, 0.60 inch, 0.61 inch, 0.62 inch, 0.63 inch, 0.64 inch, 0.65 inch, 0.66 inch, 0.67 inch, 0.68 inch, 0.69 inch, 0.70 inch, 0.71 inch, 0.72 inch, 0.73 inch, 0.74 inch, 0.75 inch, 0.76 inch, 0.77 inch, 0.78 inch, 0.79 inch, or 0.80 inch from the mid-plane 158. In further embodiments, the sole-to-strike face bridge 110 can be bounded and between the heel-side plane and the toe-side plane, but extending through the mid-plane 158.

[0189] In some embodiments, the sole-to-strike face bridge 110 is integrally formed with at least the portions of the club head which it contacts (i.e., devoid of weld beads, adhesives, etc). Stated another way, the sole-to-strike face bridge 110, the transition region and the portion of the sole to which the sole-to-strike face bridge 110 is coupled, comprise the same material or combination of materials.

[0190] The sole-to-strike face bridge 110 locally thickens the club head. The club head with the sole-to-strike face bridge 110 can have mass removed from other parts of the golf club head 100, allowing for an optimized mass-to-volume ratio to accommodate slow swing speeds. Reducing the mass-to-volume ratio can improve ball speed, trajectory, and distance.

[0191] In some embodiments, the mass of the sole-to-strike face bridge 110 is no greater than three grams. Minimizing the weight of the sole-to-strike face bridge 110 ensures that above described mass/volume relationship is satisfied to improve club head characteristics, while reducing the likelihood of a golf club head having a CT value falling outside a designed

threshold value. In alternative embodiments, the mass of the sole-to-strike face bridge 110 can be between approximately 0.5 gram – approximately 1 gram, approximately 1 gram – approximately 2 grams, or approximately 2 grams – approximately 3 grams. In other embodiments, the mass of the sole-to-strike face bridge can be approximately 0.5 grams, approximately 1 gram, approximately 2 grams, or approximately 3 grams.

[0192] As best shown in FIGS. 12 and 13, the golf club head 100 comprises at least one sole-to-strike face bridge 110 that intersects and extends beyond the mid-plane 158 in a direction toward the heel 116 and/or the toe 112 of the golf club head. The sole-to-strike face bridge 110 can be defined by at least a length, a width, and a thickness. The sole-to-strike face bridge length is measured in a heel-to-toe direction, perpendicular to the mid-plane 158. The sole-to-strike face bridge width is measured in a front-to-rear direction, parallel to the mid-plane. In some embodiments, a heel-to-toe center that divides the length of the sole-to-strike face bridge 110 into two equal parts. In the same or another embodiment, the sole-to-strike face bridge 110 comprises a front-to-rear center that divides its width into two equal parts. Stated another way, at least one end of the sole-to-strike face bridge is partially distal to the mid-plane 158 intersection line. In alternative embodiments, the entire sole-to-strike face bridge can be located between the mid-plane and the heel end 118 or the toe end 114, but not intersecting the mid-plane.

[0193] In some embodiments, the sole-to-strike face bridge 110 is aligned such that the heel-to-toe center 160 is coplanar with the mid-plane 158. In other embodiments, the sole-to-strike face bridge 110 is offset from the mid-plane 158. In some of these embodiments, the sole-to-strike face bridge center is offset from the mid-plane 158 by between 0.5 inch and 1.0 inch. In other embodiments, the sole-to-strike face bridge center is offset from the mid-plane by between 1.0 inch and 2.0 inches.

[0194] The sole-to-strike face bridge length does not extend entirely from the heel end 118 to the toe end 114. Instead, the sole-to-strike face bridge length extends along a only portion of the heel-to-toe length of the transition region in which it lies. In some embodiments, the sole-to-strike face bridge length can be between 0.75 inch and 4 inches. For example, the sole-to-strike face bridge length can be between 0.75 inch and 1 inch, 1 inch and 1.25 inches, 1.25 inches and

1.50 inches, 1.50 inches and 1.75 inches, 1.75 inches and 2 inches, 2 inches and 2.25 inches, 2.25 inches and 2.5 inches, 2.5 inches and 2.75 inches, 2.75 inches and 3 inches, 3 inches and 3.25 inches, 3.25 inches and 3.5 inches, 3.5 inches and 3.75 inches, or 3.75 inches and 4 inches. In some embodiments, the sole-to-strike face bridge length can be between 15% and 85% of the length of the transition region from the heel end 118 to the toe end 114.

[0195] As described above, the sole-to-strike face bridge 110 lies at least partially within the continuous transition region 119. In some embodiments, the sole-to-strike face bridge width extends across the entire transition region front-to-rear width. In some embodiments, the sole-to-strike face bridge width extends across only a portion of the transition region front-to-rear width. In some of these embodiments and others, the sole-to-strike face bridge width extends beyond the continuous transition region 119 and onto the sole 104. The sole-to-strike face bridge width can be between 50% and 100% of the transition region width. In some embodiments wherein the sole-to-strike face bridge extends beyond the transition region, the sole-to-strike face bridge width can be greater than the transition region width. In these embodiments, the sole-to-strike face bridge width can be up to 150% of sole-to-strike face bridge width.

[0196] The sole-to-strike face bridge width does not extend entirely from the strike face 106 to rear of the golf club head 100. In some embodiments, the sole-to-strike face bridge width can be between 0.40 inch and 0.80 inches. For example, the sole-to-strike face bridge width can be between approximately 0.40 inch and approximately 0.50 inch, approximately 0.50 inch and approximately 0.6 inches, approximately 0.6 inches and approximately 0.7 inches, or approximately 0.7 inches and approximately 0.80 inches. In other embodiments, the sole-to-strike face bridge width can be approximately 0.40 inch, approximately 0.45 inch, approximately 0.50 inch, approximately 0.55 inch, approximately 0.60 inch, approximately 0.65 inch, approximately 0.70 inch, approximately 0.75 inch, or approximately 0.80 inch.

[0197] In some embodiments, the sole-to-strike face bridge is integrally formed with at least the portions of the club head which it contacts. The sole-to-strike face bridge, the transition region, and the portion of the sole which the sole-to-strike face bridge lies comprise the same material or combination of materials.

[0198] In some embodiments, the sole-to-strike face bridge 110 has a generally projected rectangular shape when viewed from a top plane. In other embodiments, the sole-to-strike face bridge 110 can have one of the following shapes: oval, circle, trapezoidal, rounded rectangle, square, rounded square, or another polygon.

[0199] The sole-to-strike face bridge 110 can have a variable or constant thickness across the width and/or length. In some of these embodiments, the sole-to-strike face bridge 110 comprises a non-transitioned, constant thickness across both of its width and length. In other embodiments, the sole-to-strike face bridge 110 comprises a constant thickness across only one of the width or length, and a variable (or transitioned) thickness across the other of the width or length.

[0200] In some embodiments, the sole-to-strike face bridge 110 is thickest at its center. In these embodiments, the sole-to-strike face bridge thickness transitions circumferentially (or radially) from the center and the center of the reinforcement region comprises a rounded or pointed peak. In other words, the sole-to-strike face bridge 110 thickness reduces linearly or curvedly away from the center (of both the width and the length) in all directions. The transition rate will vary in some directions relative to others based on the sole-to-strike face bridge dimensions, such that the sole-to-strike face bridge thickness is the same at all edges of the sole-to-strike face bridge. The thickness transitions linearly, curvedly, or in a stepped formation toward its edges in a direction away from the center and toward the front, rear, the heel end 118, and the toe end 114. The front, rear, the heel end 118, and the toe end 114 edges of the sole-to-strike face bridge are transitioned such that they transition substantially seamlessly with the surrounding golf club head. In other words, the thickness of the sole-to-strike face bridge 110 reduces to that of the surrounding golf club head at its edges so as to prevent the existence of a substantial lip or step that differentiates the sole-to-strike face bridge from the surrounding club head.

[0201] In some embodiments, the sole-to-strike face bridge front-to-rear cross-sectional shape differs from the sole-to-strike face bridge heel-to-toe cross-sectional shape. In others of these embodiments, the sole-to-strike face bridge front-to-rear cross-sectional shape is similar to the sole-to-strike face bridge heel-to-toe cross-sectional shape. In some embodiments, the sole-to-strike face bridge comprises a slightly curved cross-sectional shape.

[0202] The crown-to-strike-face bridge and the sole-to-strike face bridge can increase the I_{xx} by adding mass to the crown transition and/or the sole transition thereby locating mass further from the CG in the vertical direction and therefore increasing the force required to rotate the club head in about the X'-axis.

IV. Additional Features

[0203] FIGS. 27-29 schematically illustrate various embodiments of a golf club head 100 in various views. For ease of discussion, the features shown on the golf club head 100 are applicable to various embodiments of the golf club head 100 according to the present invention. Any one or more of the features described in the various embodiments below can be used in combination with one another.

[0204] The golf club head 100 comprises a body 101 that defines an interior cavity 103 that is substantially closed/hollow. The body 101 defines a front 105, a rear 107 opposite the front 105, a heel 116, and a toe 112 opposite the heel 116. The body 101 comprises a strike face 106 near the front 105, a crown 102 near an upper portion of the golf club head 100, and a sole 104 near a lower portion of the golf club head 100. The body 101 further comprises a hosel 111 near the heel 116 for receiving a shaft or an adjustable hosel feature 148.

V. Multi-Material Construction

[0205] In some embodiments, the golf club head 100 is formed of multiple different materials, referred to herein as a “multi-material construction”. More specifically, one or more low-density materials, such as composite, replace metal materials in selected areas of the golf club head 100 to increase discretionary mass, which can be redeployed to increase MOI and/or locate CG as desired. The golf club head 100 body 101 comprises a frame 121 and one or more lightweight inserts. The frame 121 is formed from a metallic material to provide a durable structure that receives the one or more inserts. The frame 121 surrounds or forms one or more openings configured to receive one or more inserts. The frame can surround or form a crown opening 141, a sole opening 143, a central opening 145, or various combinations thereof. The inserts can be crown inserts 122, sole inserts 123, central inserts 124 that continuously wrap around the crown 102, the sole 104, the heel

116, the toe 112, or various combinations thereof. The one or more inserts are secured to the frame 121 to define the body 101.

[0206] The frame 121 can comprise one or more materials such as steel, stainless steel, tungsten, aluminum, titanium, vanadium, chromium, cobalt, nickel, other metals, or metal alloys. In some embodiments, the frame 121 material can comprise a Ti-8Al-1Mo-1V alloy, or a 17-4 stainless steel. In some embodiments, the frame 121 material can be formed from C300, C350, Ni (Nickel)-Co(Cobalt)-Cr(Chromium)-Steel Alloy, 565 Steel, AISI type 304 or AISI type 630 stainless steel, 17-4 stainless steel, a titanium alloy, for example, but not limited to Ti-6-4, Ti-3-8-6-4-4, Ti-10-2-3, Ti 15-3-3-3, Ti 15-5-3, Ti185, Ti 6-6-2, Ti-7s, Ti-9s, Ti-92, or Ti-8-1-1 titanium alloy, an amorphous metal alloy, or other similar metals.

[0207] The one or more inserts are formed from a lightweight composite material, which increases discretionary mass by replacing portions of the body 101 that would otherwise be formed by the frame 121 material. In some embodiments, the one or more inserts can comprise a composite formed from a polymer resin and reinforcing fiber. The polymer resin can comprise a thermoset or a thermoplastic resin. In some embodiments, the one or more composite inserts can comprise a carbon fiber composite material having multiple layers of unidirectional carbon fibers formed as a single, continuous piece. In some embodiments, the one or more composite inserts may comprise a bi-directional woven carbon fiber composite material having a single layer formed as a single, continuous piece. In some embodiments, the one or more composite inserts can comprise a fiber reinforced thermo-plastic material. The one or more composite inserts can be extruded, compression molded, injection molded, blow molded or bladder molded, 3-D printed, or otherwise formed by any other appropriate forming means.

[0208] A golf club head 100 having a body 101 that comprises one or more discrete composite inserts is illustrated in FIGS. 30 and 31. Embodiments comprising one or more discrete composite inserts can include a crown insert 122, a sole insert 123, or a combination thereof. The golf club head 100 can comprise any number of crown inserts 122 and any number of sole inserts 123. Referring to FIG. 4, the crown insert 122 wraps around the heel 116 and the toe 112 and forms a portion of the sole 104. The one or more composite inserts are secured to the frame 121 to define the body 101. Each of the one or more discrete inserts is received within a corresponding opening

located on the frame 121. Each opening is distinct and defined by one or more portions of the frame 121. As discussed above, the frame 121 is formed from a metallic material to provide a sturdy structure for receiving the inserts, and the inserts are formed from a lightweight composite material to create discretionary mass.

[0209] A golf club head 100 having a body 101 that comprises a continuous, central insert 124 (referred to as a “central insert 124”) is illustrated in FIGS. 32 and 33. The central insert 124 is secured to the frame 121 to define the body 101. The central insert 124 wraps continuously around the body 101 and forms at least a portion of the crown, at least a portion of the sole 104, and at least a portion of the body 101 perimeter near both the heel end 118 and the toe end 114. The central insert 124 can be a single component or multiple components. The central insert 124 is received within a central opening located between a forward frame 121A and rearward frame 121B. As discussed above, the frame 121 is formed from a metallic material to provide a sturdy structure for receiving the inserts, and the central insert 124 is formed from a lightweight composite material, to create discretionary mass.

[0210] In some embodiments, the golf club head 100 can comprise an adjustable shaft-receiving mechanism to adjust the loft angle and/or lie angle for a particular player, as best shown in FIG. 65A. The adjustable shaft-receiving mechanism can be similar to those described in U.S. Patent application Ser. No. 15/003,494, filed on January 21, 2016, now U.S. Patent No. 9,868,035, granted on January 16, 2018; and U.S. Patent application Ser. No. 17/304,836, filed on January 25, 2021, now U.S. Patent No. 11,607,590, granted on March 21, 2023; which are both incorporated fully herein by reference.

[0211] In the illustrated embodiment, the adjustable shaft-receiving mechanism comprises a shaft sleeve 1126 configured to receive a golf club shaft and retained within the hosel 111 by a fastener 1127. The shaft sleeve 1126 and the hosel 111 comprise complementary geometries that allow the shaft sleeve 1126 to be removably rotated into a plurality of different configurations. Rotating the shaft sleeve 1126 between different configurations will adjust a loft angle 20 and/or a lie angle 25 of the golf club head 100.

[0212] In some embodiments, as best shown in FIGS. 34 and 35, the golf club head 100 can comprise a lightweight shaft-receiving structure 1125 which creates discretionary mass. Referring

to FIG. 65A, the shaft-receiving structure 1125 has a reduced amount of structural mass. At least a portion of the shaft sleeve 1126 is exposed to the interior cavity 103. In the present embodiment, rather than being retained by an internal structure such as an interior hosel tube or hosel wall, the shaft sleeve 1126 is retained and supported in the golf club head 100 by structures that also form at least a portion of the exterior of the body 101. In many embodiments, the lightweight shaft-receiving structure 1125 comprises an upper end 1128A and a lower end 1128B. In the present embodiment, the shaft sleeve 1126 is secured only at the upper end 1128A and the lower end 1128B. A gap 1130 is formed between the upper end 1128A and lower end 1128B such that the gap 1130 opens into the interior cavity 103. The shaft sleeve 1126 is inserted through a hosel bore opening 1129 and retained at the upper end by the hosel 111. The shaft sleeve 1126 can be secured to the golf club head 100 by a fastener 1127.

[0213] The magnitude of discretionary mass created by the lightweight shaft-receiving structure 1125 can be quantified with reference to a hosel mass zone (HMZ) formed about a hosel axis 30, as shown in FIG. 66. The hosel axis extends longitudinally through the hosel. In particular, the hosel mass zone (HMZ) can be formed as an imaginary cylinder centered about the hosel axis 30 and extending from the hosel bore opening 1129 toward the ground plane 10. The hosel mass zone (HMZ) may have a hosel mass zone radius R_{HMZ} . The radius R_{HMZ} can have a value of 2 times the outer radius (R_H) of the hosel 111.

[0214] The hosel mass zone (HMZ) may contain a small amount of the total golf club head mass. For example, the golf club head mass within the hosel mass zone (HMZ) can be between 5 grams and 35 grams. In some embodiments, the golf club head mass within the hosel mass zone (HMZ) can be less than 35 grams, 30 grams, 25 grams, 20 grams, 15 grams, or less than 10 grams. A hosel mass zone (HMZ) containing a small amount of the golf club head mass is indicative of a lightweight shaft-receiving structure 1125, which effectively removes mass from the heel end 118 of the golf club head 100.

[0215] The golf club head mass within the hosel mass zone (HMZ) can be described relative to the total golf club head mass. In many embodiments, the golf club head mass within the hosel mass zone (HMZ) can be between 1% and 15% of the total golf club head mass. In some embodiments, the golf club head mass within the hosel mass zone (HMZ) can be less than 15%, 14%, 13%, 12%,

11%, 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, or less than 1% of the total golf club head mass. A hosel mass zone (HMZ) containing a small percentage of the golf club head mass is indicative of a lightweight shaft-receiving structure 1125, which effectively removes mass from the heel end 118 of the golf club head 100.

[0216] The lightweight shaft-receiving structure 1125 can create between 3 grams and 12 grams of discretionary mass in comparison to a conventional shaft-receiving structure wherein, the shaft sleeve is concealed from the interior cavity 103 by a supporting structure such as a hosel tube or an interior hosel wall. In some embodiments, the lightweight shaft-receiving structure 1125 can create between 3 grams and 5 grams, 4 grams and 6 grams, 5 grams and 7 grams, 6 grams and 8 grams, 7 grams and 9 grams, 8 grams and 10 grams, 9 grams and 11 grams, or between 10 grams and 12 grams of discretionary mass in comparison to a prior-art shaft receiving structure. In some embodiments, the lightweight shaft-receiving structure 1125 can create greater than 3 grams, 4 grams, 5 grams, 6 grams, 7 grams, 8 grams, 9 grams, or greater than 10 grams of discretionary mass in comparison to a conventional shaft receiving structure. Reducing the mass of the lightweight shaft-receiving structure 1125 by eliminating redundant supporting structures increases discretionary mass to be re-allocated to other areas of the golf club head 100.

[0217] In some embodiments, the golf club head 100 can include one or more weight system(s) 140 comprising one or more removable weight(s) 142. In many embodiments, the weight system can be located in the sole 104 and/or in the rear 107. In some embodiments, the one or more weight system(s) 140 and/or the one or more removable weight(s) 142 can be located towards the sole 104 and rear, thereby locating CG lower and further back on the golf club head 100. In many embodiments, the one or more weight system(s) 140 removably receive the one or more removable weight(s) 142. In these embodiments, the one or more removable weight(s) 142 can be coupled to the one or more weight system(s) 140 using any suitable method, such as a threaded fastener, an adhesive, a magnet, a snap fit, or any other mechanism capable of securing the one or more removable weight(s) 142 to the one or more weight system(s) 140. The one or more removable weight(s) 142 can adjust the moment of inertia (MOI) properties and center of gravity (CG) location.

[0218] The frame 121 can further comprise one or more mass pad(s) 144, as illustrated in FIG. 37. The one or more mass pad(s) 144 distribute weight around the golf club head 100 to achieve desired performance characteristics, such as increasing MOI or locating CG in a desirable position. The one or more mass pad(s) 144 comprise fixed concentrations of material in locations that can alter MOI, CG, or other parameters associated with the golf club head 100. The frame 121 can comprise one or more mass pad(s) 144 located along a desired portion of the frame 121. In many embodiments, discretionary mass can be distributed to the one or more mass pad(s) 144. In some embodiments, the one or more mass pad(s) 144 can be formed integrally with the frame 121. In other embodiments, the one or more mass pad(s) 144 can be formed separately and attached to the frame 121 via a coupling mechanism such as welding, brazing, mechanical coupling, adhesive coupling, or any other suitable means. In many embodiments, the one or more mass pad(s) 144 can contact a portion of the one or more composite inserts.

[0219] The golf club head 100 can include external features that produce aerodynamic effects, such as one or more turbulator(s) 146 as described in U.S. Patent application Ser. No. 13/536,753, filed on June 28, 2021, now U.S. Pat. No. 8,608,587, granted on Dec. 17, 2013, entitled "Golf Club Heads with Turbulators and Methods to Manufacture Golf Club Heads with Turbulators," which is fully incorporated herein by reference. Turbulators alter the aerodynamic crown profile by disrupting and delaying flow separation, thereby reducing drag produced by the golf club head 100 during a swing.

[0220] The plurality of turbulators 146 can project from an outer surface of the crown 102 and include a length, extending between the front 105 and the rear 107 of the golf club head 100, and a width, extending from the heel 116 to the toe 112 of the golf club head 100 as illustrated in FIG. 31. In many embodiments, the length of each turbulator (in a front-to-rear direction) is greater than its width (in a heel-to-toe direction). In some embodiments, each the plurality of turbulators 146 comprises the same width. In some embodiments, one or more of the plurality of turbulators 146 can vary in height relative to the native contour of the golf club head 100 outer surface. In some embodiments, one or more of the plurality of turbulators 146 can have a greater height toward the apex of the crown 102 than near the front of the crown 102. In other embodiments, the plurality of turbulators 146 can have a greater height toward the front of the crown 102 and lower in height

toward the apex of the crown 102. In other embodiments, the plurality of turbulators 146 can comprise a constant height profile. Further, in some embodiments, at least a portion of at least one turbulator 146 is located between the strike face and an apex of the crown 102, and the spacing between adjacent turbulators 146 is greater than the width of each of the adjacent turbulators 146.

[0221] The wood type golf club heads disclosed herein can be a driver type golf club head, a fairway type golf club head, or a hybrid type golf club head. The various variable face thickness profiles and the features described herein can be used with an iron-type golf club head, including a hollow body iron-type golf club head and a cavity back iron-type golf club head.

VI. Example I

[0222] Described herein are qualitative and quantitative test data comparing three wood-type club heads having different strike face profiles, as described above. The findings include player test results comparing ball flight characteristics (i.e., ball speed, launch angle, spin rate, carry distance, and max height). Further, the test compared the effect of the different strike face profiles on player satisfaction regarding the club head performance. Players provided feedback on notable metrics pertaining to qualitative club head performance, including perceived club head responsiveness (or “feedback”), perceived performance, and sound desirability. Players also considered the club head responsiveness (or “feel”) to be encompassed by performance. In general, golfers tend to correlate good club head performance with increased ball speed, straight ball flight, a soft feel, and limited off-center spin.

[0223] The first wood-type club head (hereafter referred to as the “first exemplary club head”) comprised a strike face including an outer periphery, a border perimeter, a thin periphery, an outer transition, an inner transition, a hinge, a central transition, and a central region. The central region comprises the thickest region of the strike face and is surrounded by the central transition. The hinge surrounds the central region and comprises a localized thin ring-like structure surrounding the central region. The strike face performance characteristics of the first exemplary club head significantly relates to the relationship between the central region and the hinge.

[0224] The second wood-type club head (hereafter referred to as the “control club head”) differs from the first exemplary club head. Specifically, the control club head was devoid of a

hinge and a crown-to-strike face bridge and a sole-to-strike face bridge. However, like the exemplary club head, the control club head comprises a central region and a transition region surrounding the central region. Further, the central region of the control club head comprises the thickest region of the strike face.

TABLE 1

Club	Launch Angle (degrees)	Spin Rate (rpm)	Carry Distance (yds)	Max Height (yds)
Control Club Head	13.5	2424	257.6	31.3
First Exemplary Club Head (Central Region and Hinge)	13.8	2638	258.2	33.7

[0225] The first exemplary club head performed similarly to the control club head with respect to each ball flight metric. Specifically, the first exemplary club head exhibited a 0.3-degree increase (2.2% increase) in launch angle, a 214-rpm increase (8.8% increase) in spin rate, a 0.6-yard increase (0.23% increase) in carry distance, and a 2.4-yard increase (7.7% increase) in maximum height. In general, the ball flight metrics of the first exemplary embodiment were preferable compared to the control club head. Specifically, the carry distance is improved along with a greater spin rate which corresponds to better stopping power.

[0226] After testing, the participants compared the first exemplary club head and the control club head based on perceived performance, analyzed by perceived responsiveness (or “feedback”) and sound desirability. As such, participants were asked to compare the performance of the first exemplary club head to the control club head on a scale from “Moderately Less Desirable” to “Moderately More Desirable.” In between these choices, there was: “Slightly Less Desirable”, “No Difference”, and “Slightly More Desirable.” “Moderately Less Desirable” represented a decrease in satisfaction relative to the control club head, “Slightly Less Desirable” represented a slight decrease in satisfaction relative to the control club head, “No Difference” represented similar satisfaction between the first exemplary club head and the control club head, “Slightly More

Desirable” represented a moderate increase in satisfaction relative to the control club head, and “Moderately More Desirable” represented a substantial increase in satisfaction relative to the control club head.

TABLE 2

Feedback Desirability between the First Exemplary Club Head and Control Club Head						
	Moderately Less Desirable	Slightly Less Desirable	No Difference	Slightly More Desirable	Moderately More Desirable	Total Votes
First Exemplary Club Head (Central Region and Hinge) [Rev3]	0	5	6	6	0	17

TABLE 3

Summary of Table 2 Data	
Number of Participants who Voted Slightly More Desirable or Moderately More Desirable	6
Number of Participants who Voted No Difference	6
Total Number Participants	17
Percentage of Participants who Voted Slightly More Desirable or Moderately More Desirable	35%
Percentage of Participants who Voted No Difference or Better	71%

[0227] Table 2 above exhibits participant responses comparing the first exemplary club head to the control club head for feedback. Table 3 above illustrates the percentage of players who ranked the exemplary club head “No Difference”, “Slightly More Desirable”, or “Moderately More Desirable” than the control club head for feedback. The first exemplary club head was rated “No Difference”, “Slightly More Desirable”, or “Moderately More Desirable” when compared to

the control club head by 71% of the participants. Further, the exemplary club head was rated “Slightly More Desirable”, or “Moderately More Desirable” when compared to the control club head by 35% of the participants.

