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(12) **United States Patent**
Beach et al.

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(54) **GOLF CLUB HEAD**

(71) Applicant: **Taylor Made Golf Company, Inc.**, Carlsbad, CA (US)

(72) Inventors: **Todd P. Beach**, Encinitas, CA (US); **Nathan T. Sargent**, Oceanside, CA (US); **Kraig Alan Willett**, Fallbrook, CA (US)

(73) Assignee: **TAYLOR MADE GOLF COMPANY, INC.**, Carlsbad, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 14 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **16/282,386**

(22) Filed: **Feb. 22, 2019**

(65) **Prior Publication Data**

US 2019/0184244 A1 Jun. 20, 2019

Related U.S. Application Data

(63) Continuation of application No. 15/980,552, filed on May 15, 2018, now Pat. No. 10,507,365, which is a (Continued)

(51) **Int. Cl.**
A63B 53/04 (2015.01)
A63B 60/02 (2015.01)
(Continued)

(52) **U.S. Cl.**
CPC ***A63B 53/0466*** (2013.01); ***A63B 53/04*** (2013.01); ***A63B 53/06*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC A63B 53/0466; A63B 60/02; A63B 53/04; A63B 53/06; A63B 2060/002;
(Continued)

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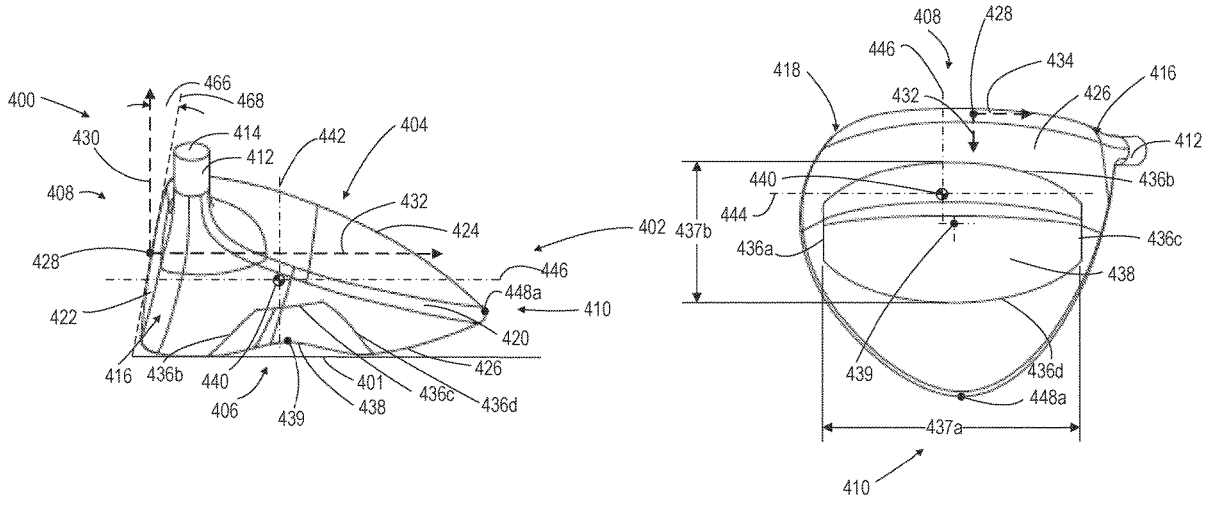
Primary Examiner — Sebastiano Passaniti
(74) *Attorney, Agent, or Firm* — Dawsey Co., LPA; David J. Dawsey

(57) **ABSTRACT**

Golf club heads are described herein, and in one embodiment including a body with an exterior surface defining a first body volume of at least about 400 cm^3. The body has a bottom portion having a sole, a top portion, a front portion, a back portion, and a front-rear dimension of at least about 111 mm. A face positioned at the front portion of the body and is configured to receive an impact. A groove located in the sole and extending from the heel portion to the toe portion. The golf club head has a moment of inertia about a center of gravity z-axis of at least about 450 $kg \cdot mm^2$ and a coefficient of restitution greater than about 0.810.

20 Claims, 18 Drawing Sheets



Related U.S. Application Data

continuation of application No. 15/177,586, filed on Jun. 9, 2016, now Pat. No. 9,993,700, which is a continuation of application No. 14/048,610, filed on Oct. 8, 2013, now Pat. No. 9,387,371, which is a continuation of application No. 13/741,193, filed on Jan. 14, 2013, now Pat. No. 8,579,722, which is a continuation of application No. 13/447,994, filed on Apr. 16, 2012, now Pat. No. 8,353,782, which is a continuation of application No. 13/195,467, filed on Aug. 1, 2011, now Pat. No. 8,157,671, which is a continuation of application No. 12/316,584, filed on Dec. 11, 2008, now Pat. No. 8,012,038.

(51) **Int. Cl.**
A63B 53/06 (2015.01)
A63B 60/00 (2015.01)
A63B 71/06 (2006.01)

(52) **U.S. Cl.**
CPC ***A63B 60/02*** (2015.10); *A63B 53/042* (2020.08); *A63B 53/0408* (2020.08); *A63B 53/0412* (2020.08); *A63B 53/0416* (2020.08); *A63B 53/0433* (2020.08); *A63B 53/0437* (2020.08); *A63B 53/0458* (2020.08); *A63B 60/002* (2020.08); *A63B 2053/0491* (2013.01); *A63B 2071/0625* (2013.01)

(58) **Field of Classification Search**
CPC A63B 2053/0416; A63B 2053/0437; A63B 2053/0408; A63B 2053/0412; A63B 2053/042; A63B 2053/0458; A63B 2071/0625; A63B 2053/0433; A63B 2053/0491
USPC 473/324–350, 287–292
See application file for complete search history.

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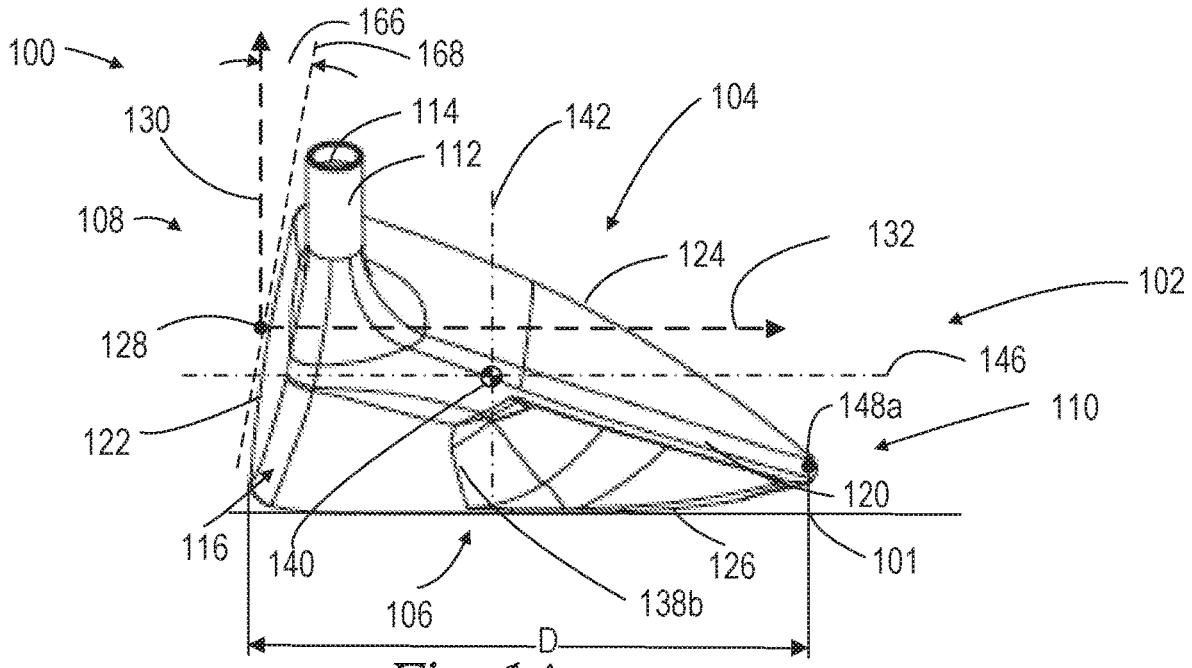
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Fig. 1A

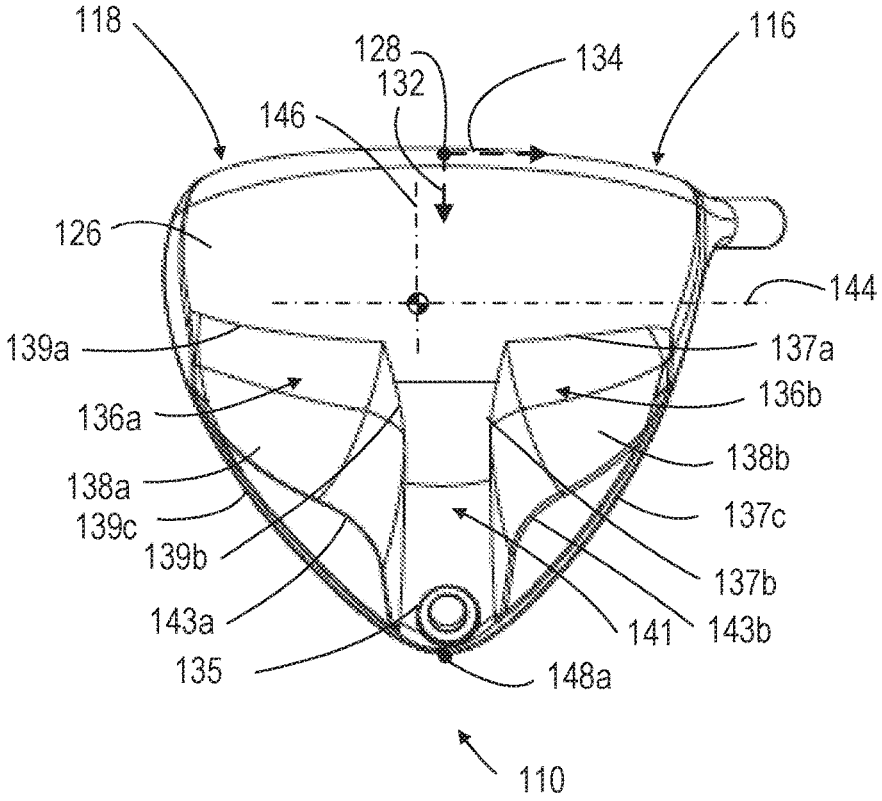
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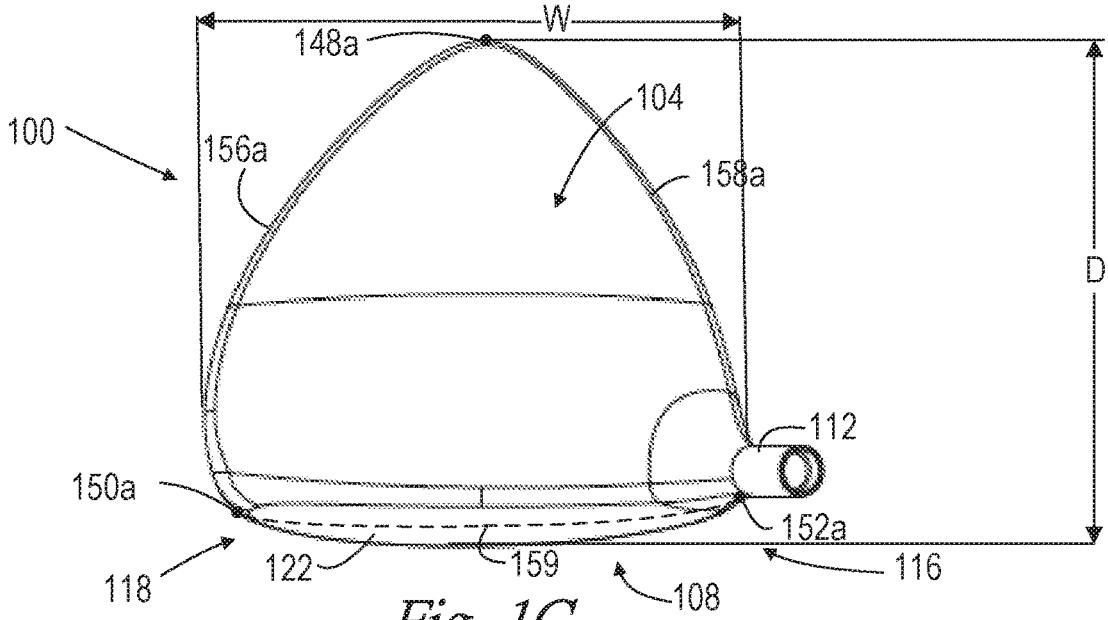
Fig. 1B