TABLE 4

Sound Desirability between the First Exemplary Club Head and Control Club Head						
	Moderately Less Desirable	Slightly Less Desirable	No Difference	Slightly More Desirable	Moderately More Desirable	Total Votes
First Exemplary Club Head (Central Region and Hinge) [Rev3]	0	3	5	8	2	18

TABLE 5

Summary of Table 4 Data	
Number of Participants who Voted Slightly More Desirable or Moderately More Desirable	10
Number of Participants who Voted No Difference	5
Total Number Participants	18
Percentage of Participants who Voted Slightly More Desirable or Moderately More Desirable	56%
Percentage of Participants who Voted No Difference or Better	83%

[0228] Table 4 above exhibits participant responses comparing the first exemplary club head to the control club head for sound desirability. Table 5 above illustrates the percentage of players who ranked the exemplary club head “No Difference”, “Slightly More Desirable”, or “Moderately More Desirable” than the control club head for feedback. The first exemplary club head was rated “No Difference”, “Slightly More Desirable”, or “Moderately More Desirable” when compared to the control club head by 83% of the participants. Further, the exemplary club head was rated

“Slightly More Desirable”, or “Moderately More Desirable” when compared to the control club head by 56% of the participants.

[0229] The player tests resulted in the first exemplary club head outperforming the qualitative parameters of the control club head (*e.g.*, perceived feedback and sound desirability). The participants in the player test felt the first exemplary club head provided better feedback and sound than the control club head. The hinge, central transition, and central region of the first exemplary club head provide advantages over the control club head. Particularly, this strike face configuration increased faceplate flexibility and deformation, leading to an increase in real and perceived feedback, as well as proved to be audibly superior to the control club head.

VII. Example II

[0230] In addition to general ball flight and feedback characteristics, the aforementioned player tests resulted in comparative analyses of ball speed for the examined club heads. An additional club (a second exemplary club head) had additional features relative to the first exemplary club head and the control club head. Specifically, the second exemplary club head comprises similar features compared to the first exemplary club head. These similar features includes a strike face including an outer periphery, a border perimeter, a thin periphery, an outer transition, an inner transition, a hinge, a central transition, and a central region. The central region comprises the thickest region of the strike face and is surrounded by the central transition. The hinge surrounds the central region and comprises a localized thin ring-like structure surrounding the central region. Unlike the first exemplary club head, however, the second exemplary club head comprises a crown-to-strike face bridge and a sole-to-strike face bridge centrally positioned between the heel and toe of the club head and comprising a relatively rectangular shape. Furthermore, these bridges partially span across a crown transition region and a sole transition region, respectively. The strike face performance characteristics of the second exemplary club head relates to the combination of the crown-to-strike face bridge and sole-to-strike face bridge, the central region, and the hinge.

[0231] This player test, which utilized a robotic mechanism to simulate a standardized golf speed producing a club head speed of approximately 105 mph, reported a 0.6 mph gain in ball

speed between the control club head and the first exemplary embodiment, and a 0.9 mph gain in ball speed between the control club head and the second exemplary club head. In general, these ball speed gains result in up to 4-yards of additional carry distance, under certain conditions. The inclusion of the hinge in the first and second exemplary club heads increases strike face deflection, therefore, improving ball speed. Subsequently, the crown-to-strike face bridge and a sole-to-strike face bridge of the second exemplary club head improves structural rigidity of the strike face which also has a positive impact on ball speed compared to the first exemplary embodiment.

VIII. Example III

[0232] Described herein are computer-simulated durability and performance test data comparing three wood-type club heads having different strike face profiles, as described above. The findings include strike face durability and stress characteristics. Increasing strike face deflection allows for greater responsiveness and performance upon impact. However, variable face thickness profiles must ensure sufficient resiliency in order to avoid failure or critical deformation. Designing these variable thickness profiles in a way that achieves performance gains while maintaining durability is a crucial balance for successful club head design.

[0233] The first wood-type club head (hereafter referred to as the “Club A”) is structurally similar to the first exemplary club head of Example 1. Particularly, Club A comprised a strike face including an outer periphery, a border perimeter, a thin periphery, an outer transition, an inner transition, a hinge, a central transition, and a central region. The central region comprises the thickest region of the strike face and is surrounded by the central transition. The hinge surrounds the central region and comprises a localized thin ring-like structure surrounding the central region. The central region further defines a thickness of 0.137 inch. Moreover, the central transition comprised a central transition width of 0.150 inch and the inner transition comprised an inner transition width of 0.200 inch. Therefore, the sum of the central transition width and the inner transition width of Club A is 0.350 inch. Furthermore, a first distance perpendicular (hereafter “Depth A”) to the central region to the hinge is 0.042 inch and second distance (hereafter “Depth B”) perpendicular to the central region and a junction between the inner and outer transition regions is 0.033 inch.

[0234] The second wood-type club head (hereafter referred to as the “Club B”) is structurally similar to Club A. Particularly, Club B comprised each strike face region of the Club A. Namely, Club B defines a central region with a thickness of 0.137 inch. Alternatively, Club B comprised alternative region widths and thickness compared to Club A. Specifically, the central transition comprised a central transition width of 0.300 inch and the inner transition comprised an inner transition width of 0.200 inch. Therefore, the sum of the central transition width and the inner transition width of Club B is 0.500 inch. Furthermore, a first distance (hereafter “Depth A”) perpendicular to the central region to the hinge is 0.042 inch and second distance (hereafter “Depth B”) perpendicular to the central region and a junction between the inner and outer transitions is 0.033 inch. The hinge of Club B is spaced further from the center of the strike face when compared to the hinge of Club A. Specifically, the Club B hinge is spaced 0.150 inch further from the strike face center than the Club A hinge. Subsequently, the junction between the inner and outer transitions is closer to the perimeter of the strike face in the Club B.

[0235] The third wood-type club head (hereafter referred to as the “control club head”) is structurally identical to the control club head described in Example 1. As previously mentioned, the control club head was devoid of a hinge and a crown-to-strike face bridge and a sole-to-strike face bridge. However, like Club A and Club B, the control club head comprised a central region and a transition region surrounding the central region. Further, the central region of the control club head comprises the thickest region of the strike face. Similar to the aforementioned Clubs A and B, the control club head central region defines a thickness of 0.137 inch. Table 6, shown below, displays an overview of the geometric dimensions, including thicknesses, depths, and widths, for the analyzed club heads.

Table 6

Club Head	Central Transition Width (inch)	Inner Transition Width	Central Region Thickness	Depth A	Depth B
Control Club Head	N/A	N/A	0.137	N/A	N/A
Club A	0.150	0.200	0.137	0.042	0.033

Club B	0.300	0.200	0.137	0.042	0.033
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[0236] As previously discussed, the strike face features of the Clubs A and B offer performance improvements from generic club head strike faces. Namely, the combination of the hinge, central transition, and central region of Clubs A and B provide increased faceplate flexibility and deformation, leading to an increase in ball speed and other launch characteristics, as well as providing superior audible characteristics. By varying the widths, thicknesses, and depths of each strike face variable-thickness region, durability can be maintained along with the targeted faceplate deformation.

[0237] Finite Element Analysis (FEA) simulations were used to analyze the durability characteristics of the control, Club A, and Club B heads. The test data resulted in strike face maps depicting the locations of high-stress regions. These high-stress regions generally define the locations with a greater risk of failure. However, other stress characteristics such as peak stress, average stress, and material properties affect durability, as well. Analyzing each of these factors to mitigate the risk of failure is crucial to designing a strike face that achieves ample durability and resistance to failure upon multiple impacts. Subsequently, one specific characteristic of these high-stress regions is area density. Stress area density defines how compact areas of high stress are relative to each other. Limiting high-stress regions with compact area densities allows greater stresses to be distributed across the strike face, limiting the probability of isolated failure. In relation to the control, Club A, and Club B heads, a stress-surface area [in^2] (SSA) measurement was obtained to analyze strike face durability. Particularly, SSA is a ratio between the simulated stress surface area (limited to stresses greater than 142ksi) and the total surface area of the strike face [in^2].

$$SSA = (\text{Stress Area})/(\text{Total Strike Face Area})$$

[0238] A strike face with a large SSA comprises high-stress regions that are spread across the face, leading to a lower chance of critical failure at precise points along the strike face. Alternatively, a strike face with a small SSA comprises high-stress regions that are compact, leading to a higher chance of failure at these compact stress regions. As previously mentioned,

however, there are other factors that impact durability in view of stress-surface area properties. For example, the strike face geometry determines failure vulnerability at particular locations, as well. Specifically, stresses isolated to a thickened strike face region will generally be less likely to fail relative to identical stresses isolated to a thinned strike face region. The maximum or peak stress value may determine which variable thickness designs are more prone to high stresses, as well. Likewise, average stress values provide insight regarding the totality of stresses across a strike face surface. Therefore, it is important to analyze multiple strike face characteristics when comparing and testing variable thickness strike faces for durability.

Table 7

Club Head	Central Region Thickness (in.)	FEA-Simulated Stress Area (Stresses > 142ksi) [in ²]	Total Strike Face Area [in ²]	SSA (Stress Area/Total Strike Face Area)
Control Club Head	0.128	1.78	4.0	0.445
Club A	0.137	1.82	4.0	0.455
Club B	0.137	1.03	4.0	0.258

[0239] Table 7 above shows the FEA-simulated stress-area values and calculated SSA values between the control club head, Club A, and Club B. Further, Table 7 displays geometric characteristics of the analyzed club heads, such as the central region thicknesses and strike face surface areas. FIG. 39 illustrates the location of the stresses greater than 142 ksi on the strike face of each analyzed club head. The given stress limit of 142 ksi marks the stress limit for the given strike face material. Upon re-examination utilizing an alternative strike face material, the stress limit may vary. The control club head, which comprised an SSA value of 0.445, contained high stresses isolated near or within the strike face central region. Club A, which comprised an SSA value of 0.455, contained high stresses isolated to the upper portion of the hinge and the lower portion of the hinge. Further, Club B, which comprised an SSA value of 0.258, contained high stresses scattered along the central region and areas near the lower portion of the hinge.

[0240] The control club head and Club A define relatively similar SSA values (0.445 and 0.455, respectively). FIG. 39, however, displays that these high stress regions for Club A are to a greater degree located along thin regions of the strike face than the control club head. Specifically, Club A displays high stresses along the hinge, while the control club head displays high stresses along the central region. Therefore, Club A realizes a greater probability of failure at the strike face when compared to the control club head, due to the location of the realized stresses. However, the inclusion of the hinge and localized thin and thick regions around the central region target performance benefits (i.e., ball speed) relative to the control club head. Adjusting the geometric characteristics of the exemplary club heads (i.e., face thicknesses and localized thin/thick region dimensions) can display ample ball flight and launch improvements while dissipating stresses to areas more capable of withstanding failure.

[0241] The differences between Club A and Club B describe how the dimensions of the hinge and surrounding transition regions, relative to the central region, can relocate high stresses to thicker strike face regions. Particularly, the orientation of the non-linear bending region (generalized by the subwoofer-like topography, as described above) works to balance performance gains and durability maintenance. Though Club A defines a greater SSA value than Club B (0.455 and 0.258, respectively), FIG. 39 shows Club B strike face stresses that are more scattered relative Club A. Specifically, these stresses are located near the center of the strike face which comprises an area of greater thickness. Therefore, adjusting the localized thin and thick region dimensions (in this case, the hinge), has a direct impact on strike face stress locations and, in turn, durability.

CLAUSES

[0242] Clause 1. A golf club head, comprising: a strike face, a crown portion, a sole portion, a rear portion, a toe portion, a heel portion, and a skirt forming a hollow interior cavity, wherein the strike face comprises: a geometric center, a strike face perimeter, an outer periphery, a border perimeter, a thin periphery, an outer transition, an inner transition, a central transition, a hinge located between the central transition and the inner transition, and a central region, wherein: the central region comprises a central region thickness, the hinge comprises a hinge thickness, the outer periphery comprises an outer periphery thickness, and the thin periphery comprises a thin periphery thickness, wherein the central region thickness, the hinge thickness,

the outer periphery thickness, and the thin periphery thickness are constant, wherein the outer transition comprises an outer transition thickness, the inner transition comprises an inner transition thickness, and the central transition comprises a central transition thickness; wherein the outer transition thickness, the inner transition thickness, and the central transition thickness are not constant.

[0243] Clause 2. The golf club head of Clause 1, wherein the central region thickness is greater than the central transition thickness and the inner transition thickness, and the hinge thickness is less than the central transition thickness and the inner transition thickness.

[0244] Clause 3. The golf club head of Clause 2, wherein the central region thickness comprises a global maximum thickness of the strike face.

[0245] Clause 4. The golf club head of Clause 1, wherein the central region thickness is between 0.120 inch and 0.150 inch, the hinge thickness is between 0.0875 inch and 0.100 inch, the outer periphery thickness is between 0.09 inch to 0.11 inch, and the thin periphery thickness is between 0.07 inch and 0.08 inch.

[0246] Clause 5. The golf club head of Clause 1, wherein the central region comprises a shape from the group consisting of elliptical, oval, circular, egg, asymmetric elliptical, and oblong-ellipse.

[0247] Clause 6. The golf club head of Clause 1, wherein the central region further comprises a central region geometric center substantially coinciding with the strike face geometric center.

[0248] Clause 7. The golf club head of Clause 1, wherein the central region further comprises a central region geometric center offset from the strike face geometric center an x-axis distance between 0.0125 inch and 1.0 inch and a y-axis distance between 0.0125 inch and 1.0 inch.

[0249] Clause 8. The golf club head of Clause 1, wherein the central region comprises a central region offset angle formed between a central region major axis and a club head x-axis, wherein the central region offset angle is positive relative to the x-axis, such that the positive central region offset angle defines a toe-up central region orientation, and the central region offset angle between 0-degrees and 25-degrees.

[0250] Clause 9. The golf club head of Clause 1, wherein the central region comprises a central region offset angle formed between a central region major axis and a club head x-axis, wherein the central region offset angle is negative relative to the x-axis, such that the negative central region offset angle defines a toe-down central region orientation, and the central region offset angle is between 0-degrees and 25-degrees.

[0251] Clause 10. The golf club head of Clause 1, wherein the central region thickness is between 0.12 inch to 0.17 inch.

[0252] Clause 11. The golf club head of Clause 1, wherein the club head further comprises a weight port configured to receive and retain a removable weight.

[0253] Clause 12. The golf club head of Clause 1, wherein the club head comprises an adjustable shaft-receiving mechanism, wherein the adjustable shaft-receiving mechanism comprises a shaft sleeve configured to receive a golf club shaft and is retained within a club head hosel by a fastener; and wherein the adjustable shaft-receiving mechanism is configured to adjust a club head loft angle by rotating the shaft sleeve.

[0254] Clause 13. A golf club head, comprising: a strike face, a crown portion, a sole portion, a rear portion, a toe portion, a heel portion, and a skirt forming a hollow interior cavity, wherein the strike face comprises: a geometric center, a strike face perimeter, an outer periphery, a border perimeter, a thin periphery, an outer transition, an inner transition, a central transition, a hinge located between the central transition and the inner transition, and a central region, wherein: the central region comprises a central region thickness, the hinge comprises a hinge thickness, the outer periphery comprises an outer periphery thickness, and the thin periphery comprises a thin periphery thickness, wherein the central region thickness, the hinge thickness, the outer periphery thickness, and the thin periphery thickness are constant, wherein the outer transition comprises an outer transition thickness, the inner transition comprises an inner transition thickness, and the central transition comprises a central transition thickness; wherein the outer transition thickness, the inner transition thickness, and the central transition thickness are not constant. wherein: the central transition comprises a central transition width measured between an outermost margin of the central region to an innermost margin of the central transition, and the inner transition comprises an inner transition width measured between an innermost margin

of the inner transition to an outermost margin of the inner transition; wherein the central transition width is between 0.250 inch and 0.350 inch, and the inner transition width is between 0.150 inch and 0.250 inch.

[0255] Clause 14. The golf club head of Clause 13, wherein the central region thickness is greater than the central transition thickness and the inner transition thickness, and the hinge thickness is less than the central transition thickness and the inner transition thickness.

[0256] Clause 15. The golf club head of Clause 14, wherein the central region thickness comprises a global maximum thickness of the strike face.

[0257] Clause 16. The golf club head of Clause 13, wherein the central region thickness is between 0.120 inch and 0.150 inch, the hinge thickness is between 0.0875 inch and 0.100 inch, the outer periphery thickness is between 0.09 inch to 0.11 inch, and the thin periphery thickness is between 0.07 inch and 0.08 inch.

[0258] Clause 17. The golf club head of Clause 13, wherein the central region comprises a shape from the group consisting of elliptical, oval, circular, egg, asymmetric elliptical, and oblong-ellipse.

[0259] Clause 18. The golf club head of Clause 13, wherein the central region further comprises a central region geometric center substantially coinciding with the strike face geometric center.

[0260] Clause 19. The golf club head of Clause 13, wherein the central region further comprises a central region geometric center offset from the strike face geometric center an x-axis distance between 0.0125 inch and 1.0 inch and a y-axis distance between 0.0125 inch and 1.0 inch.

[0261] Clause 20. The golf club head of Clause 13, wherein the central region comprises a central region offset angle formed between a central region major axis and a club head x-axis, wherein the central region offset angle is positive relative to the x-axis, such that the positive central region offset angle defines a toe-up central region orientation, and the central region offset angle between 0-degrees and 25-degrees.

[0262] Clause 21. The golf club head of Clause 13, wherein the central region comprises a central region offset angle formed between a central region major axis and a club head x-axis,

wherein the central region offset angle is negative relative to the x-axis, such that the negative central region offset angle defines a toe-down central region orientation, and the central region offset angle is between 0-degrees and 25-degrees.

[0263] Clause 22. The golf club head of Clause 13, wherein the central region thickness is between 0.12 inch to 0.17 inch.

[0264] Clause 23. The golf club head of Clause 13, wherein the club head further comprises a weight port configured to receive and retain a removable weight.

[0265] Clause 24. The golf club head of Clause 13, wherein the club head comprises an adjustable shaft-receiving mechanism, wherein the adjustable shaft-receiving mechanism comprises a shaft sleeve configured to receive a golf club shaft and is retained within a club head hosel by a fastener; and wherein the adjustable shaft-receiving mechanism is configured to adjust a club head loft angle by rotating the shaft sleeve.

[0266] Replacement of one or more claimed elements constitutes reconstruction and not repair. Additionally, benefits, other advantages, and solutions to problems have been described with regard to specific embodiments. The benefits, advantages, solutions to problems, and any element or elements that may cause any benefit, advantage, or solution to occur or become more pronounced, however, are not to be construed as critical, required, or essential features or elements of any or all of the claims, unless such benefits, advantages, solutions, or elements are stated in such claim.

[0267] Moreover, embodiments and limitations disclosed herein are not dedicated to the public under the doctrine of dedication if the embodiments and/or limitations: (1) are not expressly claimed in the claims; and (2) are or are potentially equivalents of express elements and/or limitations in the claims under the doctrine of equivalents.

CLAIMS

1. A golf club head, comprising:
a strike face, a crown portion, a sole portion, a rear portion, a toe portion, a heel portion, and a skirt forming a hollow interior cavity,
wherein the strike face comprises:
a geometric center,
a strike face perimeter, an outer periphery, a border perimeter, a thin periphery, an outer transition, an inner transition, a central transition, a hinge located between the central transition and the inner transition, and
a central region,
wherein:
the central region comprises a central region thickness,
the hinge comprises a hinge thickness,
the outer periphery comprises an outer periphery thickness, and
the thin periphery comprises a thin periphery thickness,
wherein the central region thickness, the hinge thickness, the outer periphery thickness, and the thin periphery thickness are constant,
wherein the outer transition comprises an outer transition thickness, the inner transition comprises an inner transition thickness, and the central transition comprises a central transition thickness;
wherein the outer transition thickness, the inner transition thickness, and the central transition thickness are not constant.
2. The golf club head of claim 1, wherein the central region thickness is greater than the central transition thickness and the inner transition thickness, and the hinge thickness is less than the central transition thickness and the inner transition thickness.
3. The golf club head of claim 2, wherein the central region thickness comprises a global maximum thickness of the strike face.

4. The golf club head of claim 1, wherein the central region thickness is between 0.120 inch and 0.150 inch, the hinge thickness is between 0.0875 inch and 0.100 inch, the outer periphery thickness is between 0.09 inch to 0.11 inch, and the thin periphery thickness is between 0.07 inch and 0.08 inch.
5. The golf club head of claim 1, wherein the central region comprises a shape from the group consisting of elliptical, oval, circular, egg, asymmetric elliptical, and oblong-ellipse.
6. The golf club head of claim 1, wherein the central region further comprises a central region geometric center substantially coinciding with the strike face geometric center.
7. The golf club head of claim 1, wherein the central region further comprises a central region geometric center offset from the strike face geometric center an x-axis distance between 0.0125 inch and 1.0 inch and a y-axis distance between 0.0125 inch and 1.0 inch.
8. The golf club head of claim 1, wherein the central region comprises a central region offset angle formed between a central region major axis and a club head x-axis, wherein the central region offset angle is positive relative to the x-axis, such that the positive central region offset angle defines a toe-up central region orientation, and the central region offset angle between 0-degrees and 25-degrees.
9. The golf club head of claim 1, wherein the central region comprises a central region offset angle formed between a central region major axis and a club head x-axis, wherein the central region offset angle is negative relative to the x-axis, such that the negative central region offset angle defines a toe-down central region orientation, and the central region offset angle is between 0-degrees and 25-degrees.

10. The golf club head of claim 1, wherein the central region thickness is between 0.12 inch to 0.17 inch.

11. A golf club head, comprising:

a strike face, a crown portion, a sole portion, a rear portion, a toe portion, a heel portion, and a skirt forming a hollow interior cavity,

wherein the strike face comprises:

a geometric center,

a strike face perimeter, an outer periphery, a border perimeter, a thin periphery, an outer transition, an inner transition, a central transition, a hinge located between the central transition and the inner transition, and a central region,

wherein:

the central region comprises a central region thickness,

the hinge comprises a hinge thickness,

the outer periphery comprises an outer periphery thickness, and

the thin periphery comprises a thin periphery thickness,

wherein the central region thickness, the hinge thickness, the outer periphery thickness, and the thin periphery thickness are constant,

wherein the outer transition comprises an outer transition thickness, the inner transition comprises an inner transition thickness, and the central transition comprises a central transition thickness;

wherein the outer transition thickness, the inner transition thickness, and the central transition thickness are not constant;

wherein:

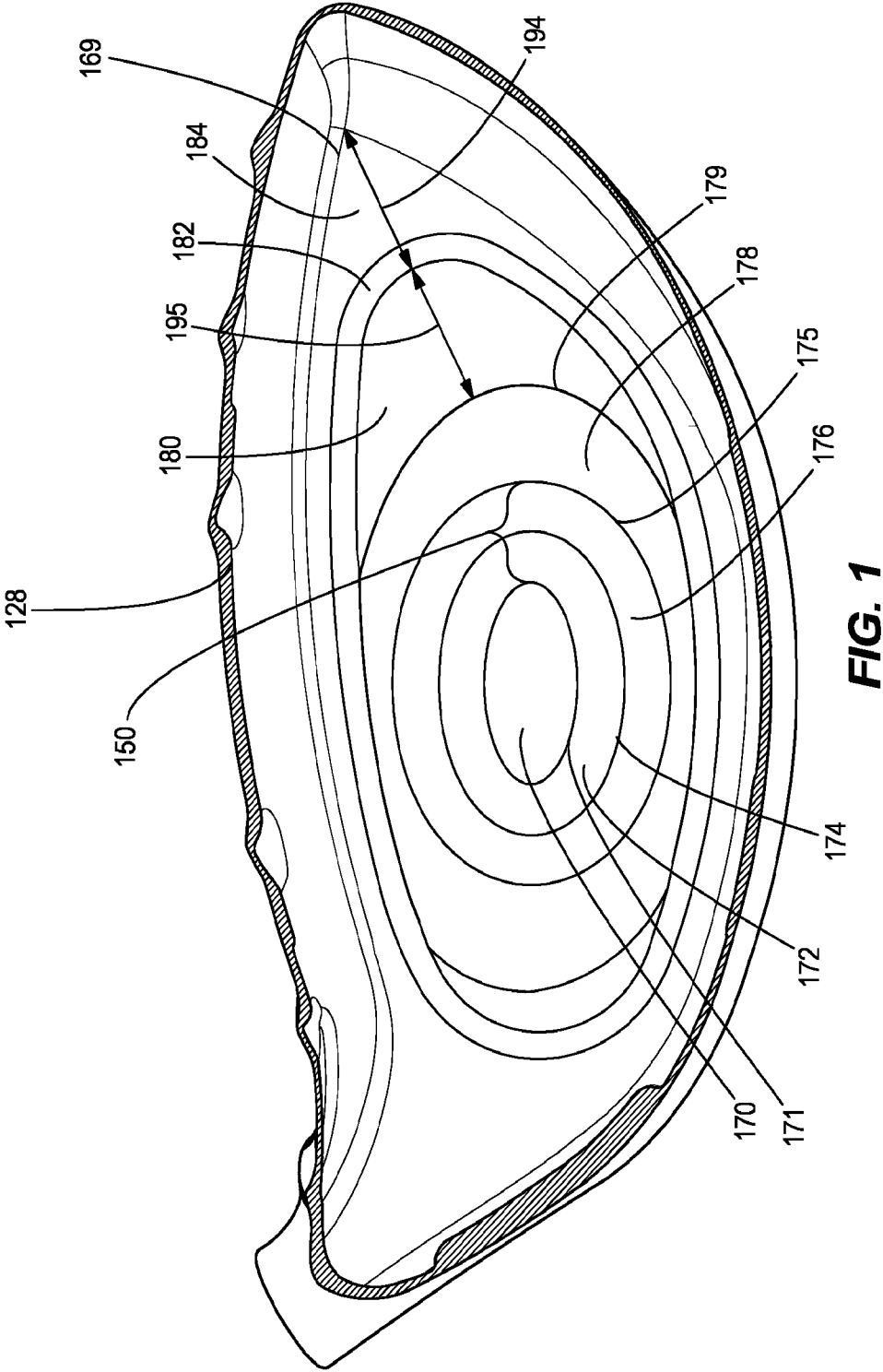
the central transition comprises a central transition width measured between an outermost margin of the central region to an innermost margin of the central transition, and

the inner transition comprises an inner transition width measured between an innermost margin of the inner transition to an outermost margin of the inner transition;

wherein the central transition width is between 0.250 inch and 0.350 inch, and the inner transition width is between 0.150 inch and 0.250 inch.