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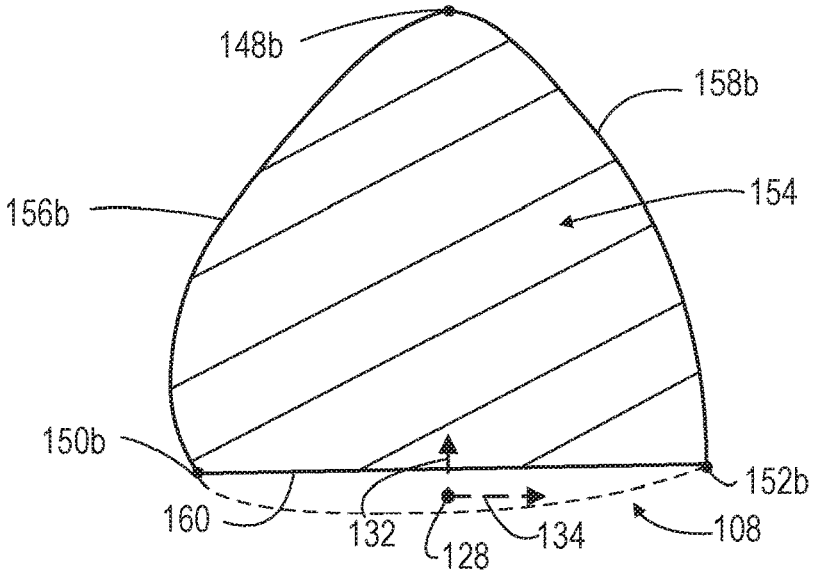

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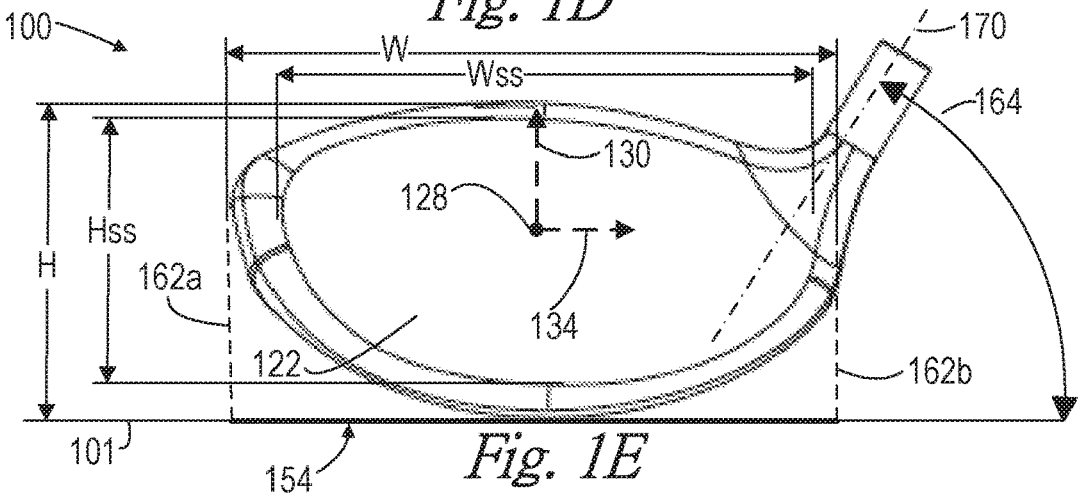