12. The golf club head of claim 11, wherein the central region thickness is greater than the central transition thickness and the inner transition thickness, and the hinge thickness is less than the central transition thickness and the inner transition thickness.
13. The golf club head of claim 12, wherein the central region thickness comprises a global maximum thickness of the strike face.
14. The golf club head of claim 11, wherein the central region thickness is between 0.120 inch and 0.150 inch, the hinge thickness is between 0.0875 inch and 0.100 inch, the outer periphery thickness is between 0.09 inch to 0.11 inch, and the thin periphery thickness is between 0.07 inch and 0.08 inch.
15. The golf club head of claim 11, wherein the central region comprises a shape from the group consisting of elliptical, oval, circular, egg, asymmetric elliptical, and oblong-ellipse.
16. The golf club head of claim 11, wherein the central region further comprises a central region geometric center substantially coinciding with the strike face geometric center.
17. The golf club head of claim 11, wherein the central region further comprises a central region geometric center offset from the strike face geometric center an x-axis distance between 0.0125 inch and 1.0 inch and a y-axis distance between 0.0125 inch and 1.0 inch.

18. The golf club head of claim 11, wherein the central region comprises a central region offset angle formed between a central region major axis and a club head x-axis, wherein the central region offset angle is positive relative to the x-axis, such that the positive central region offset angle defines a toe-up central region orientation, and the central region offset angle between 0-degrees and 25-degrees.
19. The golf club head of claim 11, wherein the central region comprises a central region offset angle formed between a central region major axis and a club head x-axis, wherein the central region offset angle is negative relative to the x-axis, such that the negative central region offset angle defines a toe-down central region orientation, and the central region offset angle is between 0-degrees and 25-degrees.
20. The golf club head of claim 11, wherein the central region thickness is between 0.12 inch to 0.17 inch.



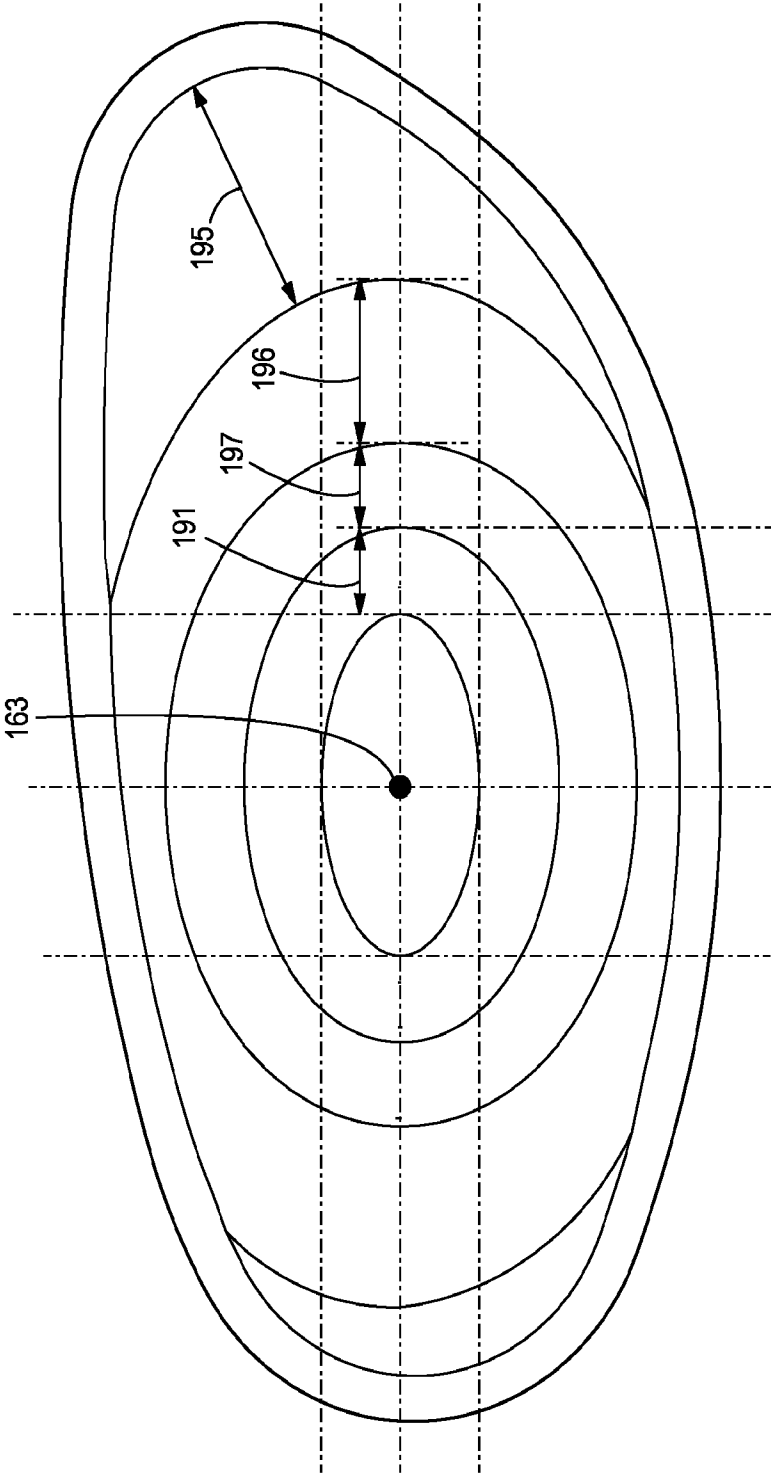
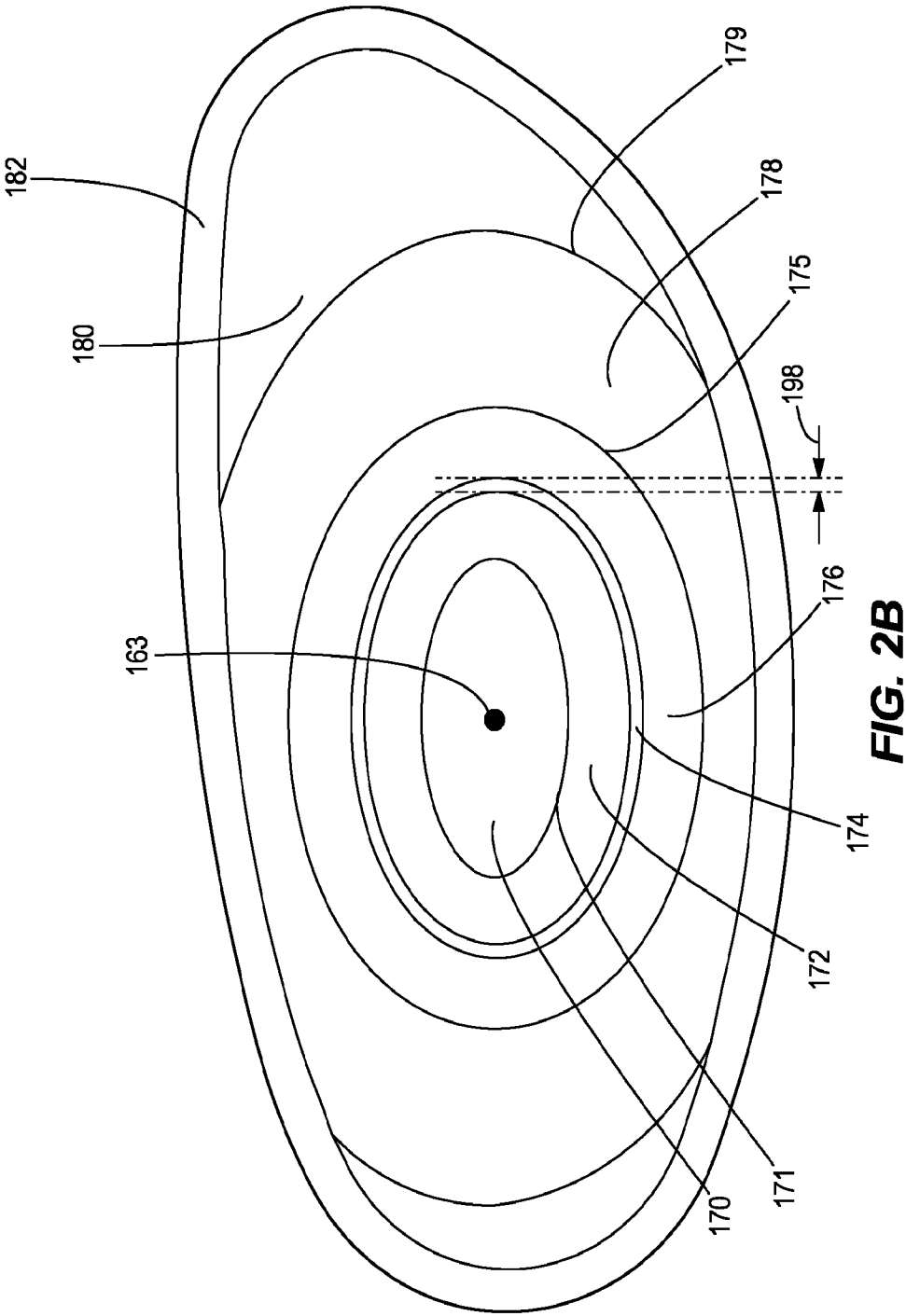
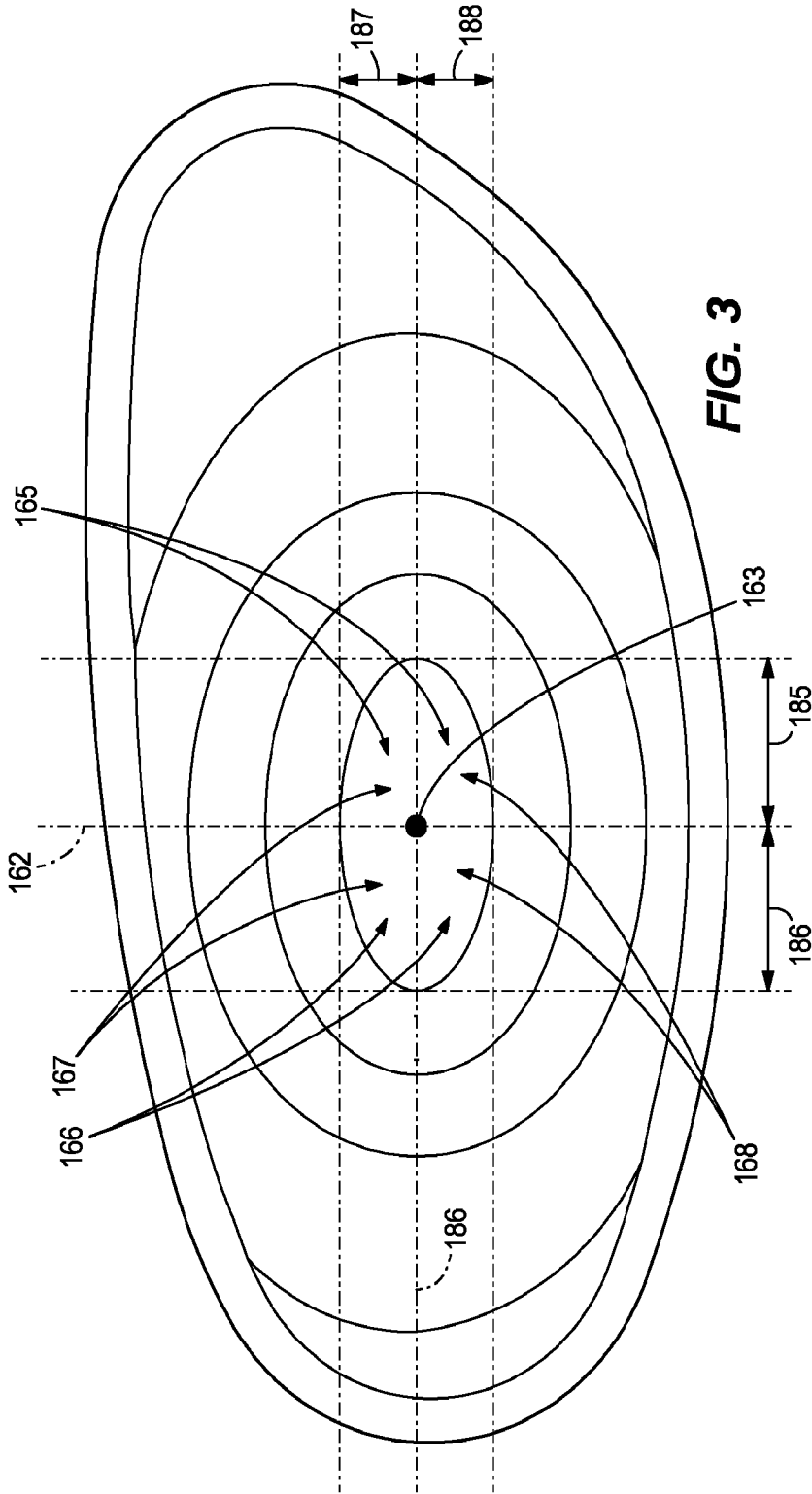
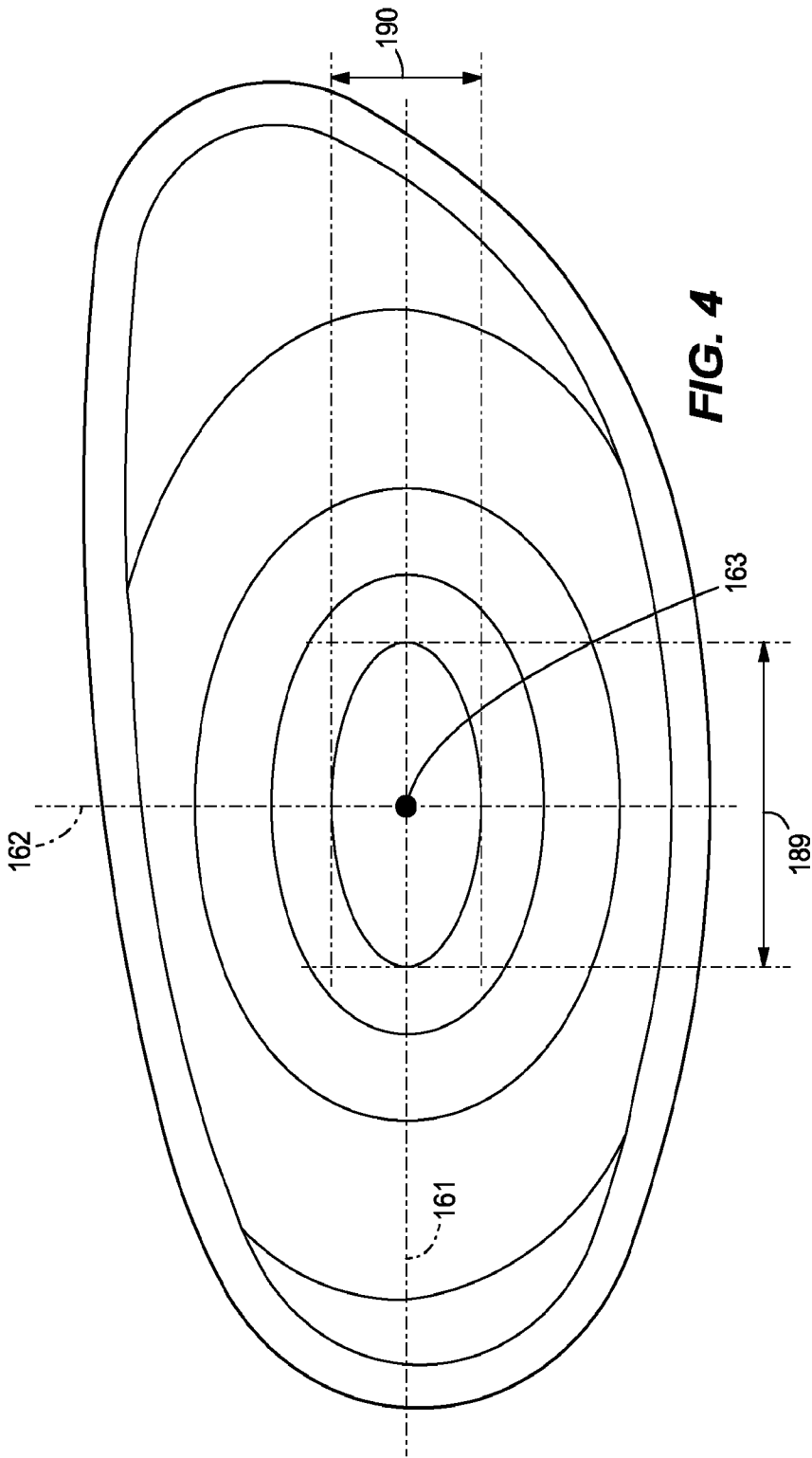


FIG. 2A





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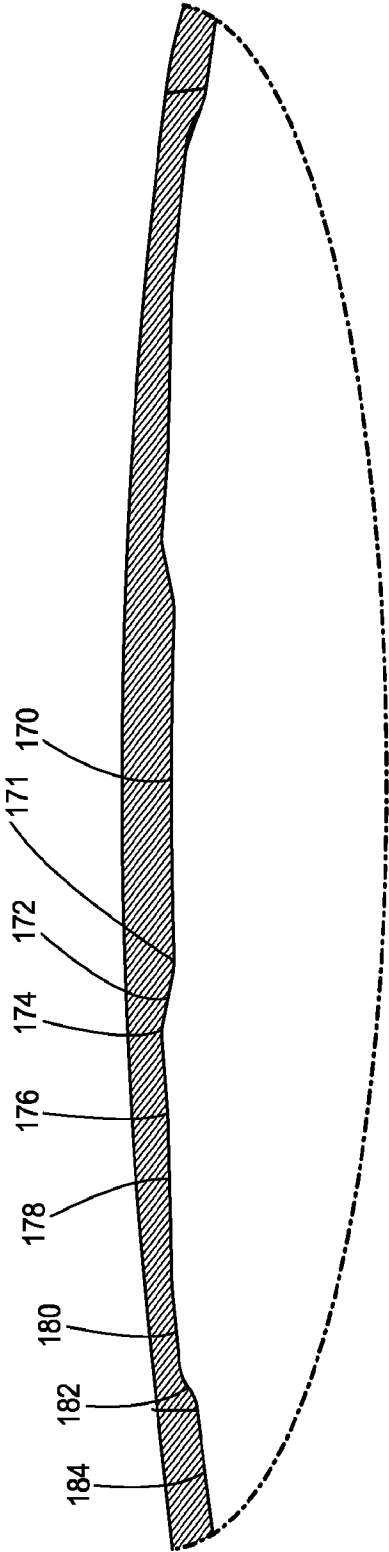
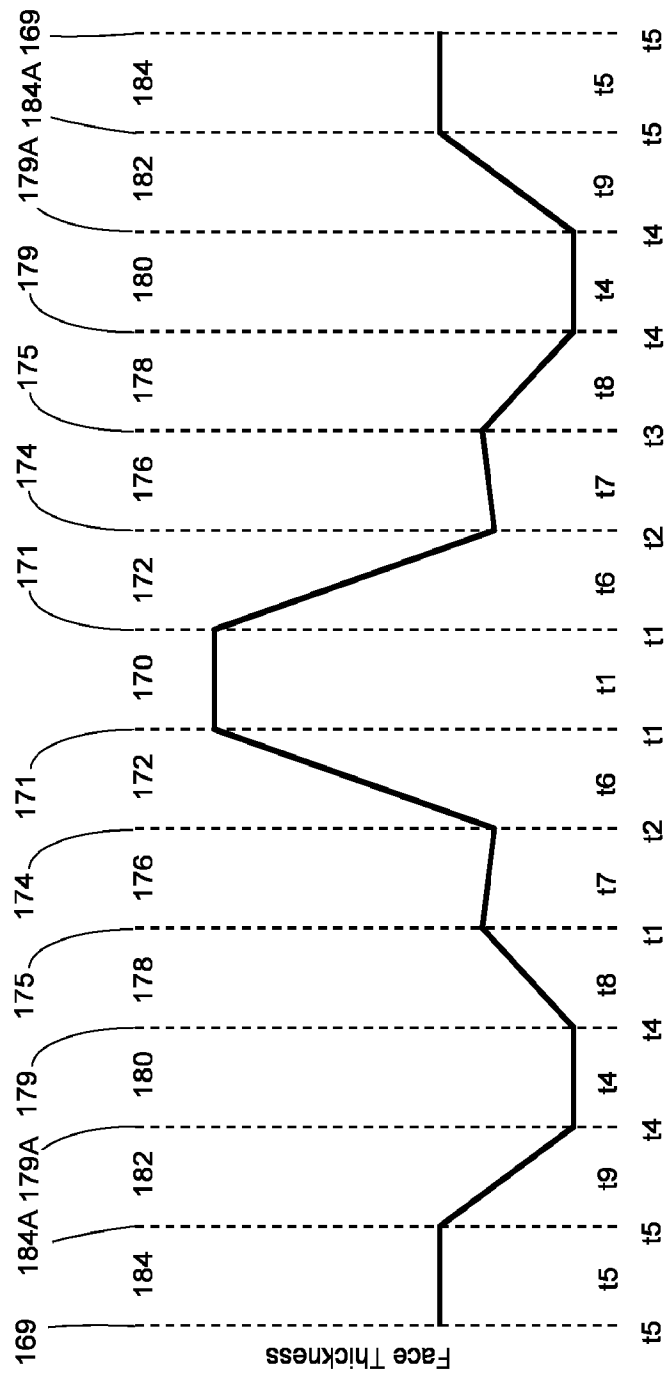
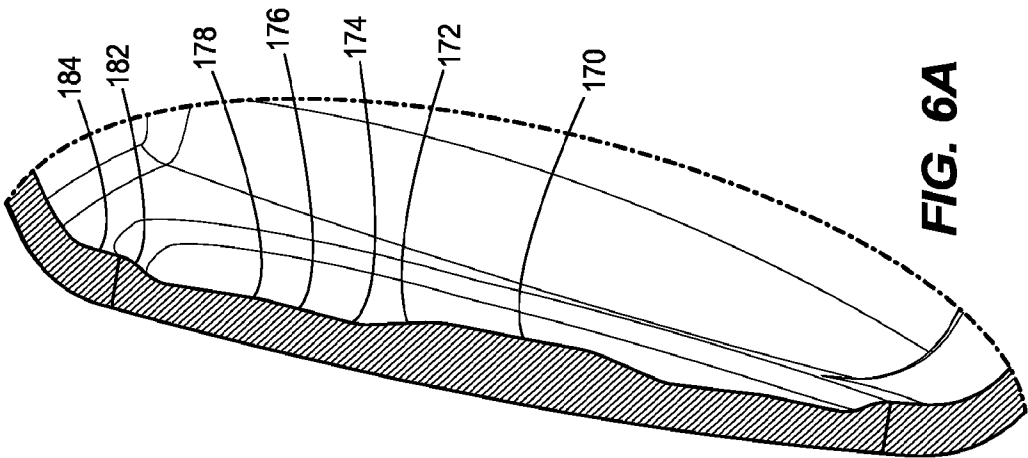
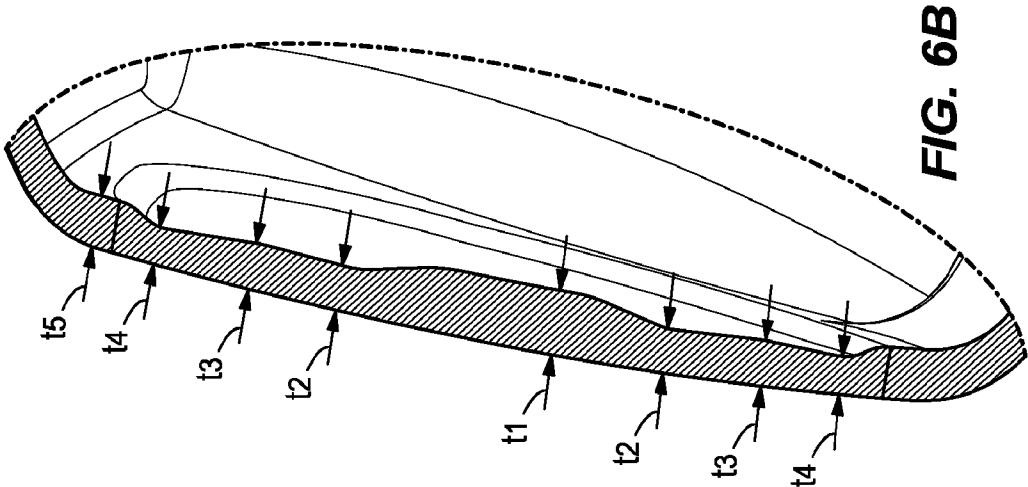


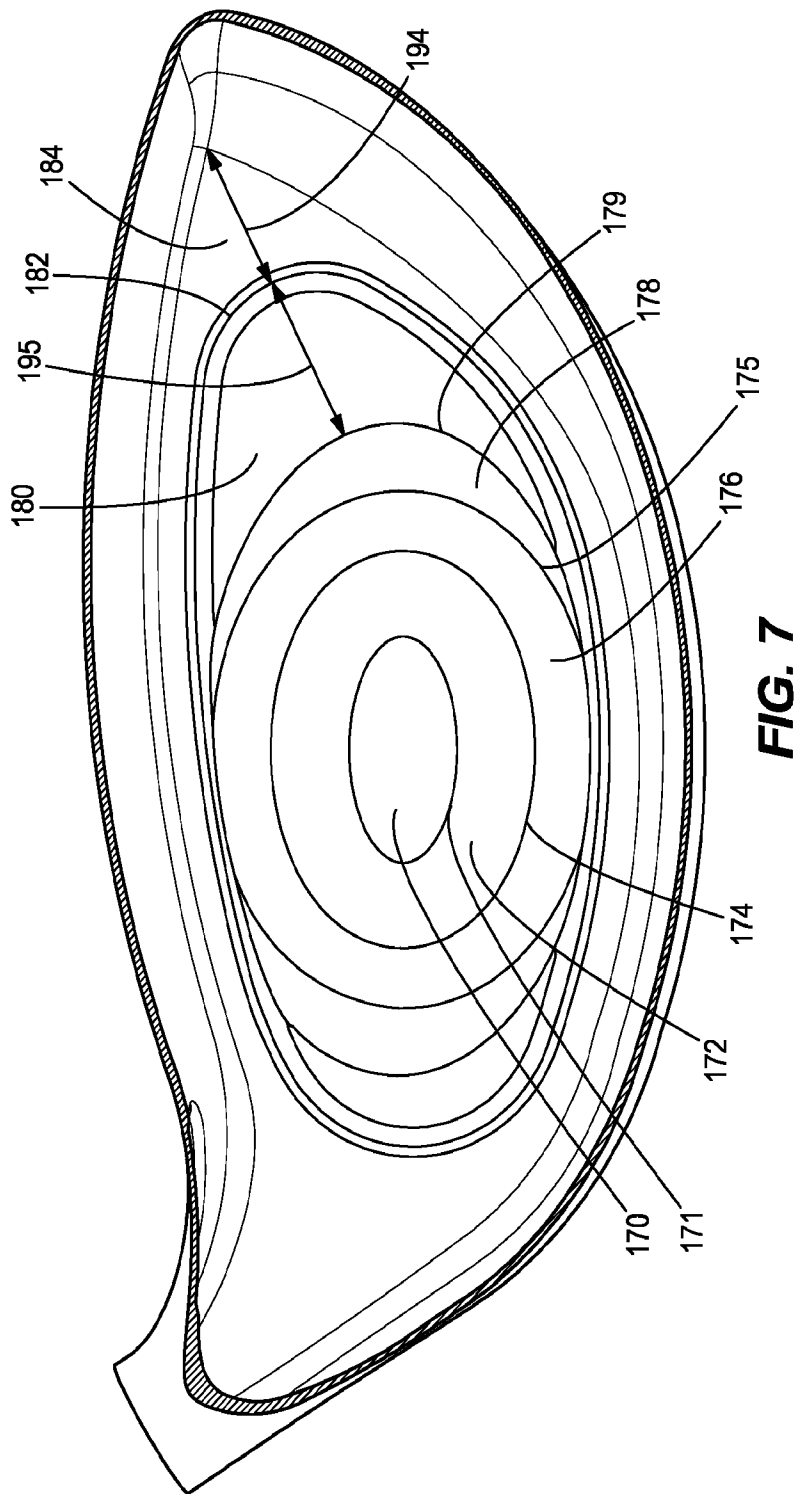
FIG. 5A



Distance in Specific Intersection Line

FIG. 5B





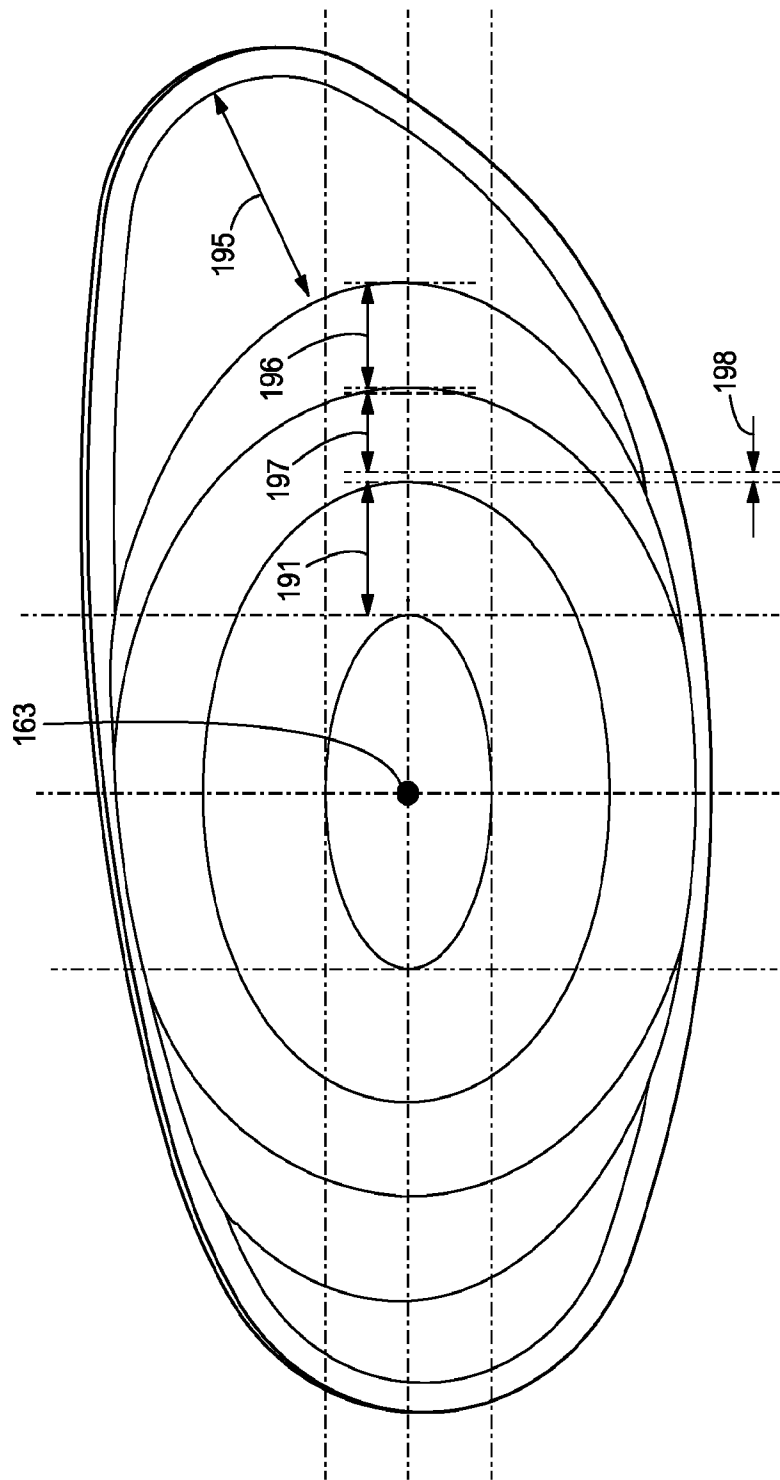


FIG. 8

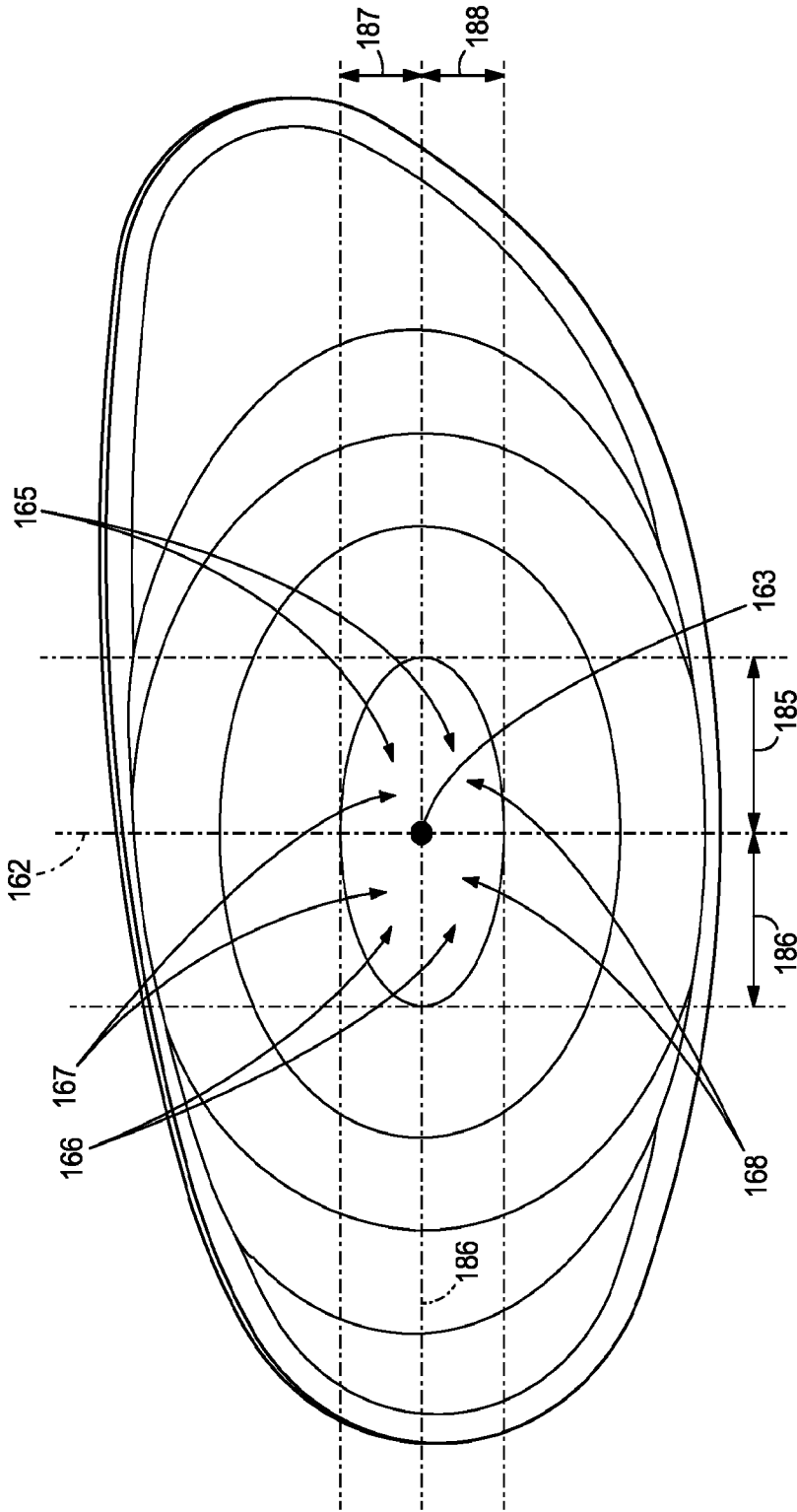


FIG. 9

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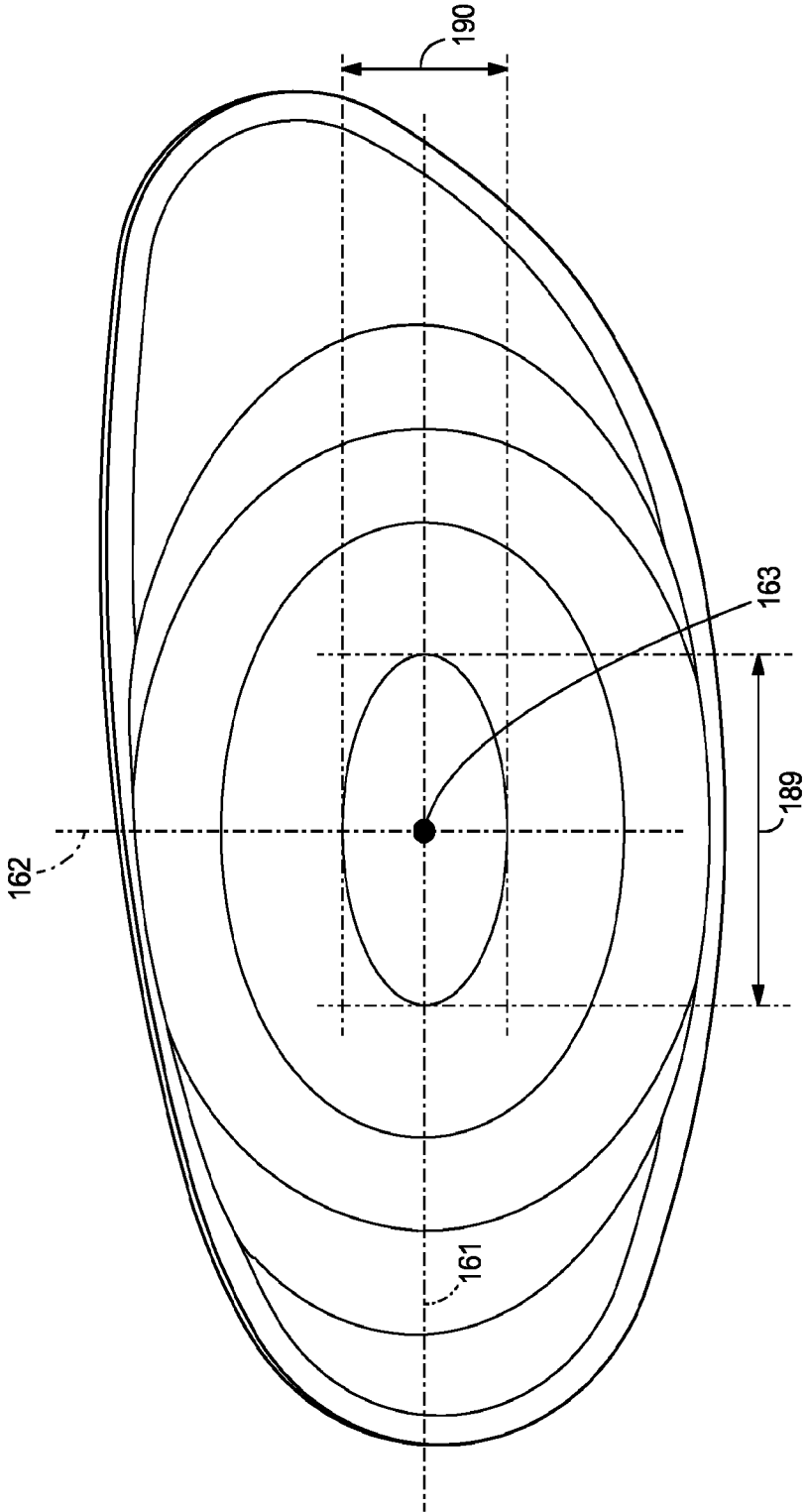


FIG. 10

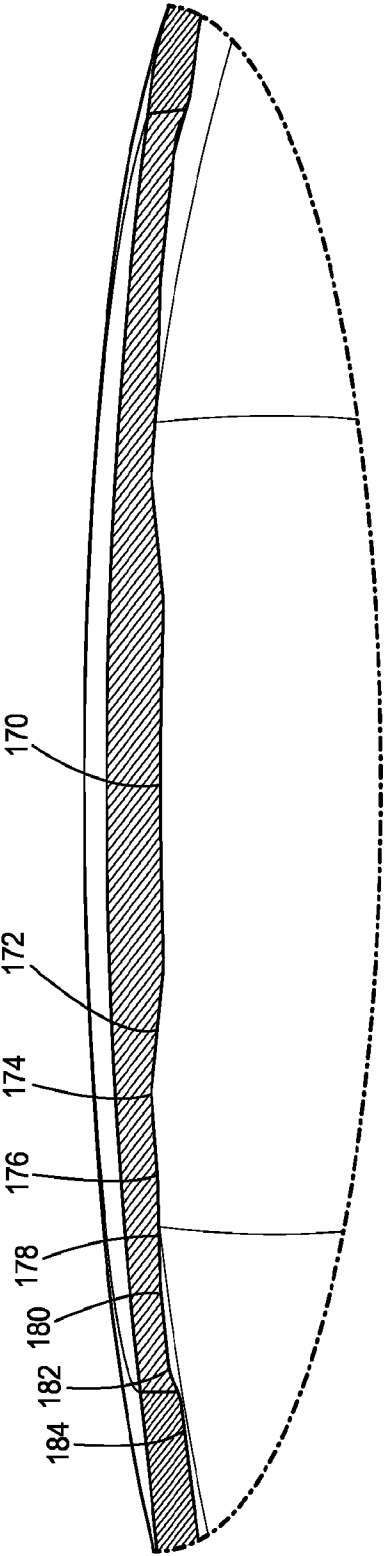
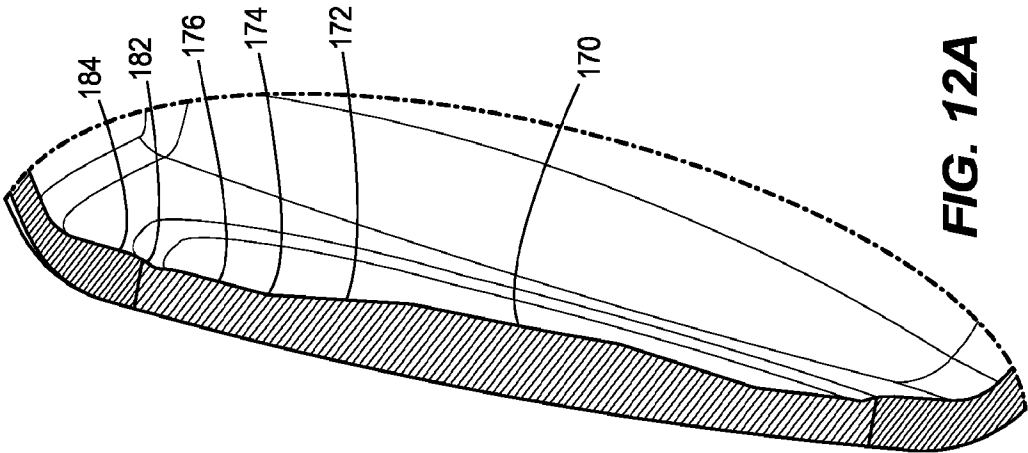
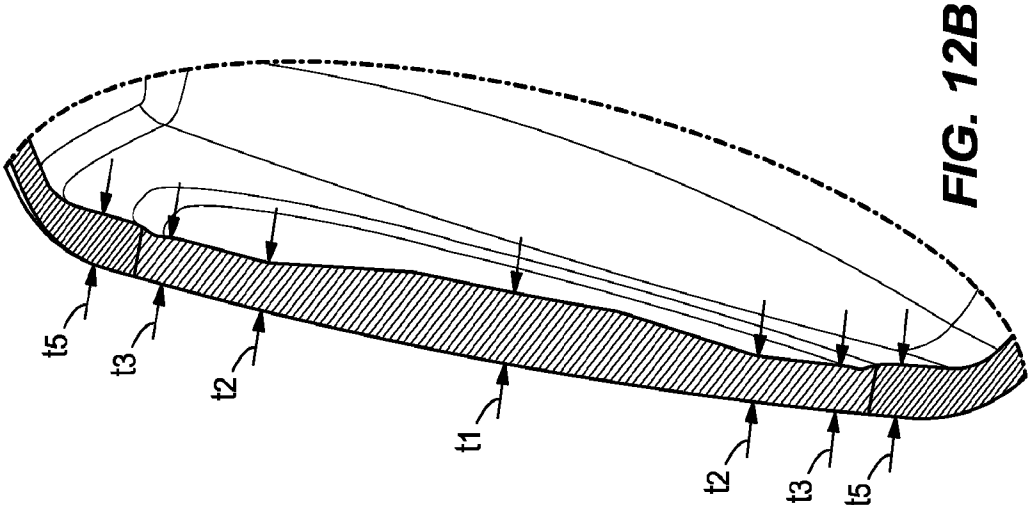