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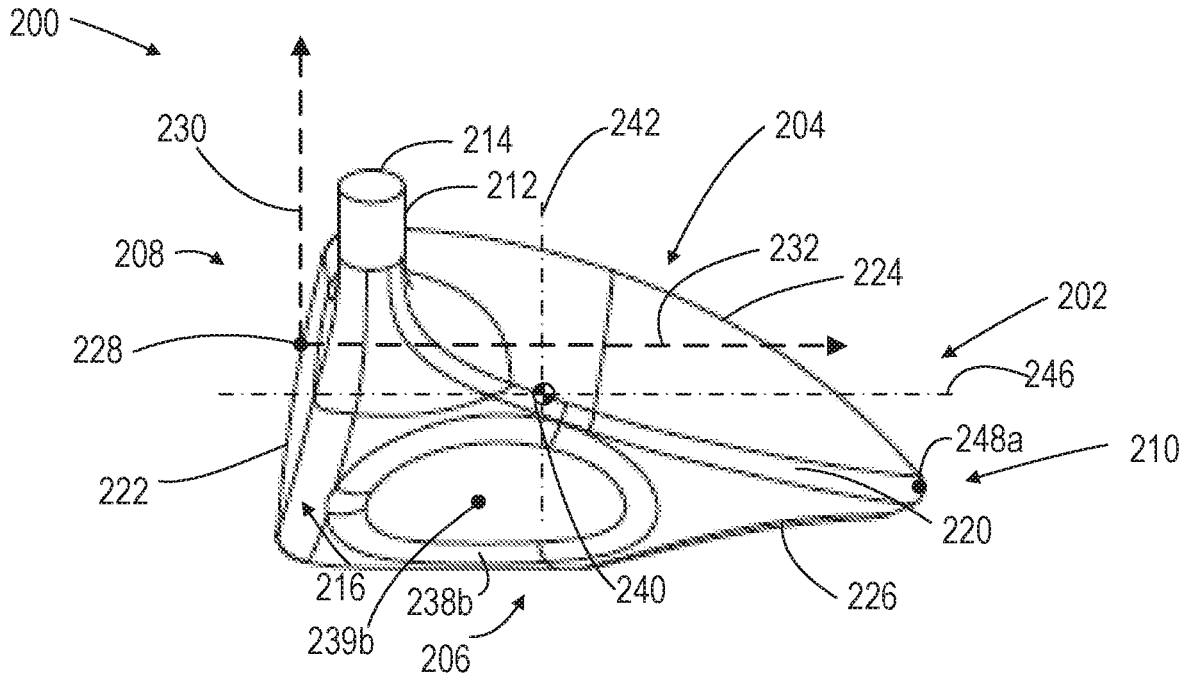
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Fig. 2A

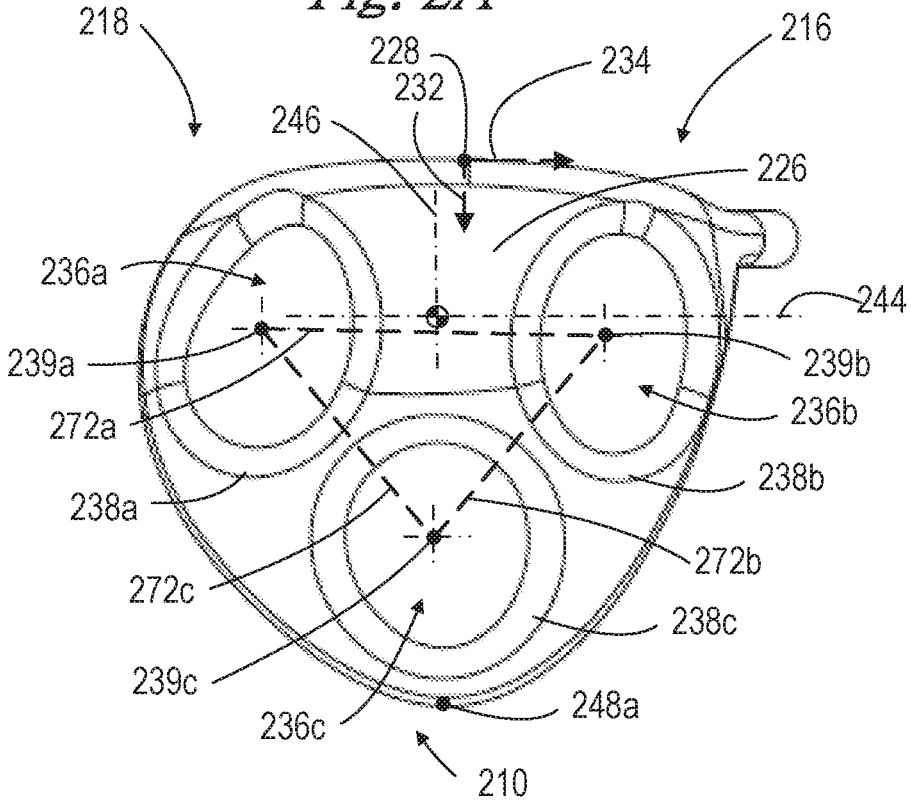
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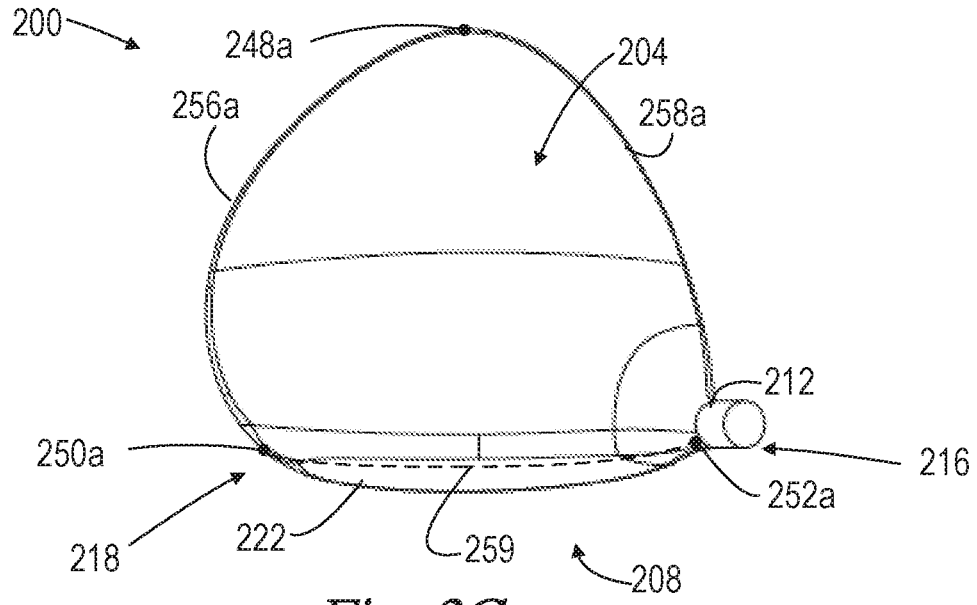
Fig. 2B



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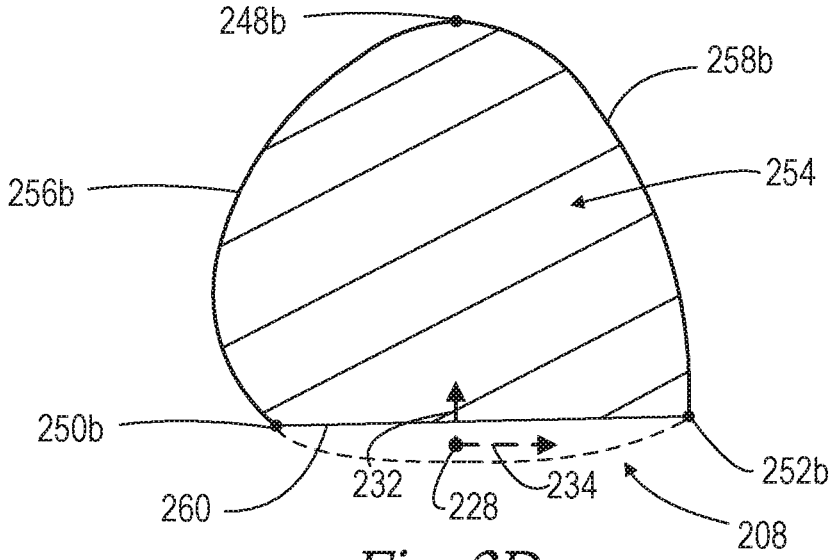

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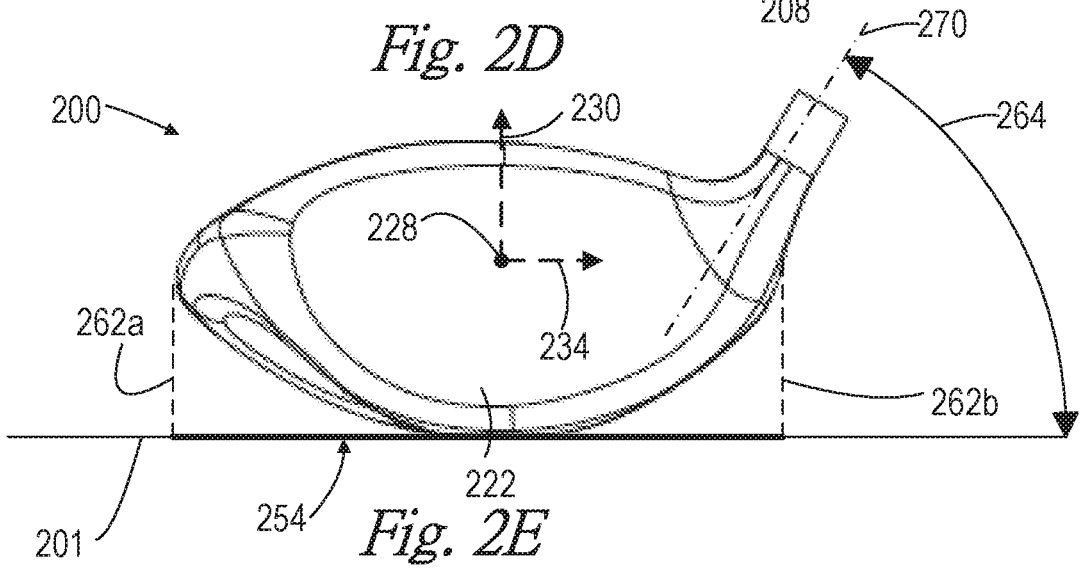

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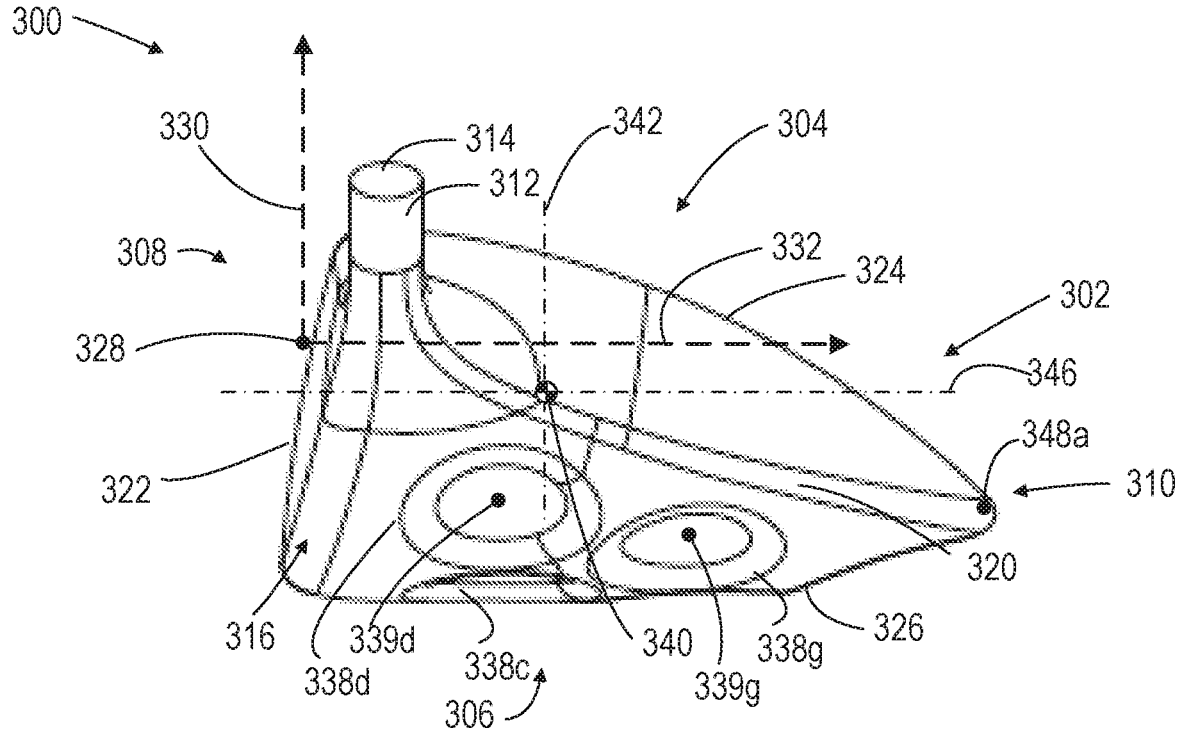
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Fig. 3A