FIG. 11



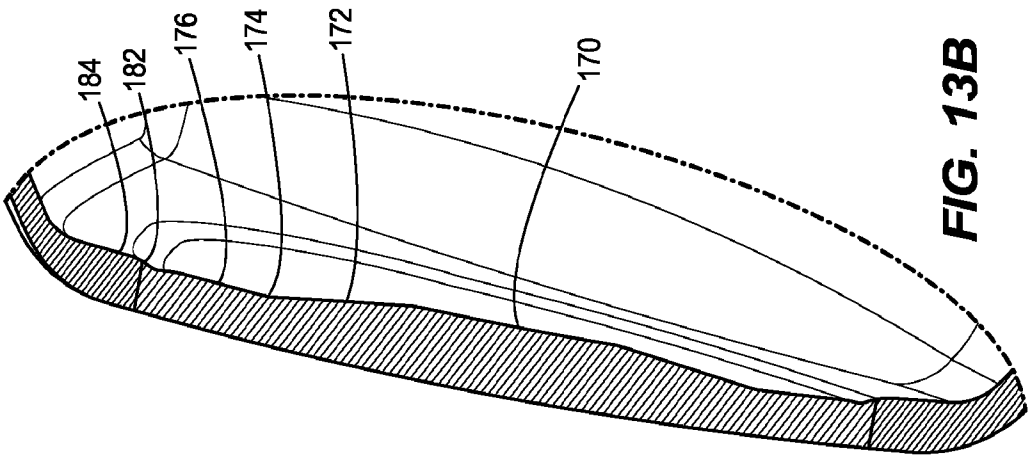


FIG. 13B

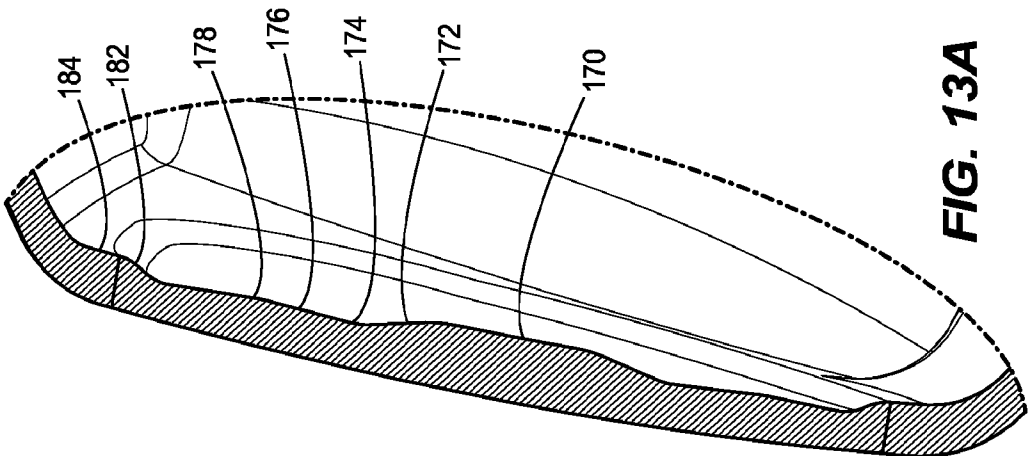


FIG. 13A

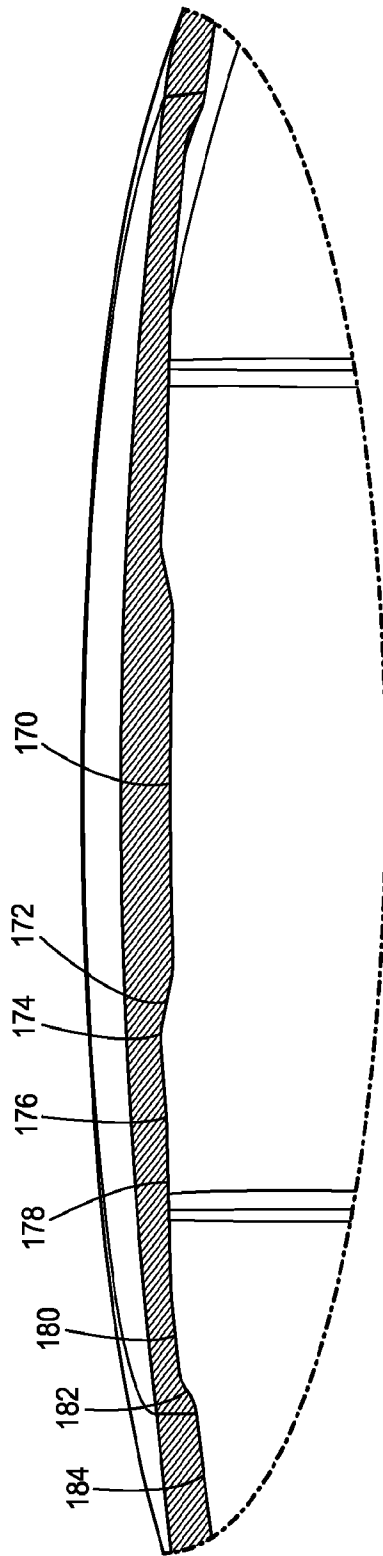


FIG. 14A

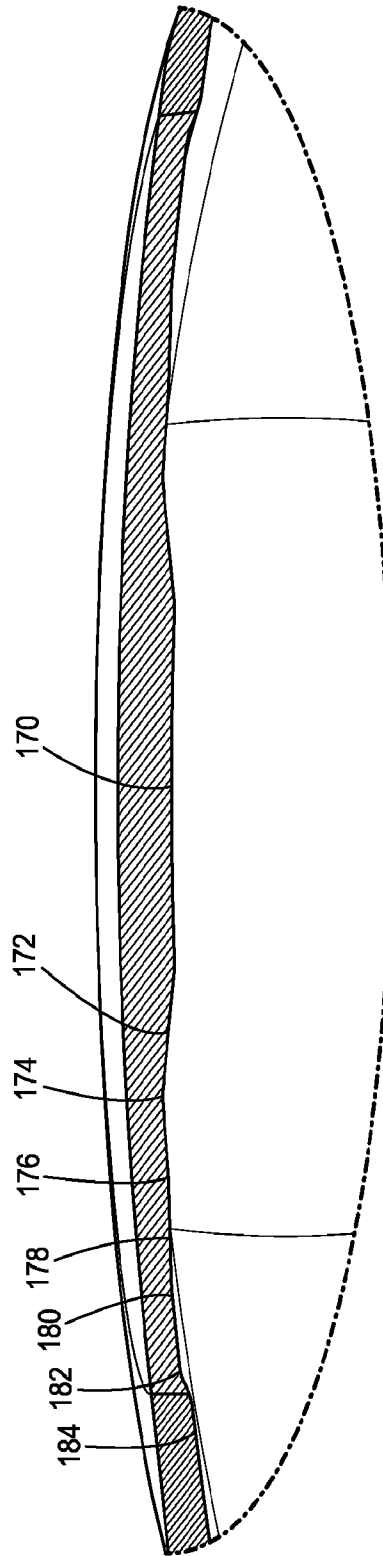
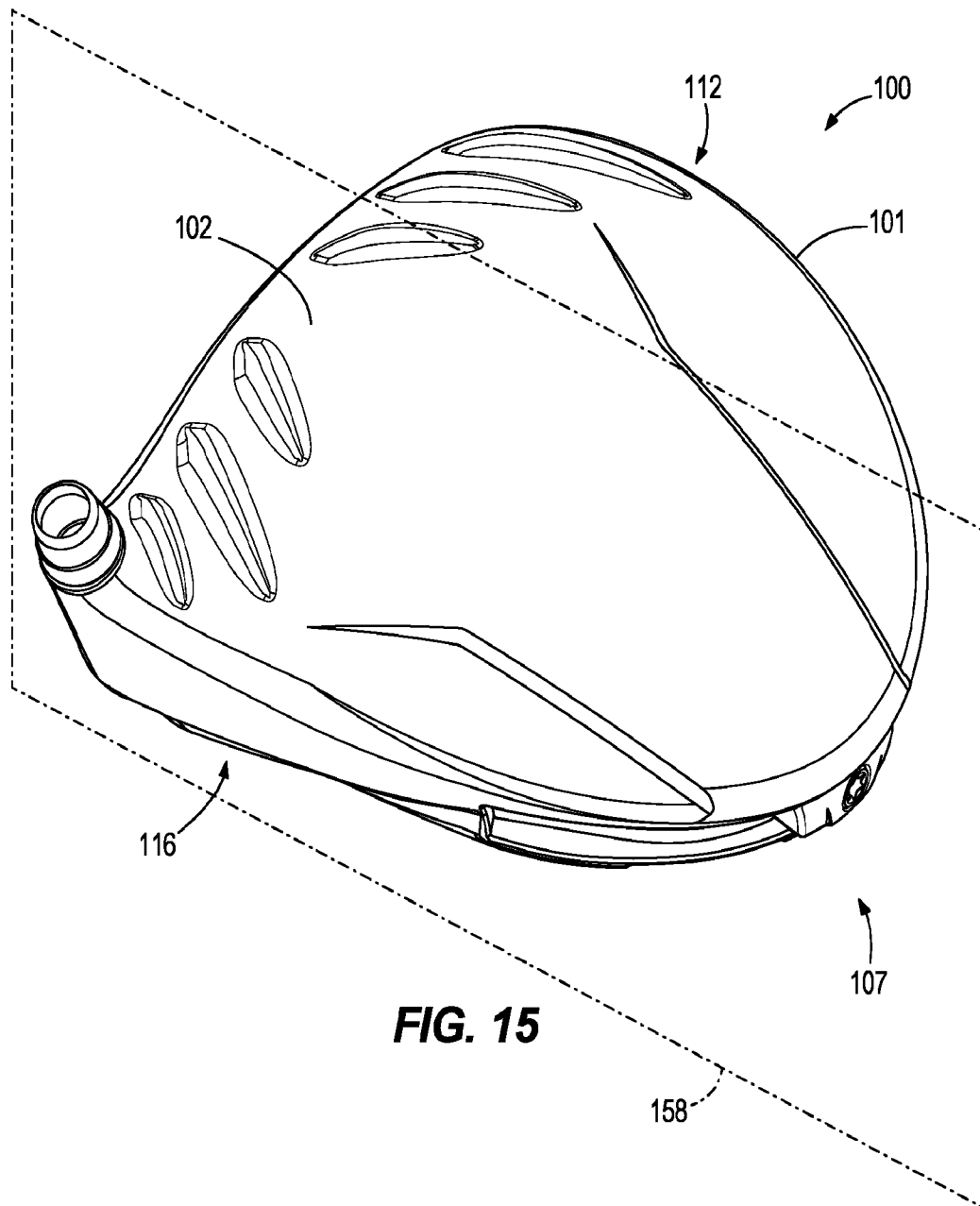
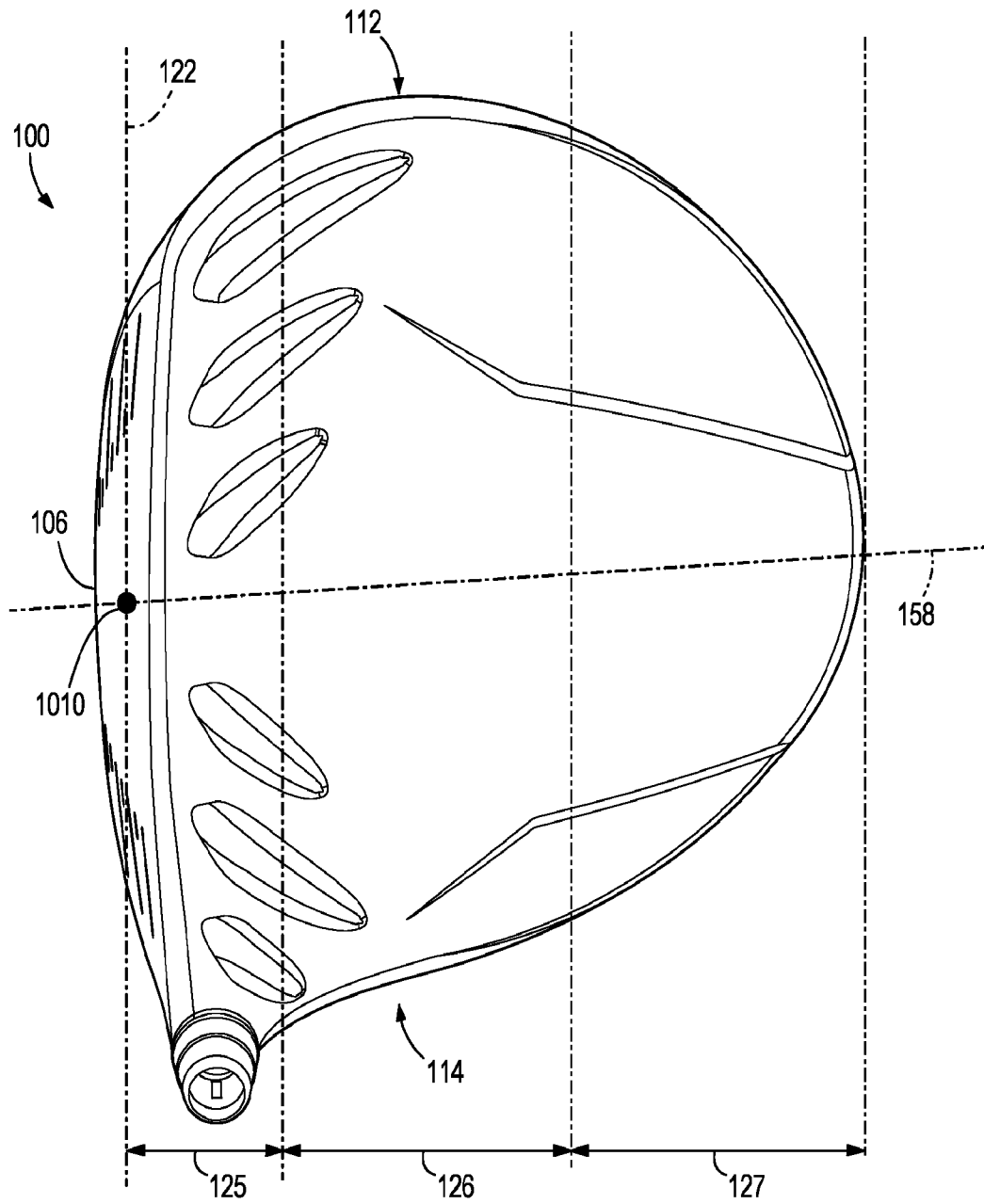


FIG. 14B

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**FIG. 16**

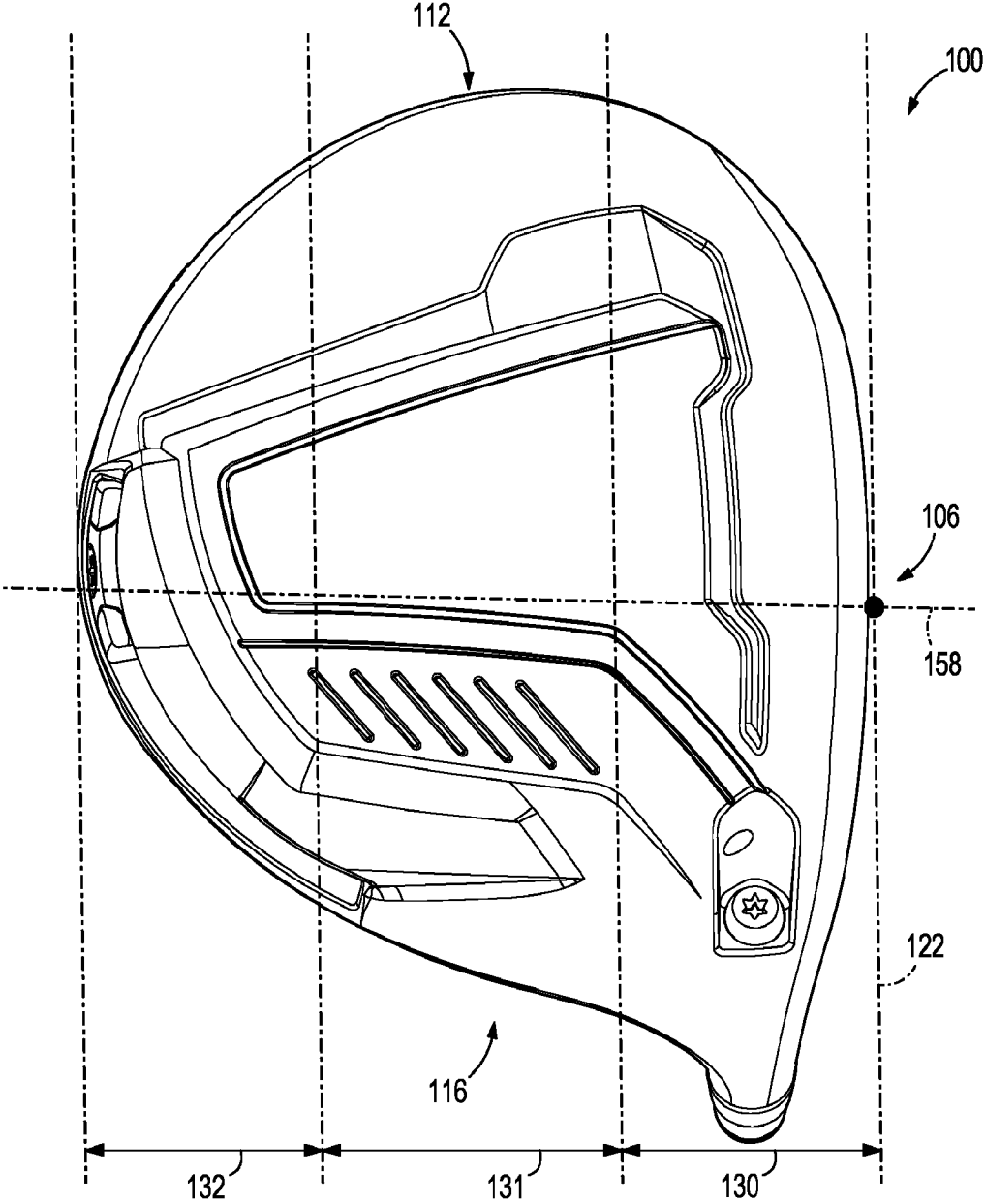


FIG. 17

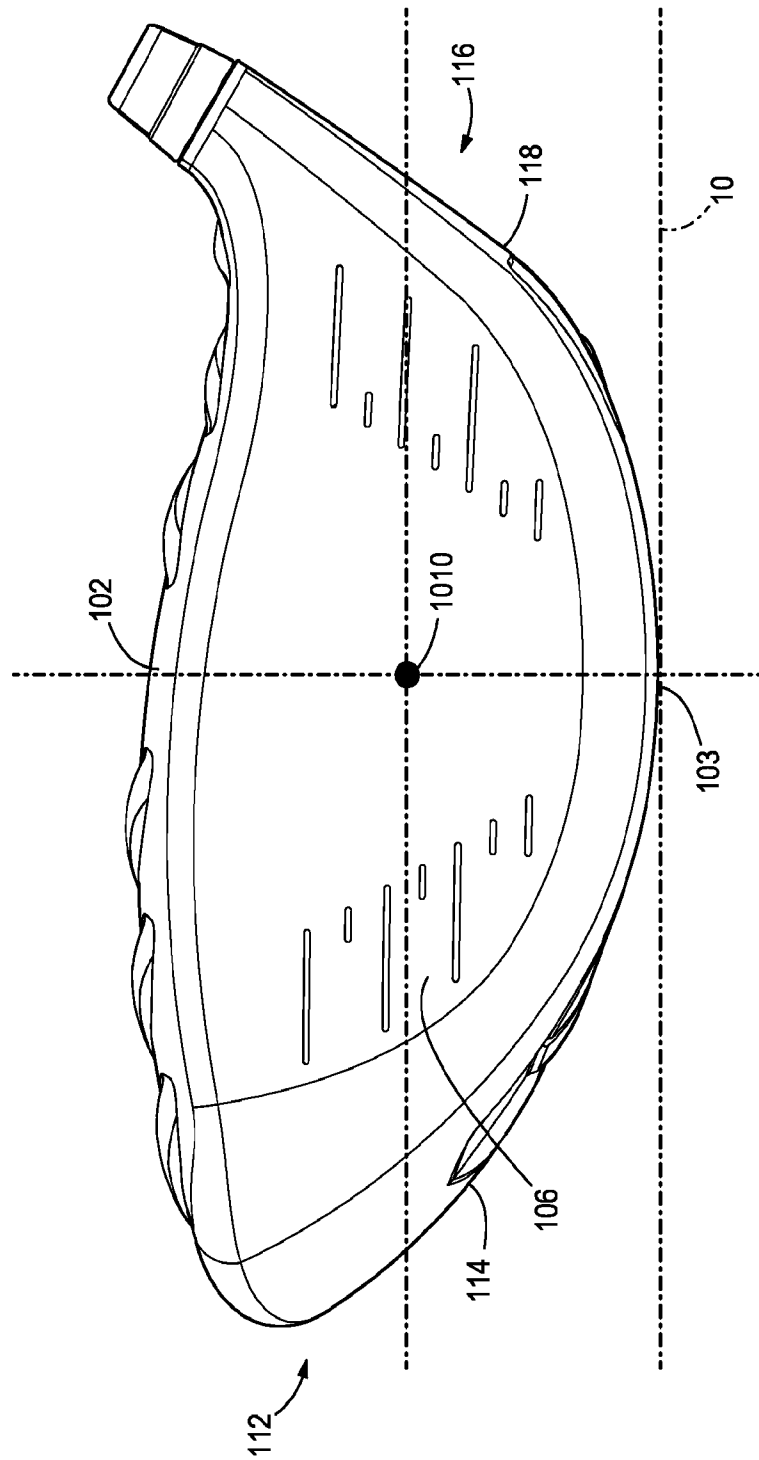


FIG. 18

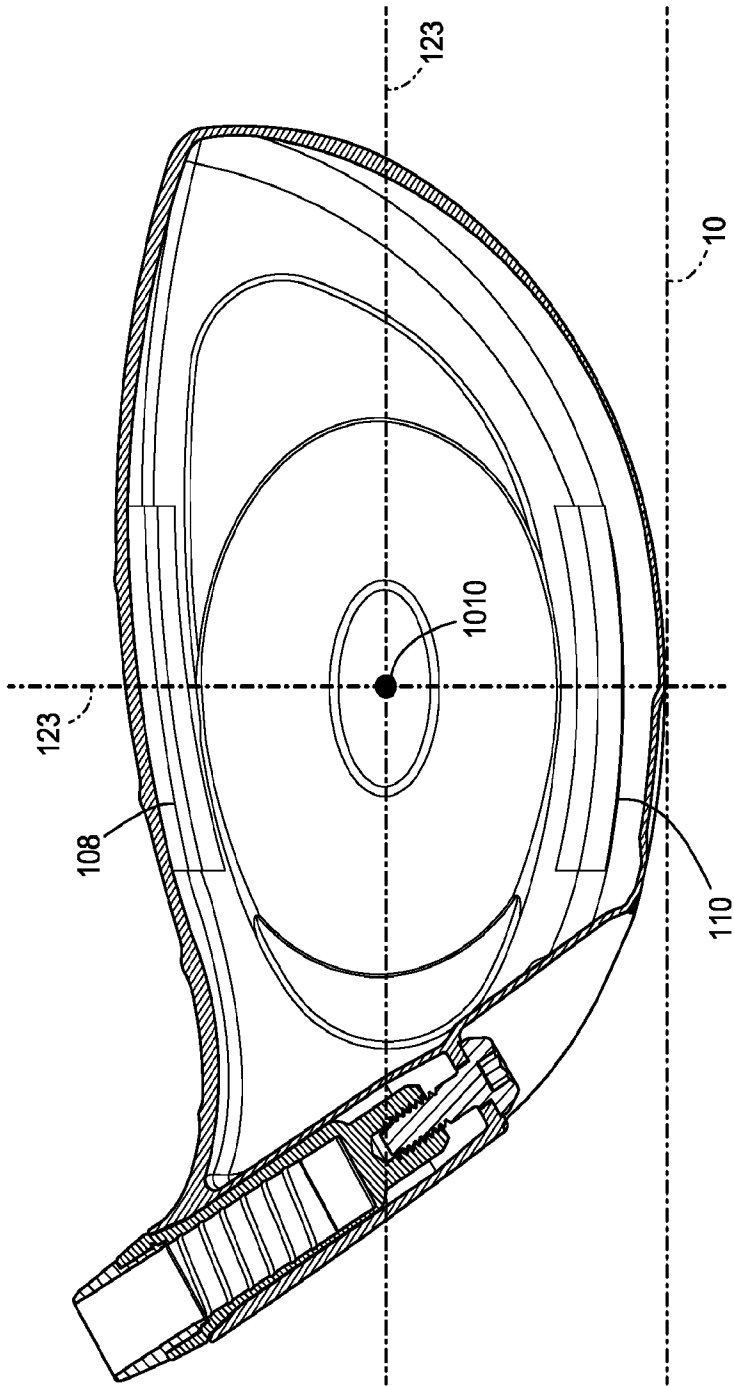
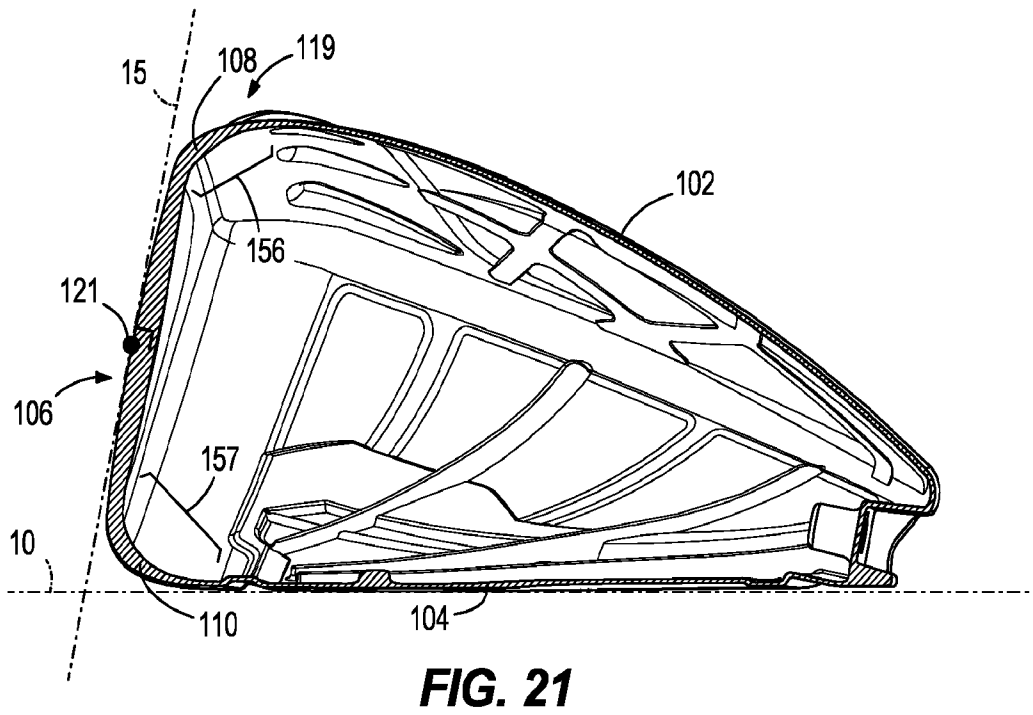
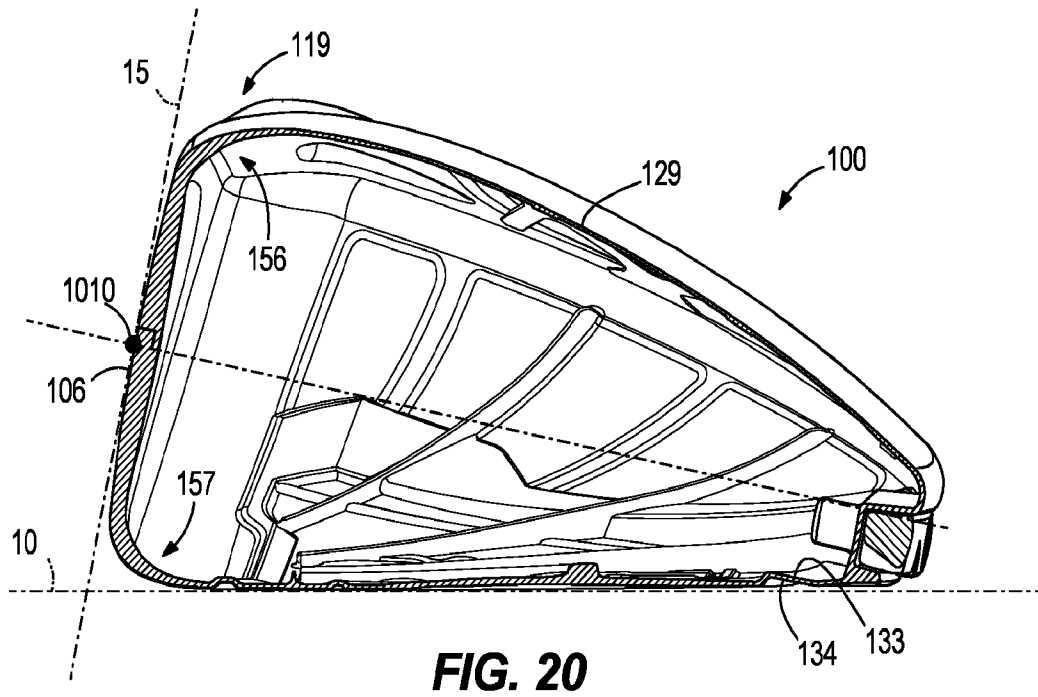
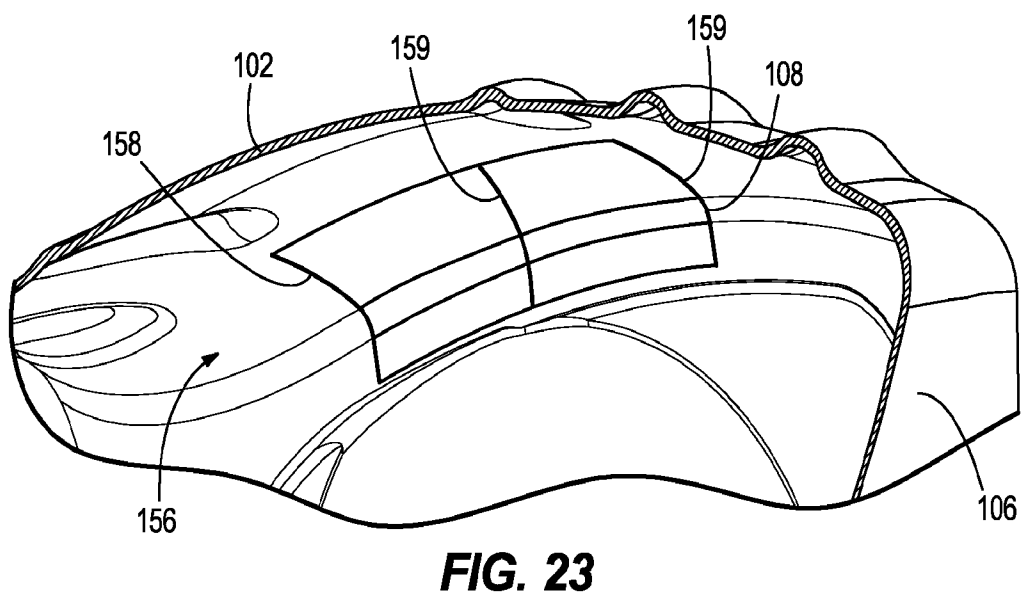
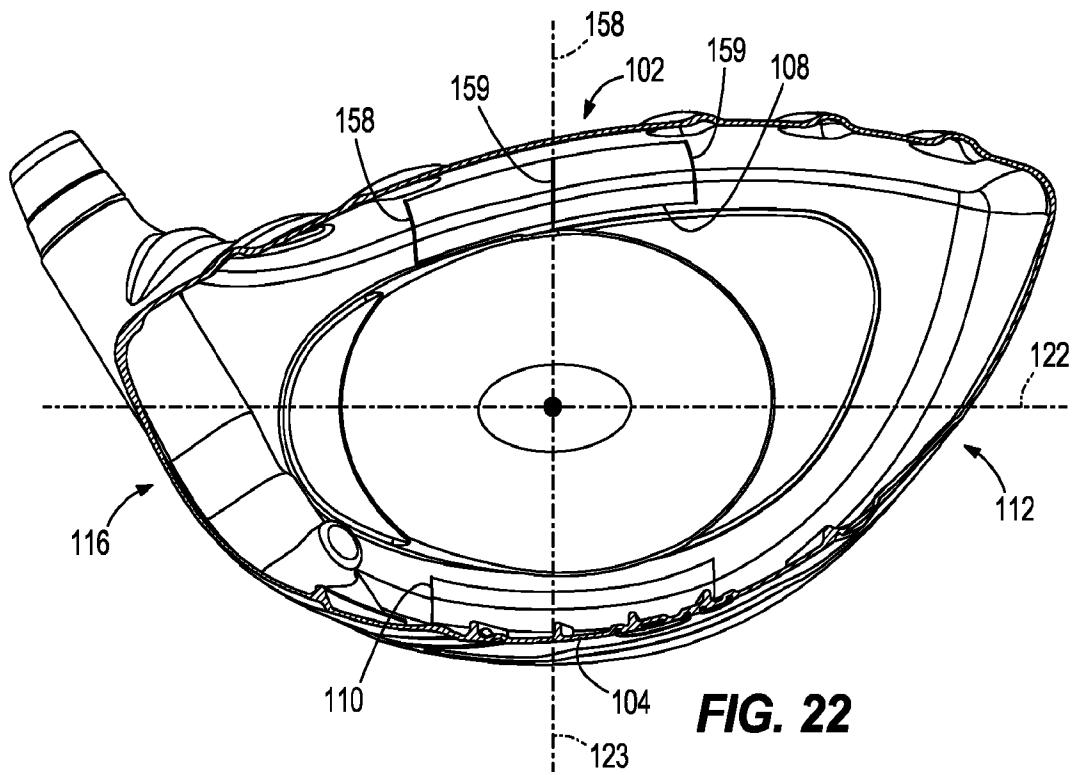