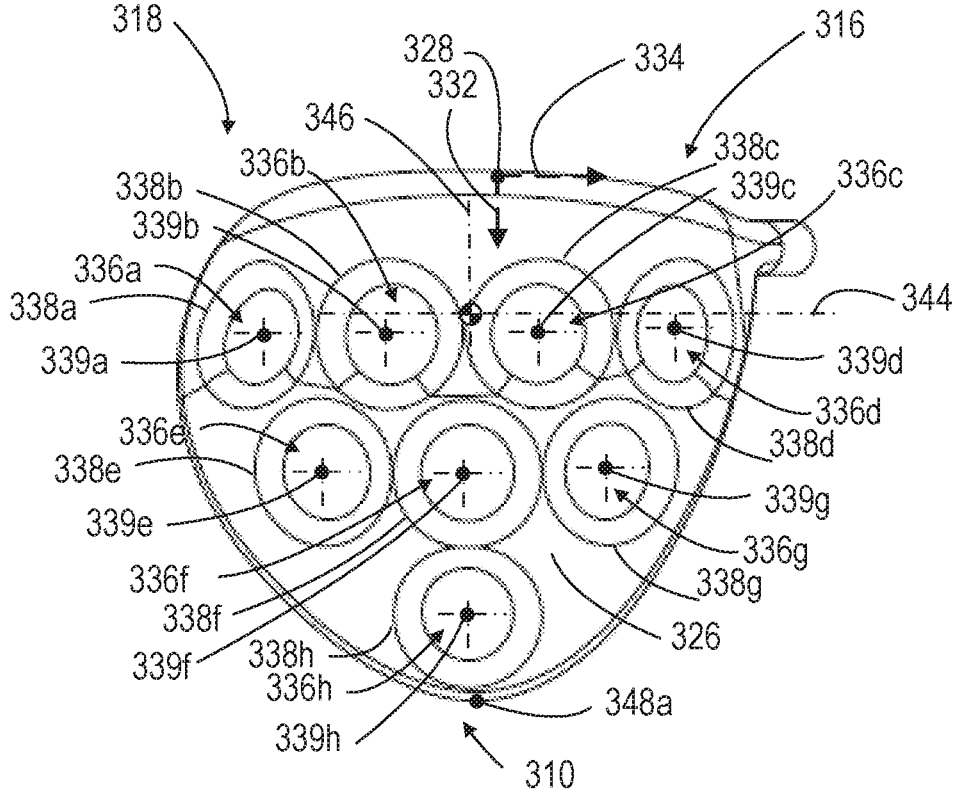
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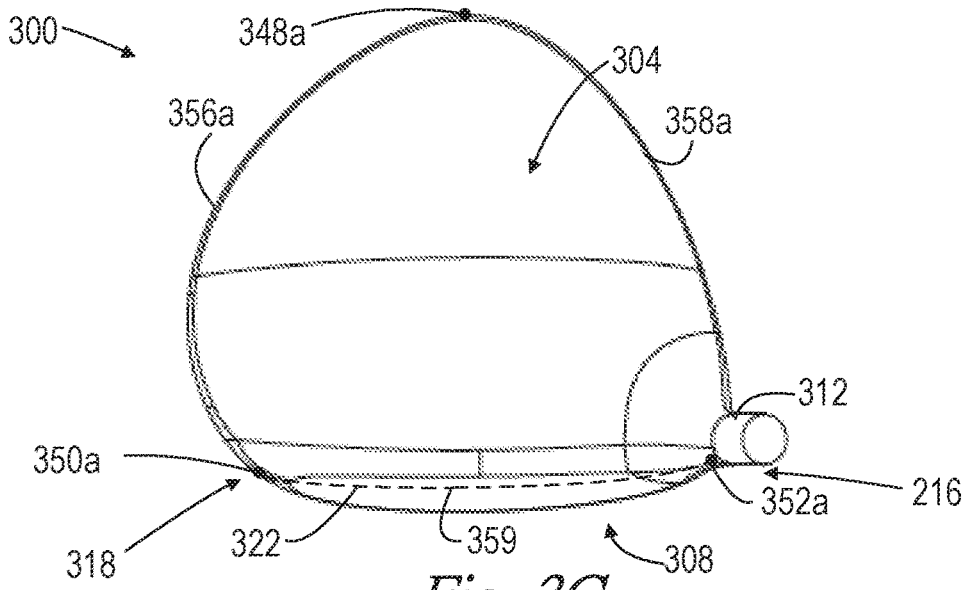
Fig. 3B