FIG. 19

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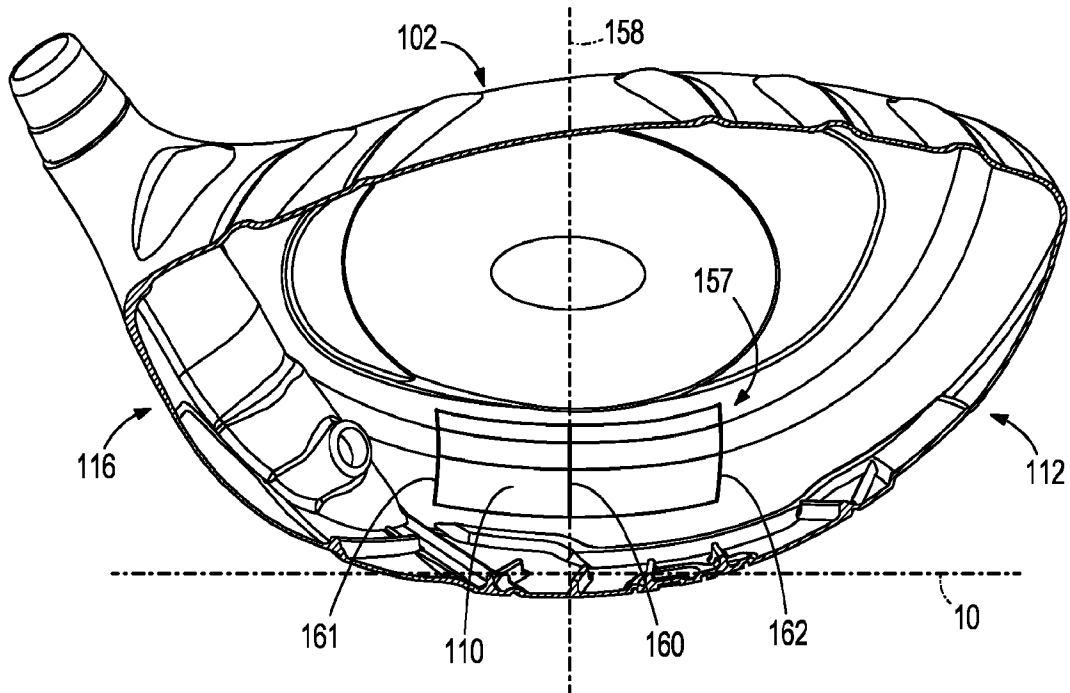


FIG. 24

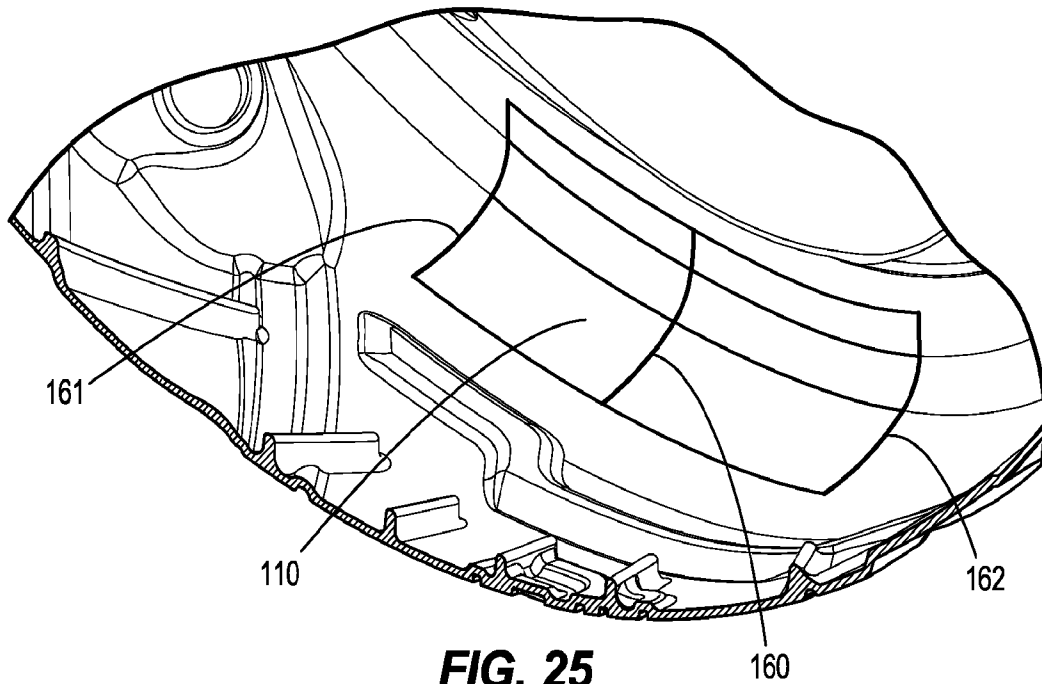
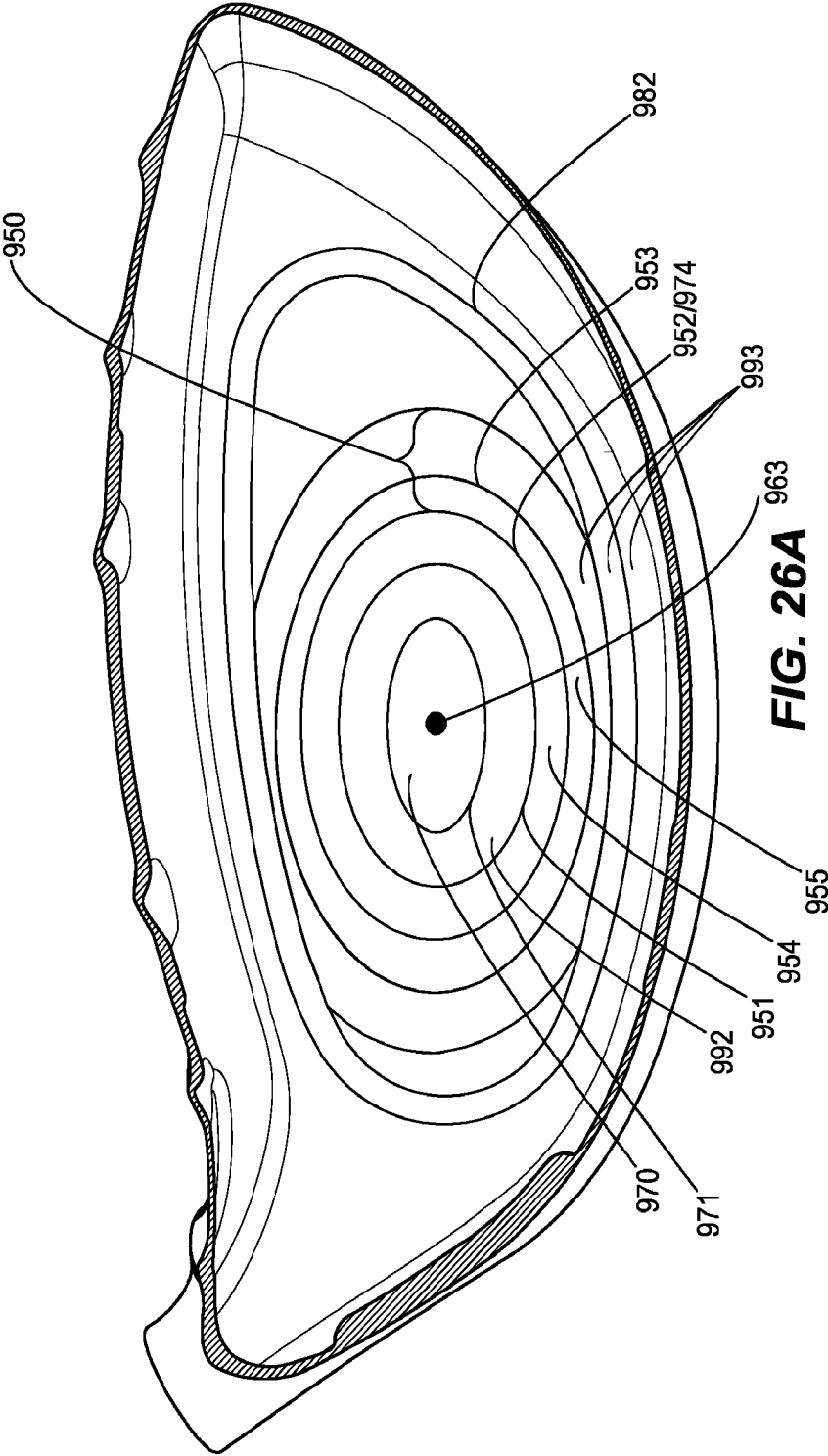


FIG. 25



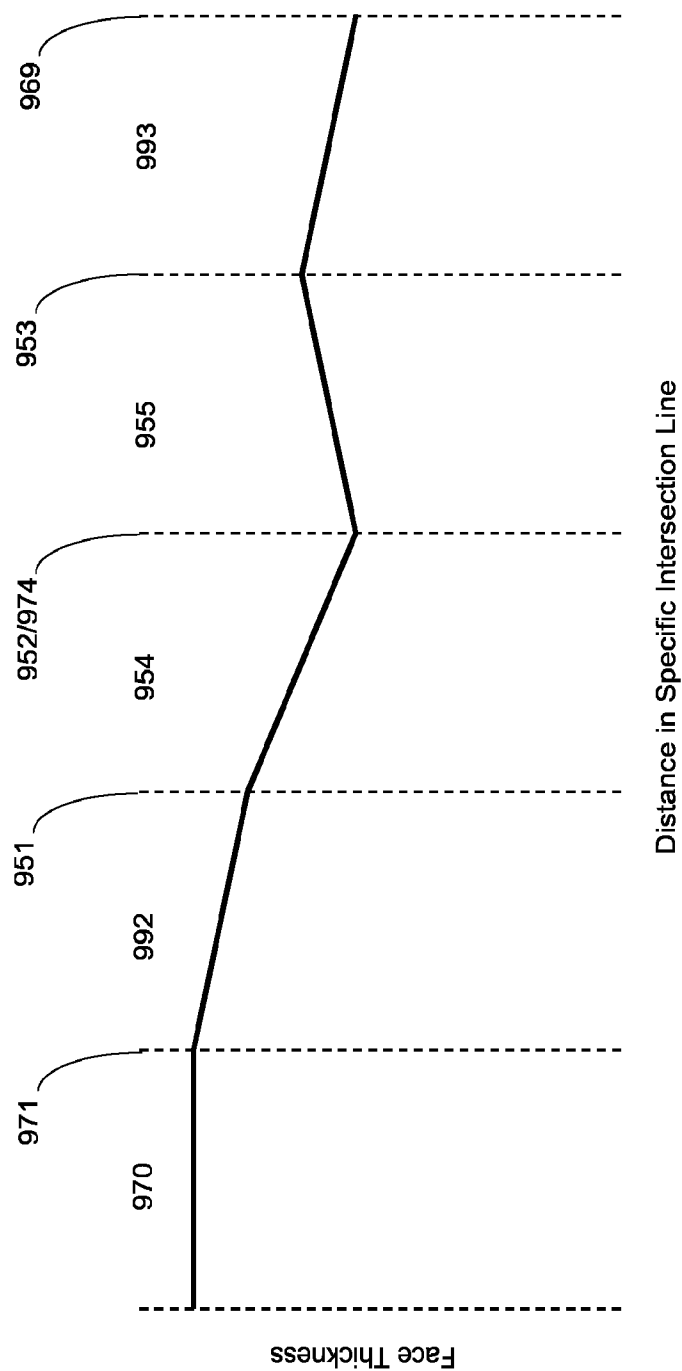


FIG. 26B

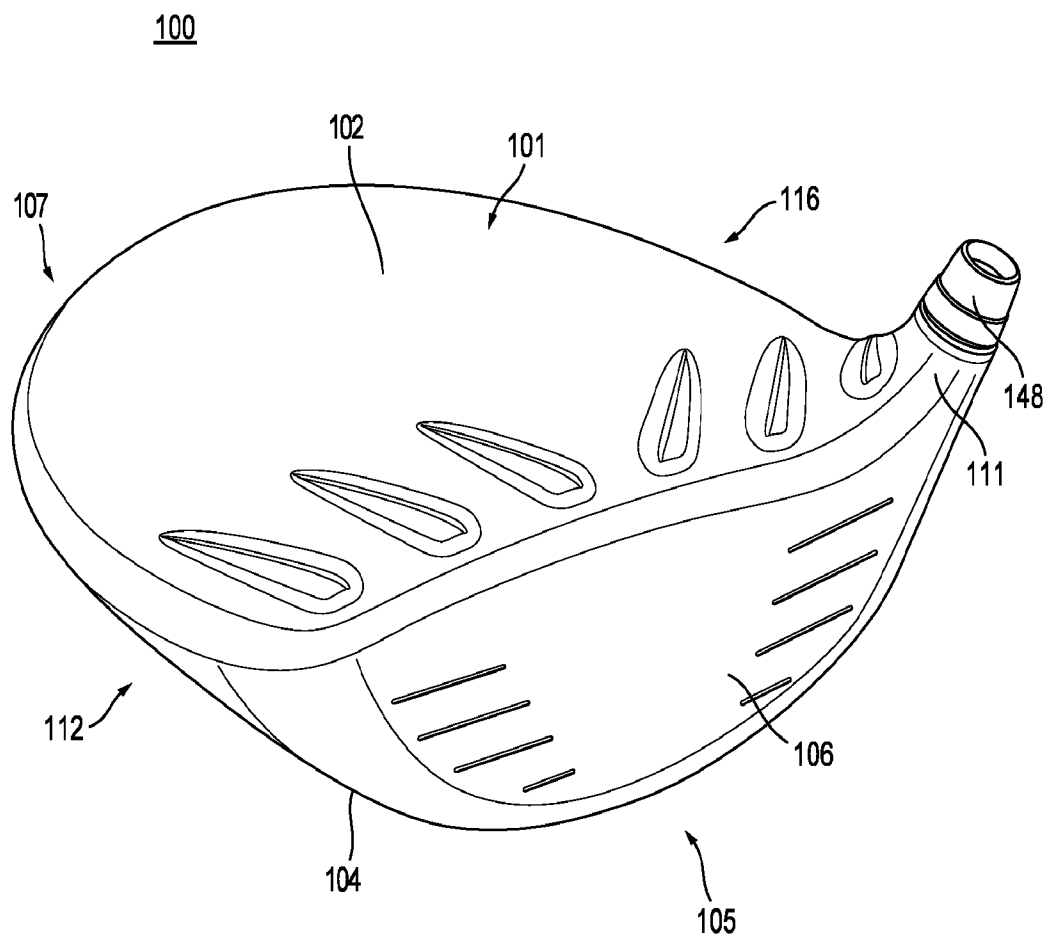


FIG. 27

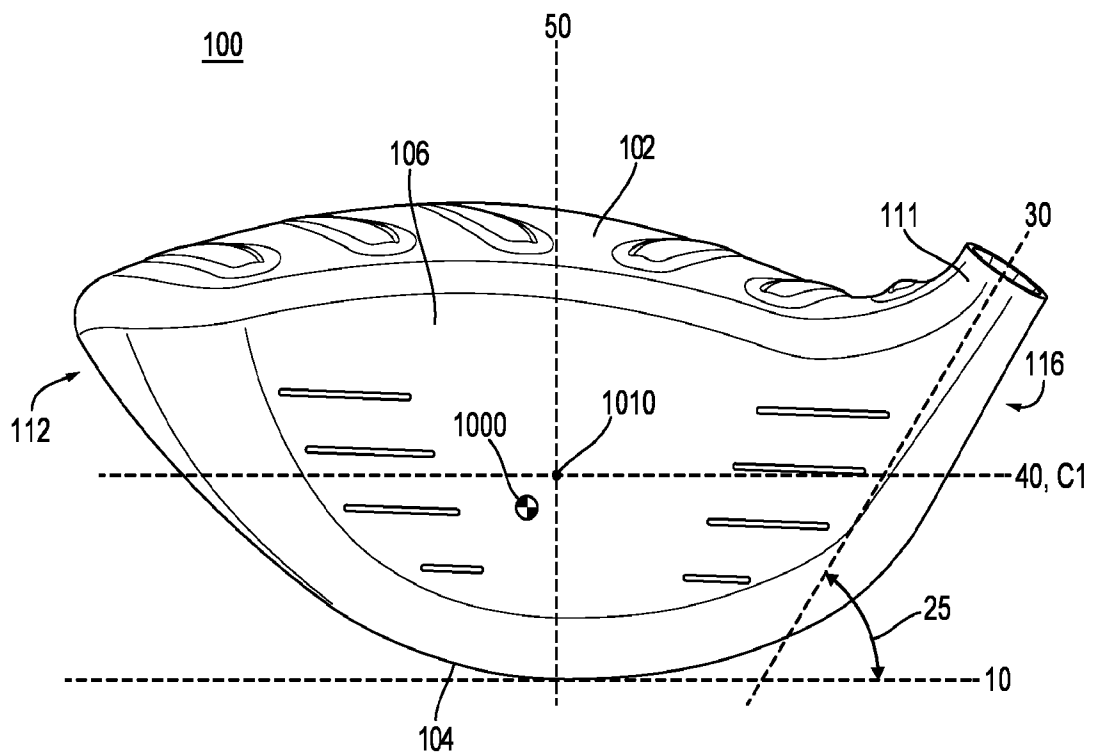


FIG. 28

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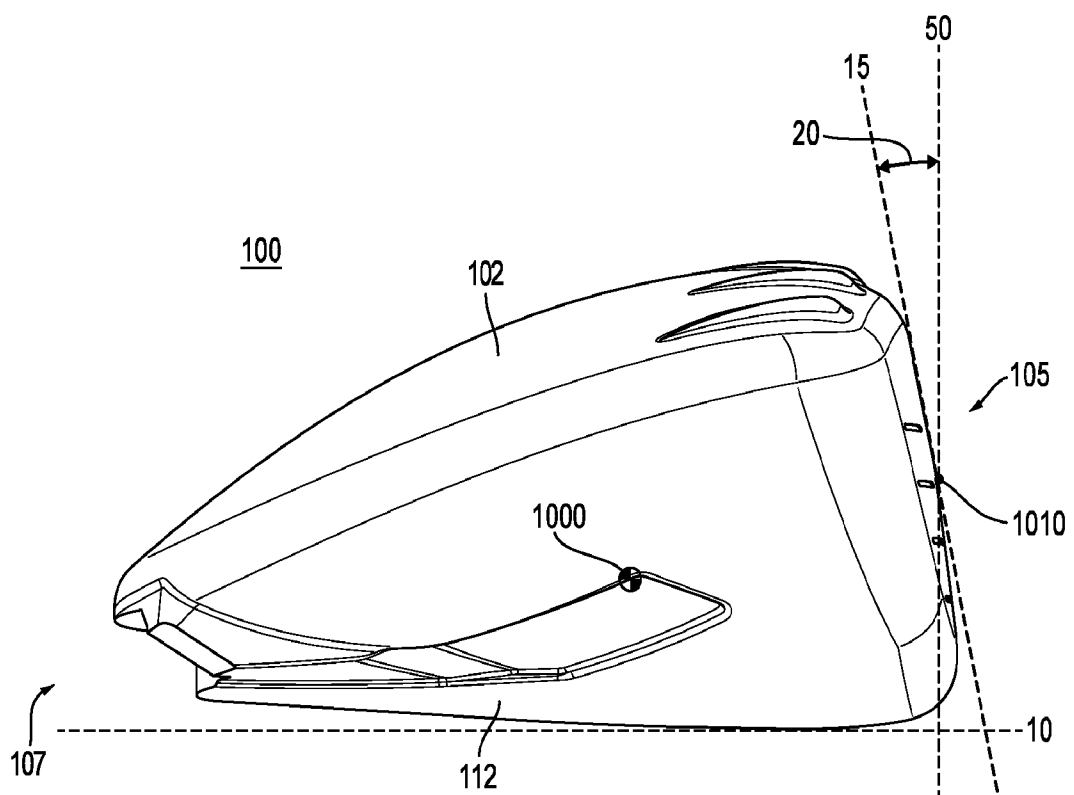


FIG. 29

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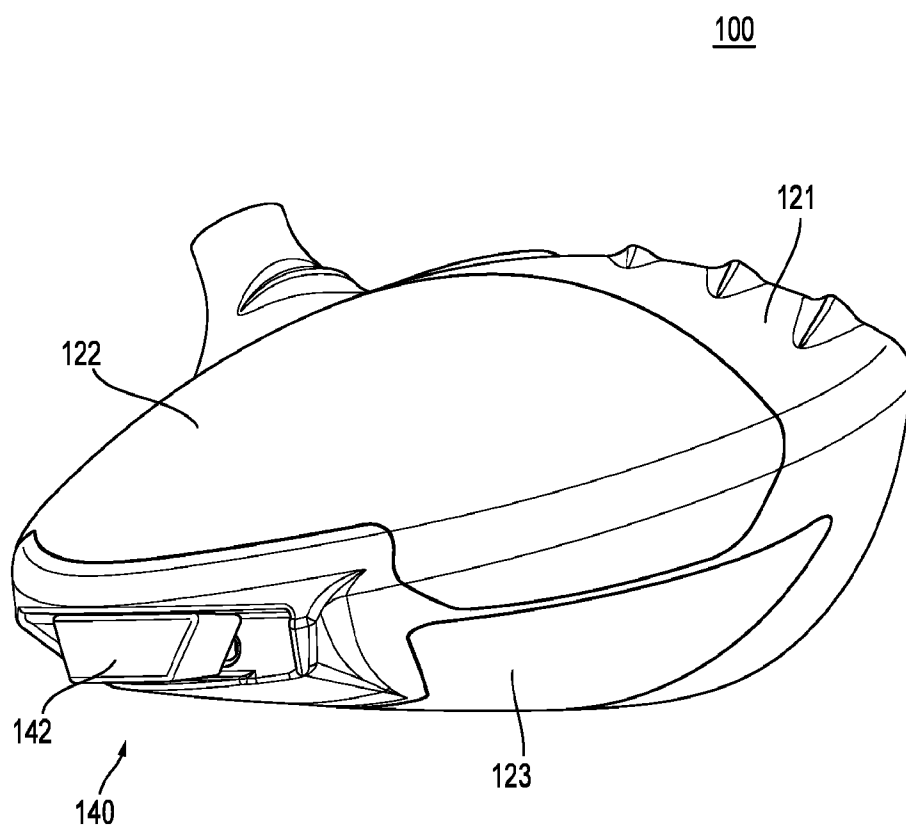


FIG. 30

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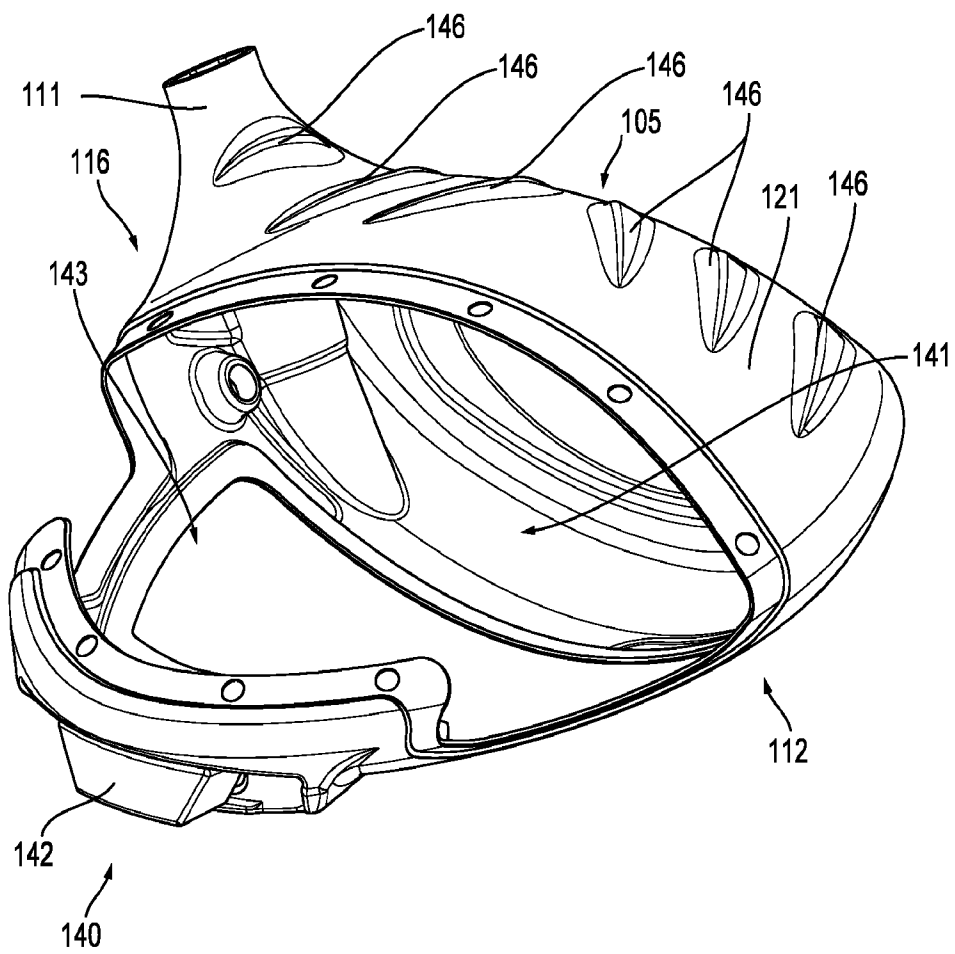


FIG. 31

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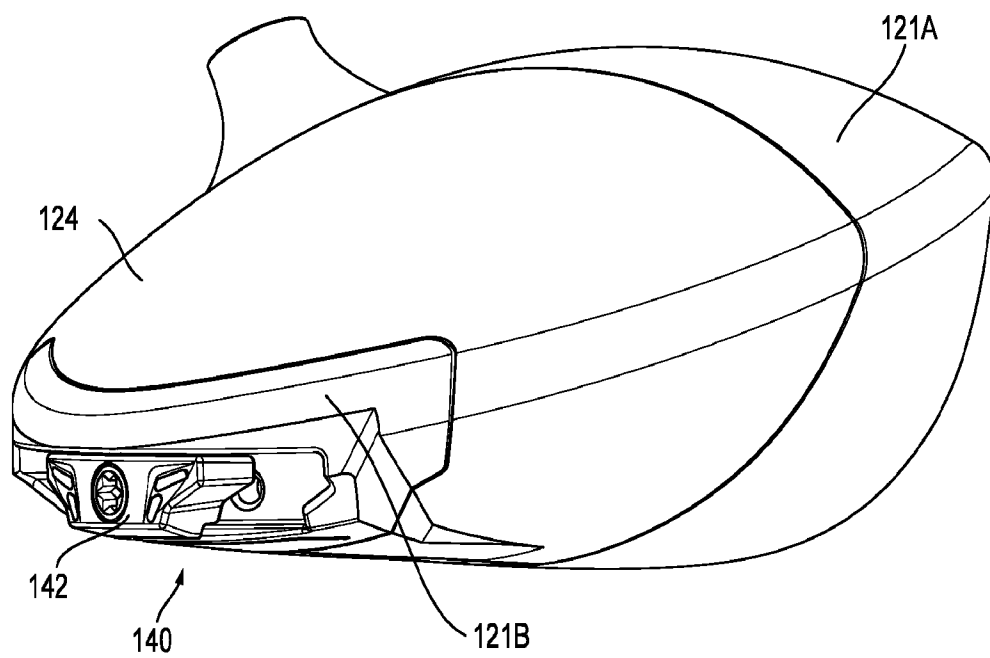


FIG. 32

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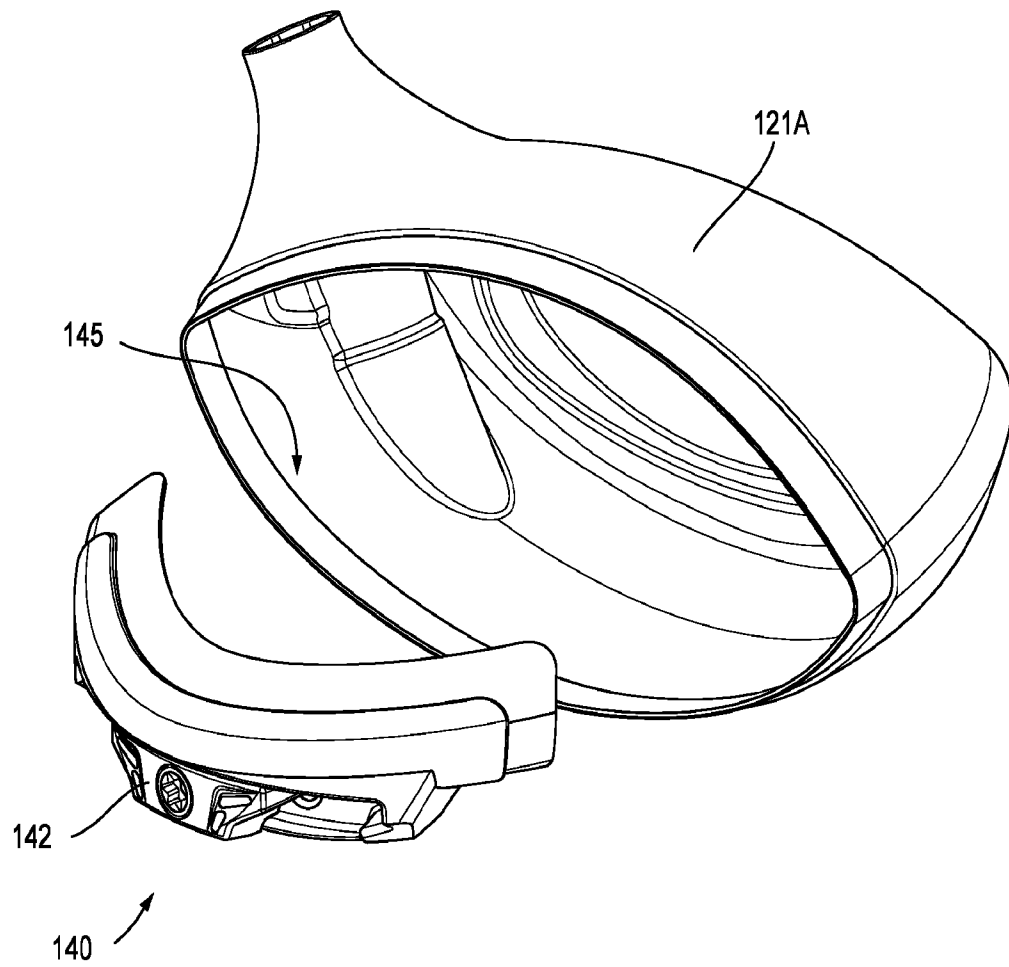


FIG. 33

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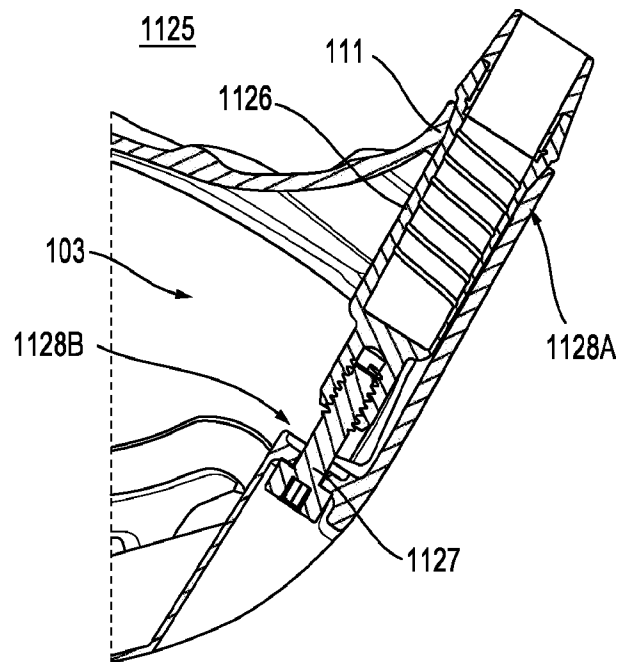


FIG. 34

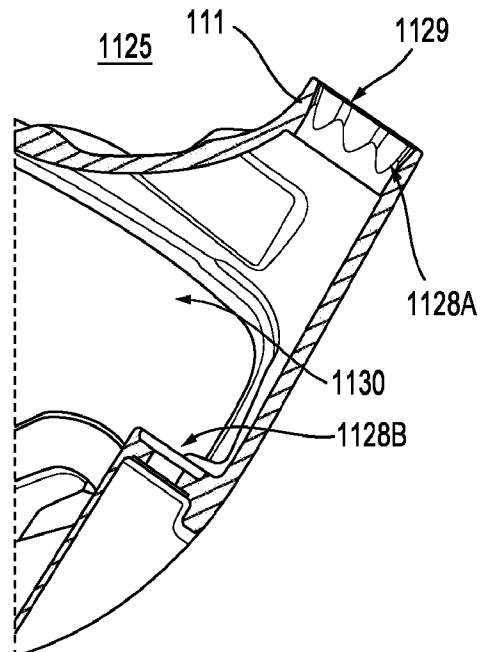


FIG. 35

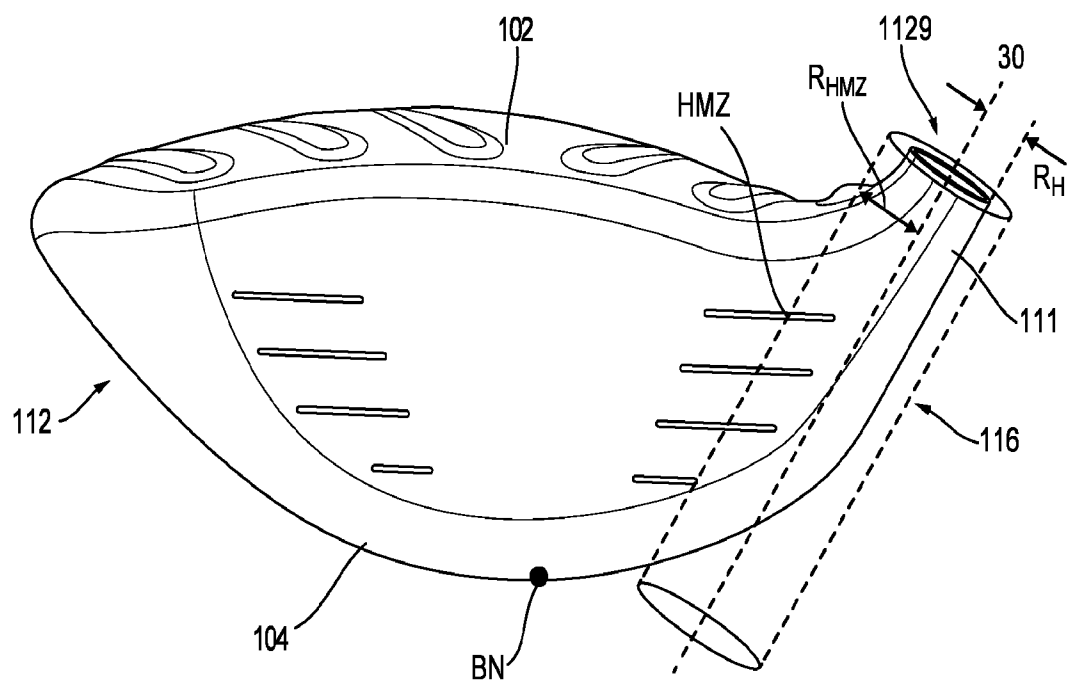


FIG. 36

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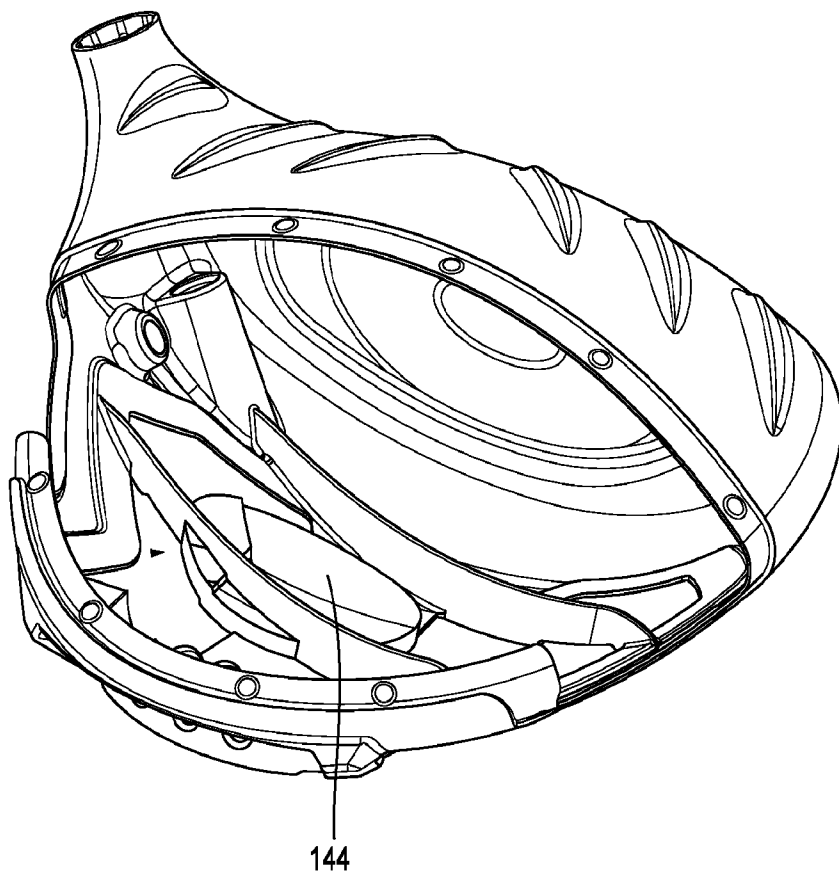


FIG. 37

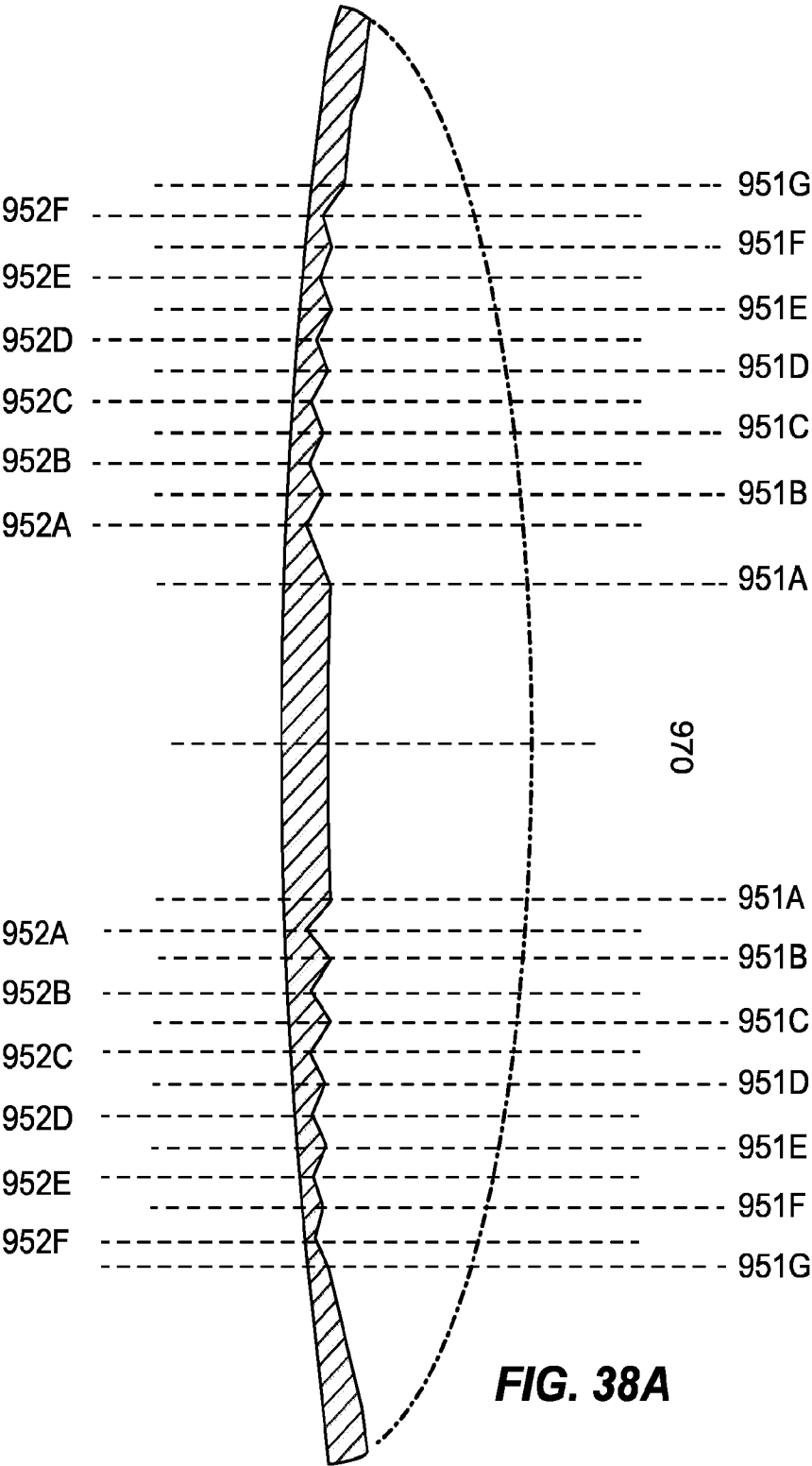


FIG. 38A

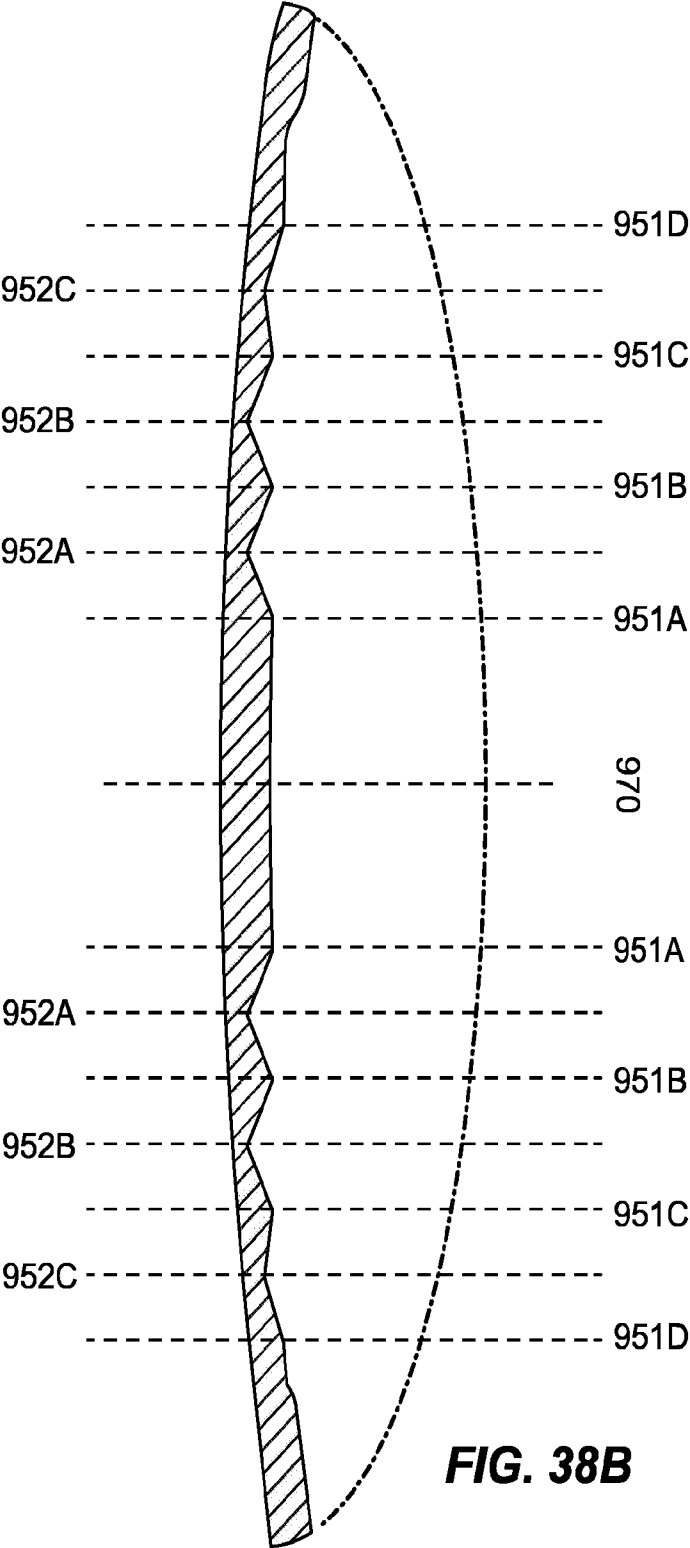
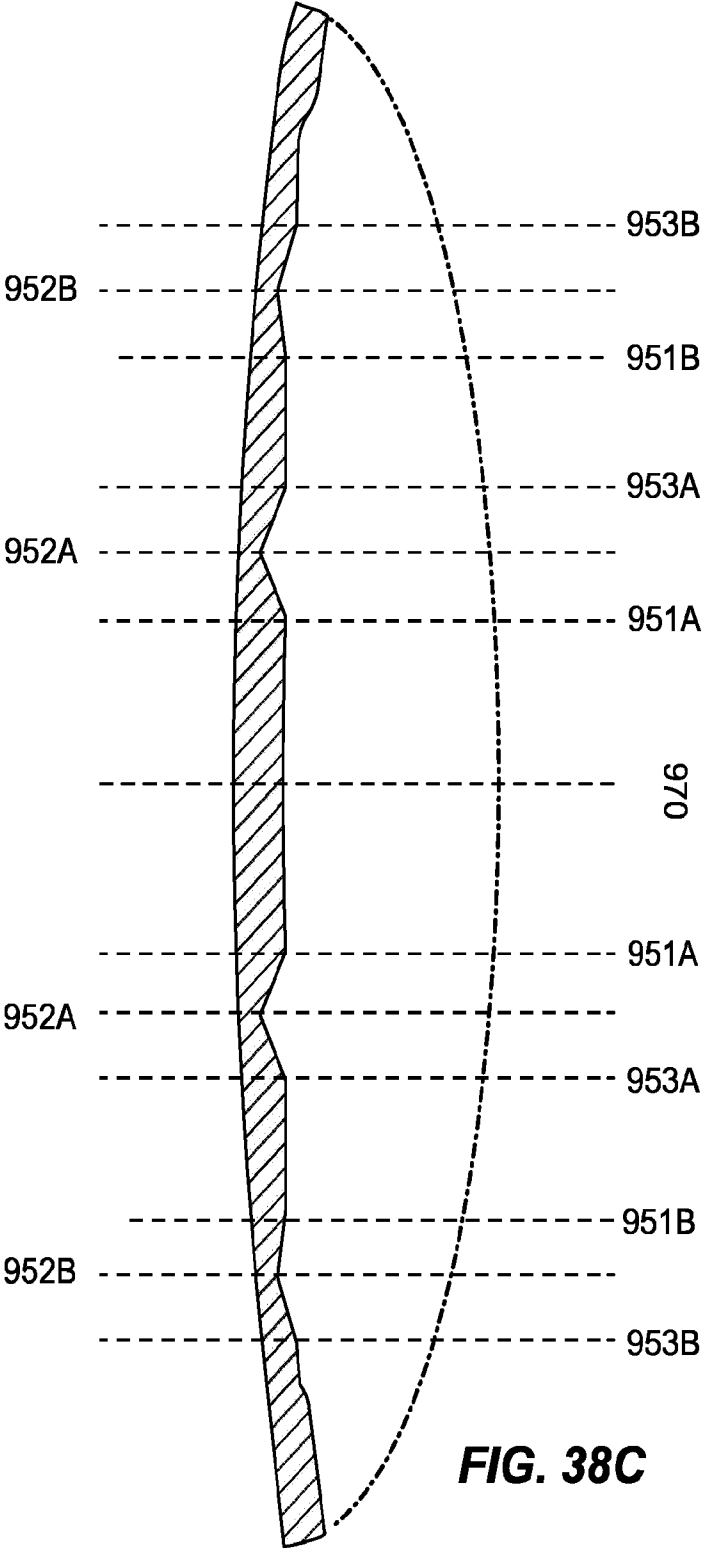
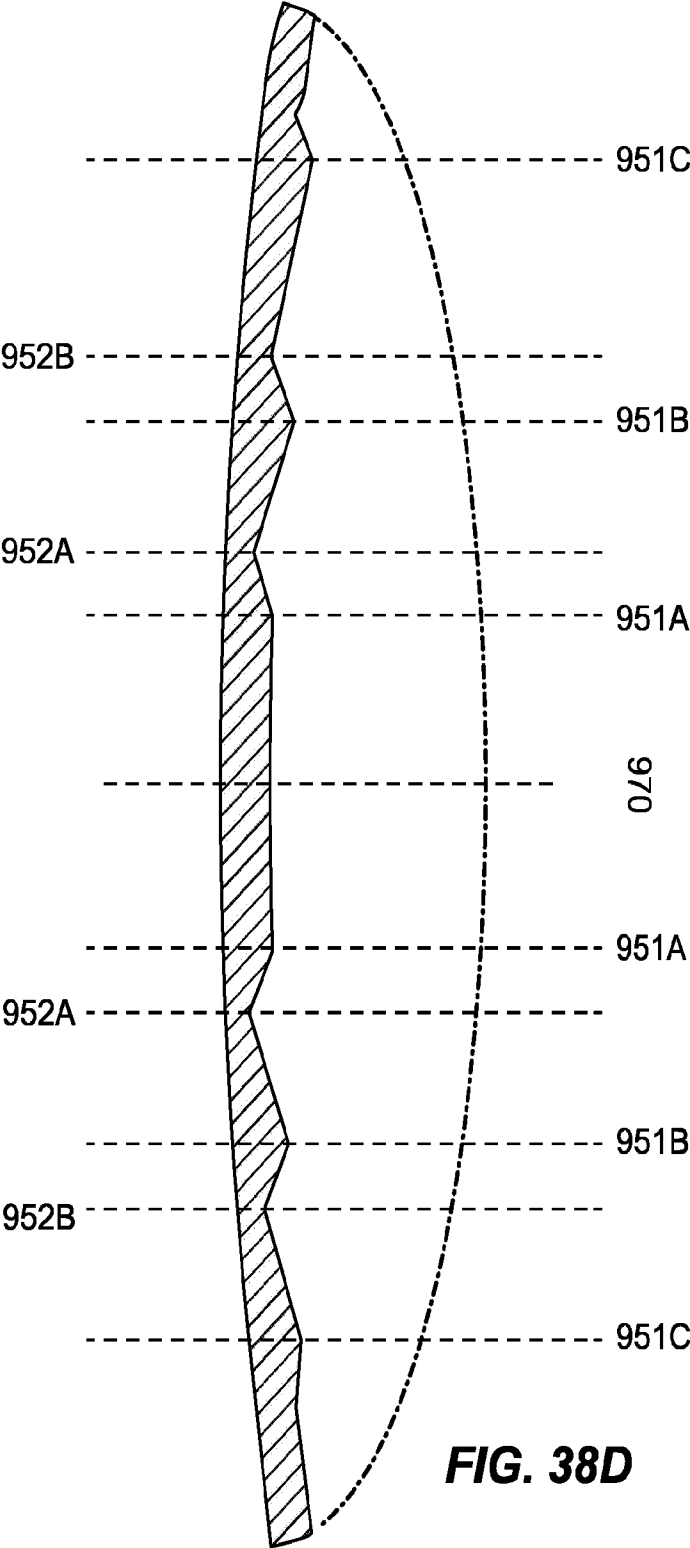