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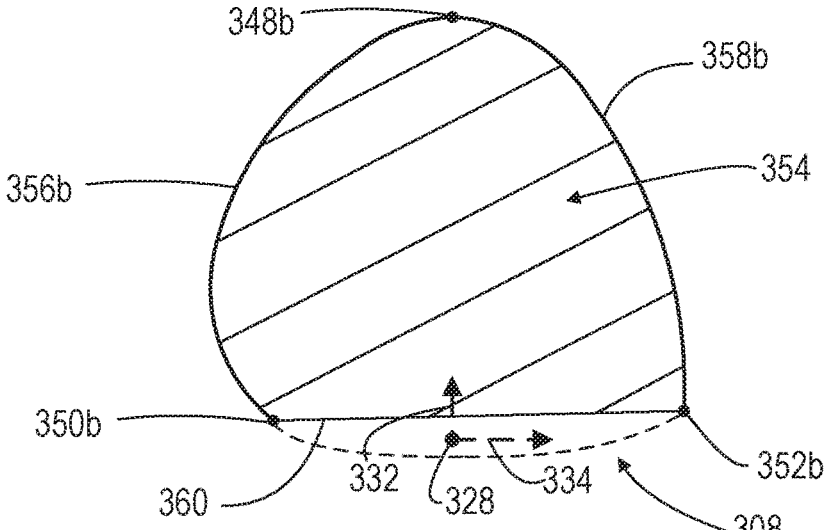

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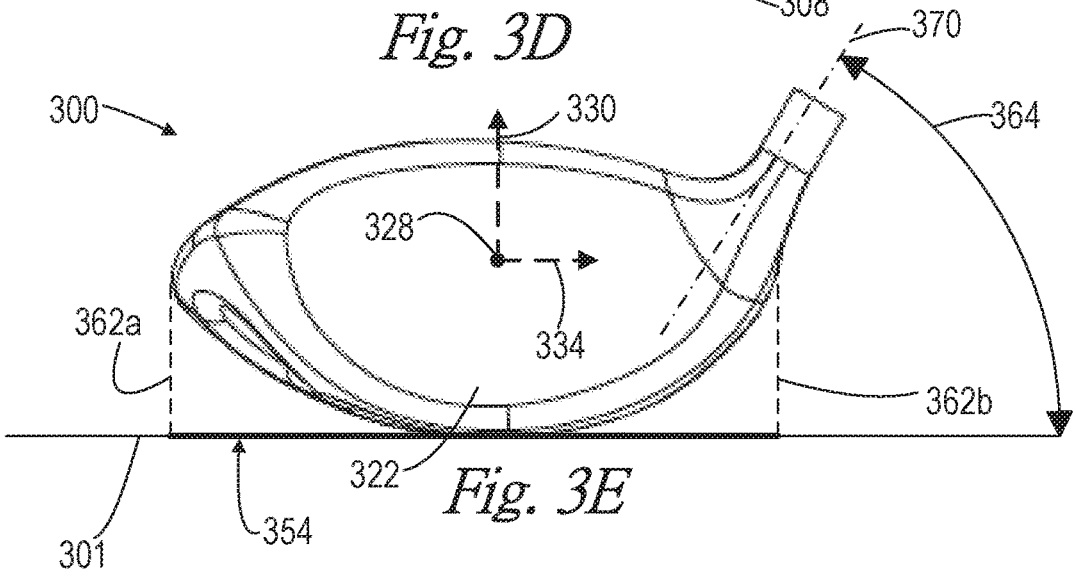

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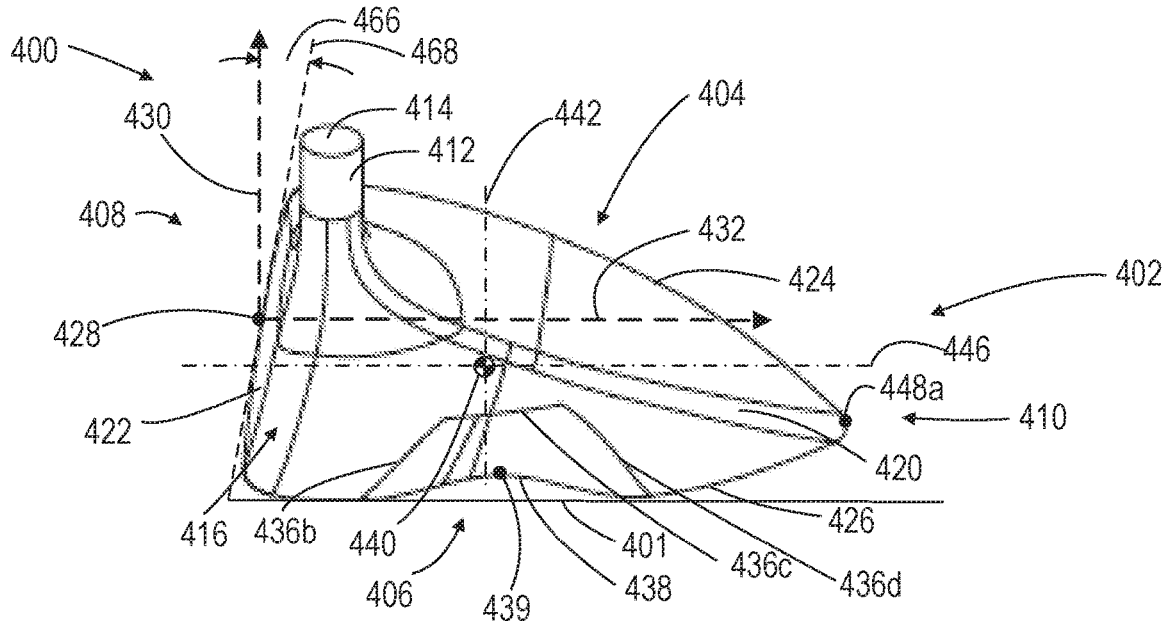
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Fig. 4A