FIG. 38B





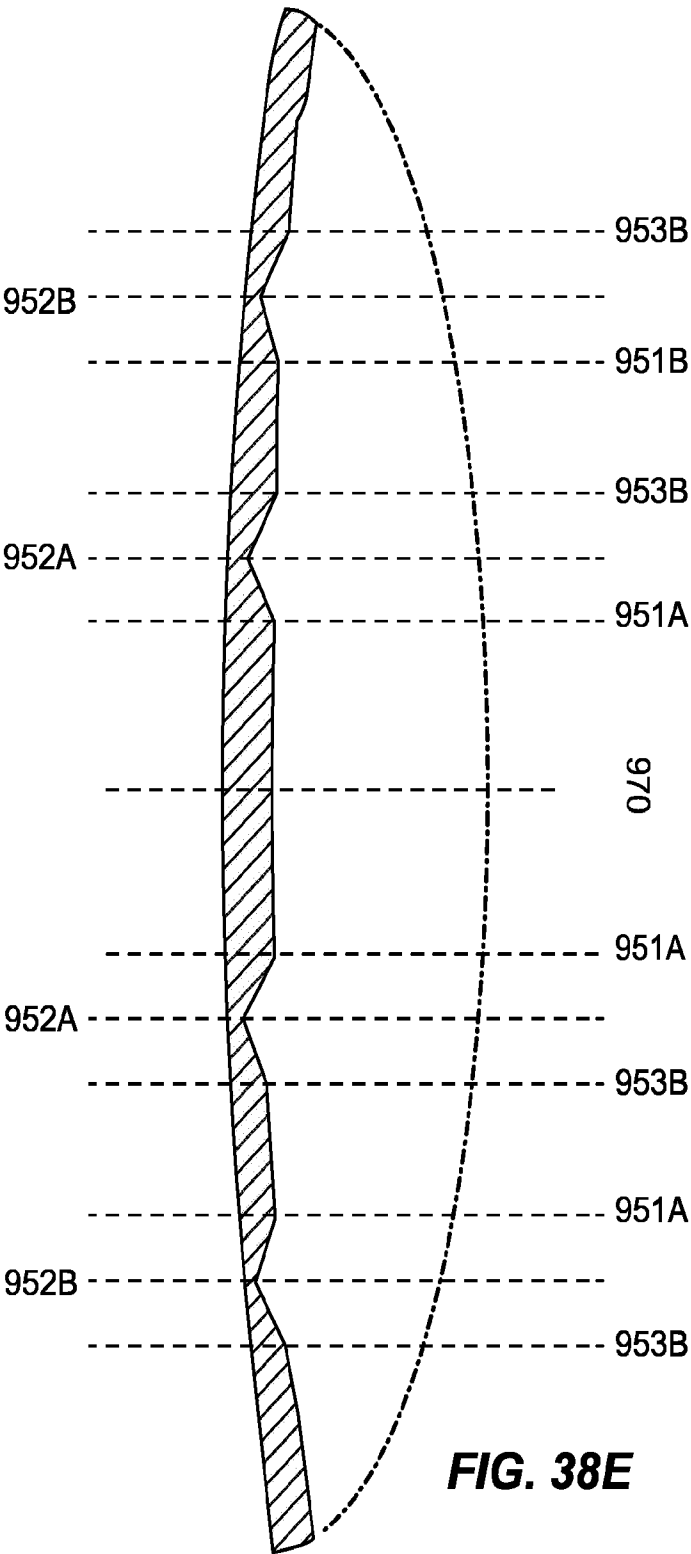


FIG. 38E

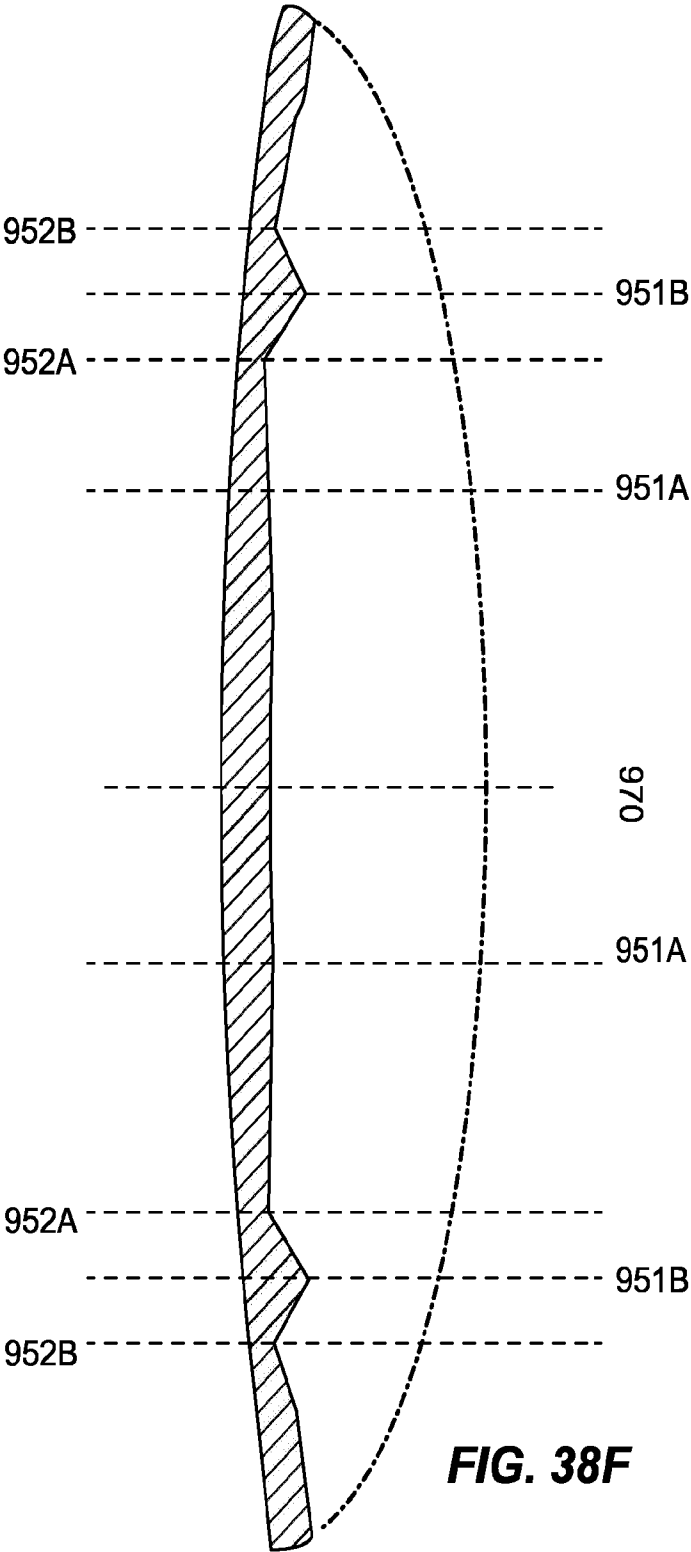


FIG. 38F

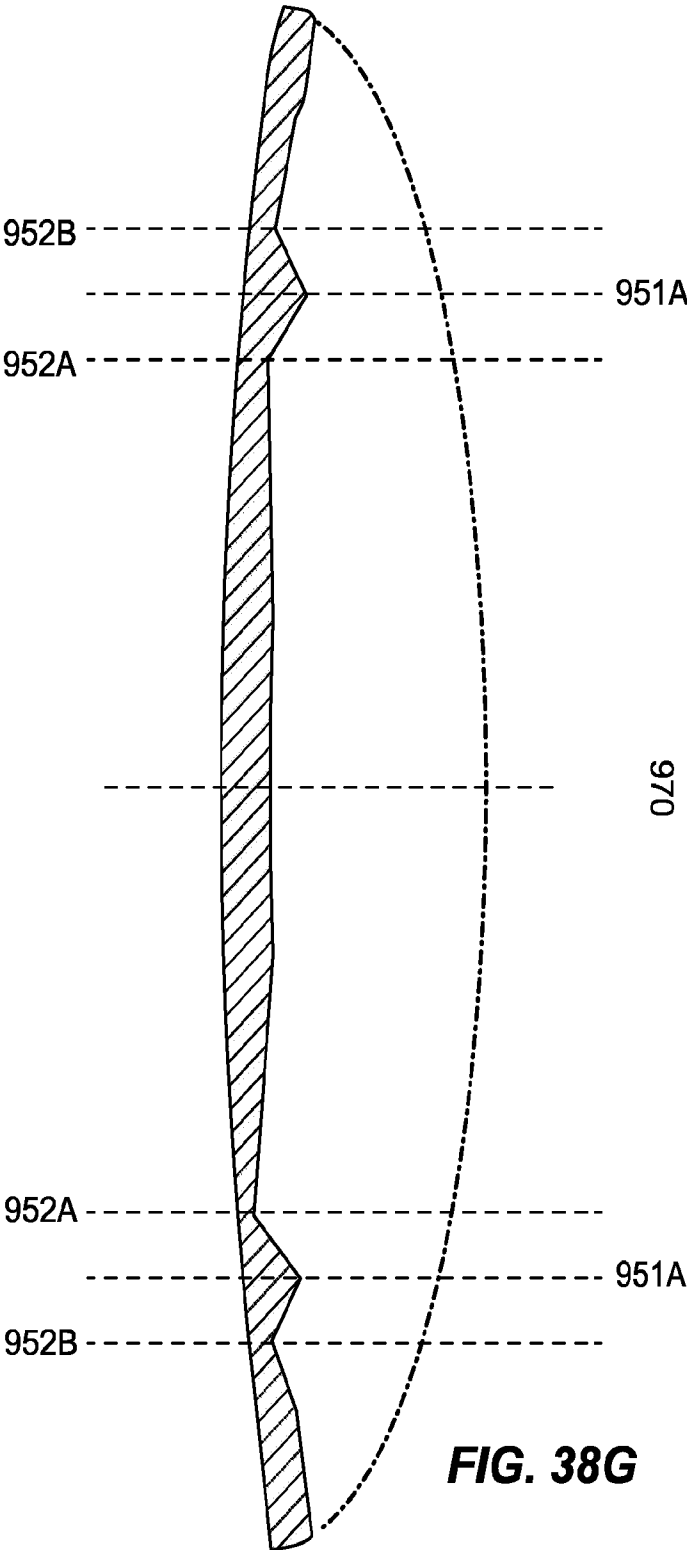
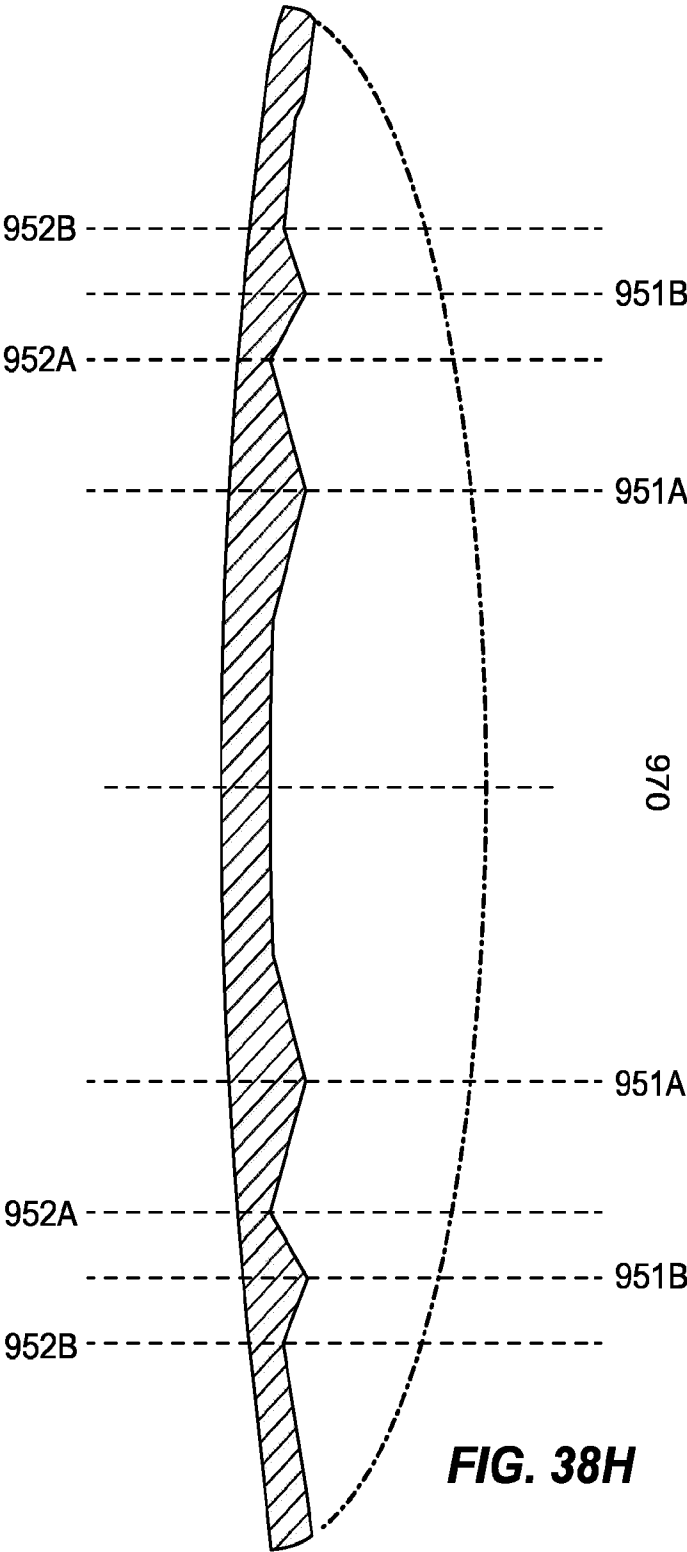


FIG. 38G



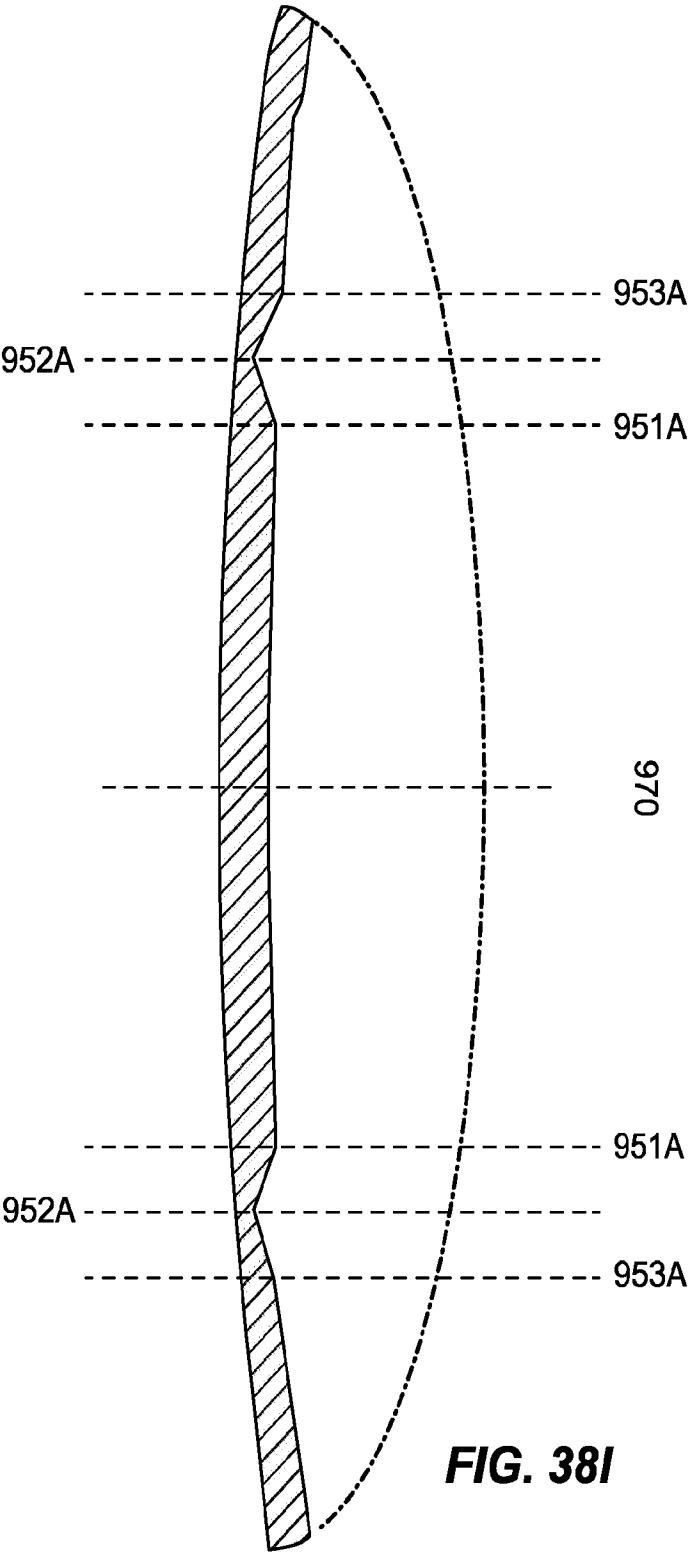
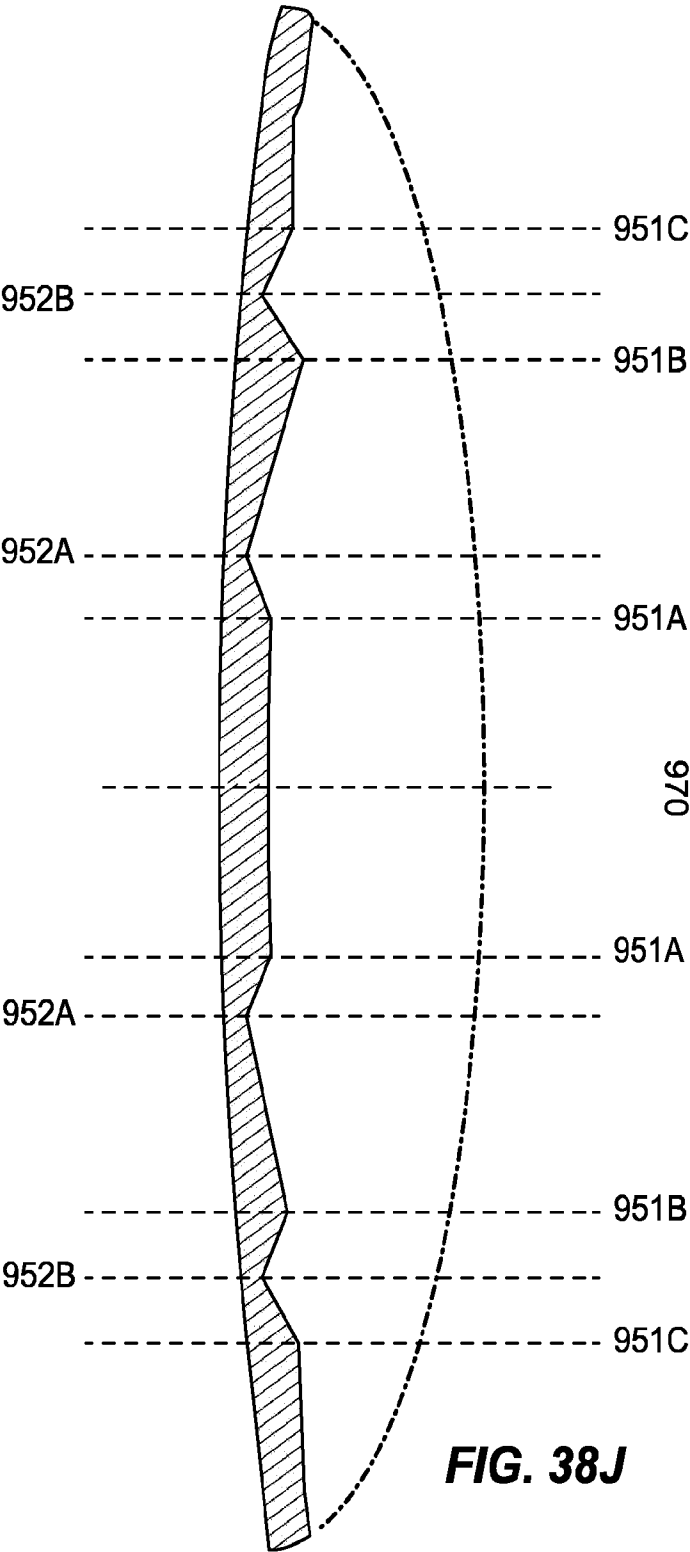


FIG. 38I



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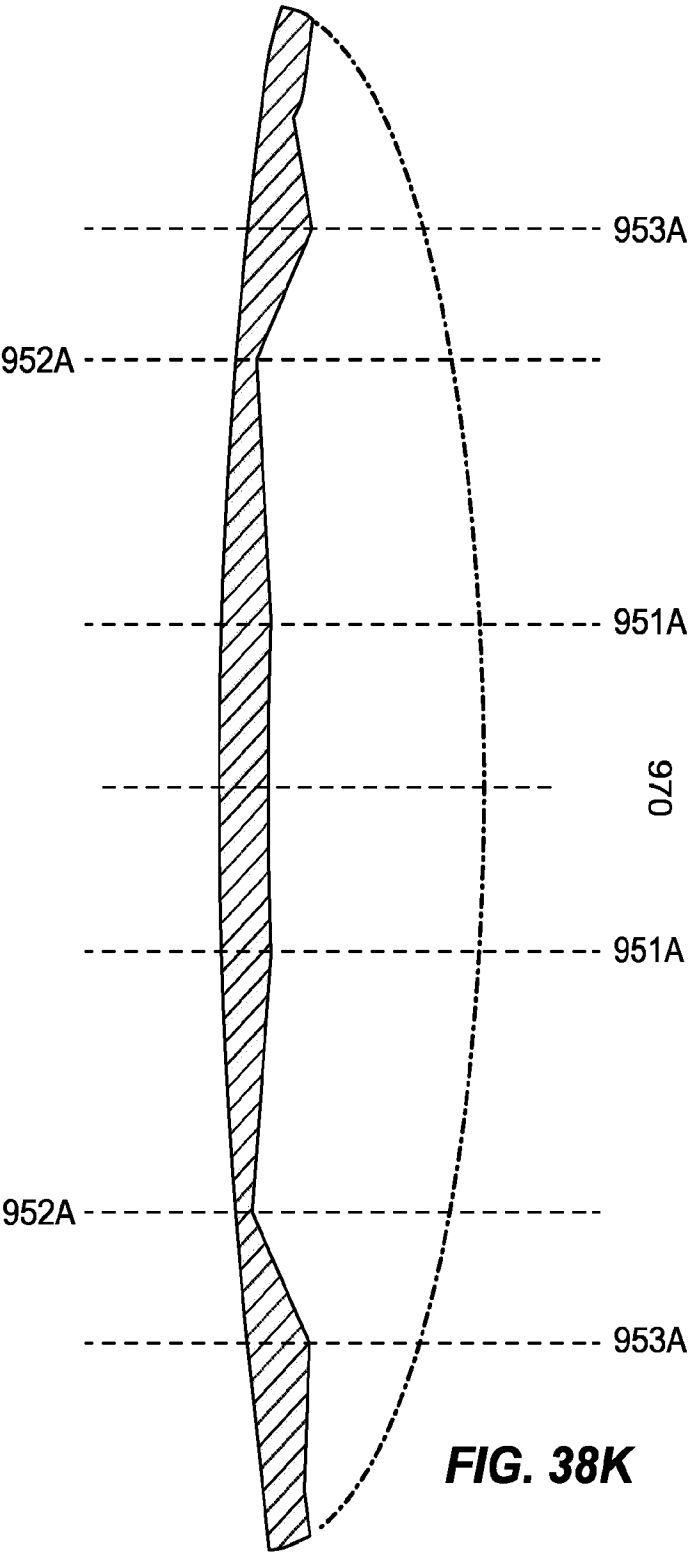
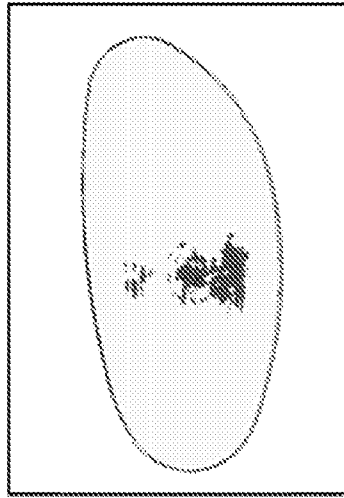


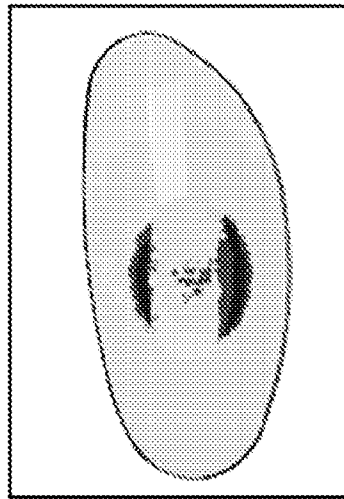
FIG. 38K

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Club head B



Club Head A



Control Club
Head

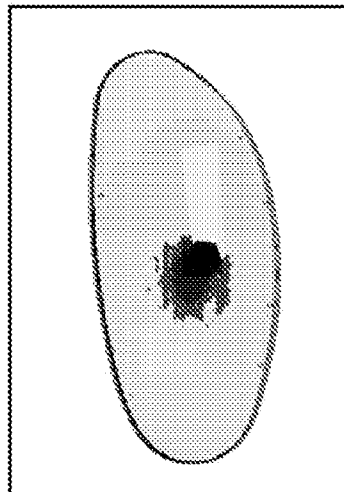


FIG. 39

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2024/054465

A. CLASSIFICATION OF SUBJECT MATTERIPC: **A63B 53/04** (2025.01); **A63B 53/08** (2025.01); **A63B 60/00** (2025.01)CPC: **A63B 53/0408**; **A63B 53/0458**; **A63B 53/0466**; **A63B 53/08**; **A63B 60/00**; **A63B 2102/32**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

See Search History Document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

See Search History Document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

See Search History Document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2012/0149495 A1 (Wada et al.) 14 June 2012 (14.06.2012) para [0028], [0035]-[0037] and figs. 1-6	1-20
A	US 2021/0023424 A1 (Acushnet Company) 28 January 2021 (28.01.2021) Entire document	1-20
A	US 6,652,391 B1 (Kubica et al.) 25 November 2003 (25.11.2003) Entire document	1-20
A	US 2019/0192927 A1 (Karsten Manufacturing Corporation) 27 June 2019 (27.06.2019) Entire document	1-20
A	US 7,438,647 B1 (Hocknell) 21 October 2008 (21.10.2008) Entire document	1-20
A	US 2023/0271067 A1 (Acushnet Company) 31 August 2023 (31.08.2023) Entire document	1-20



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See patent family annex.

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“O” document referring to an oral disclosure, use, exhibition or other means

“P” document published prior to the international filing date but later than the priority date claimed

“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

“&” document member of the same patent family

Date of the actual completion of the international search

08 January 2025 (08.01.2025)

Date of mailing of the international search report

04 February 2025 (04.02.2025)

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