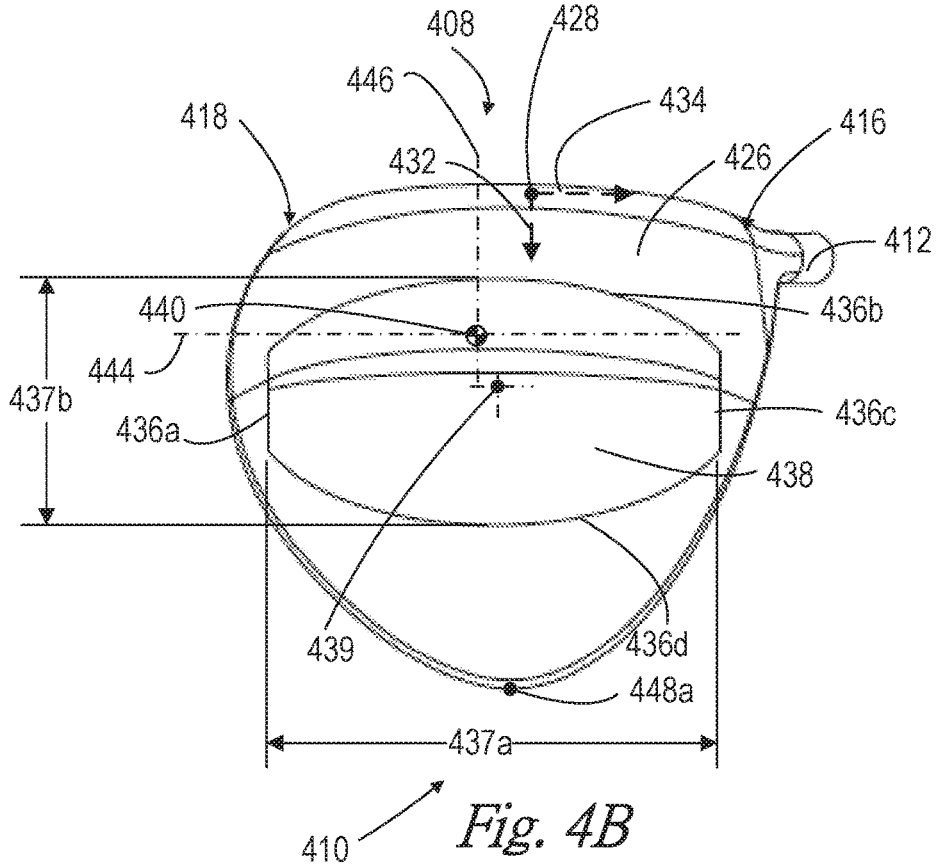
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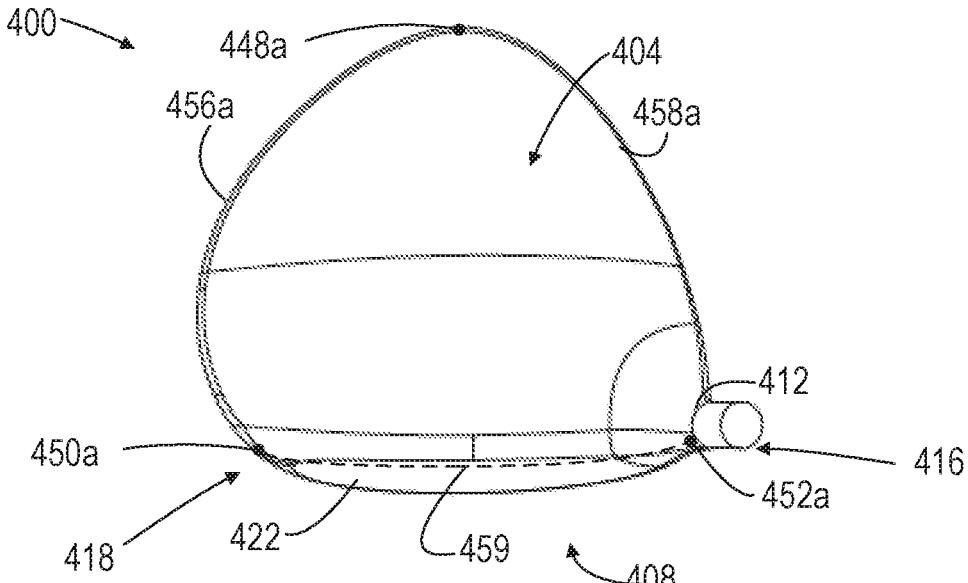
Fig. 4B



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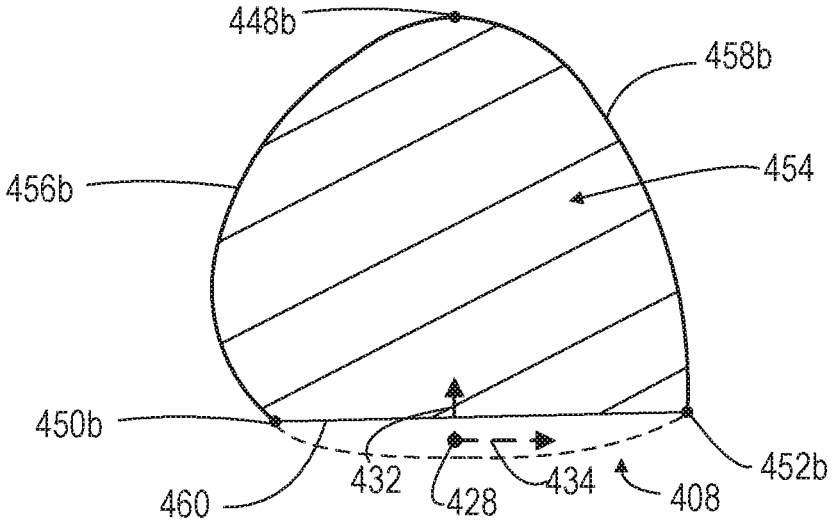

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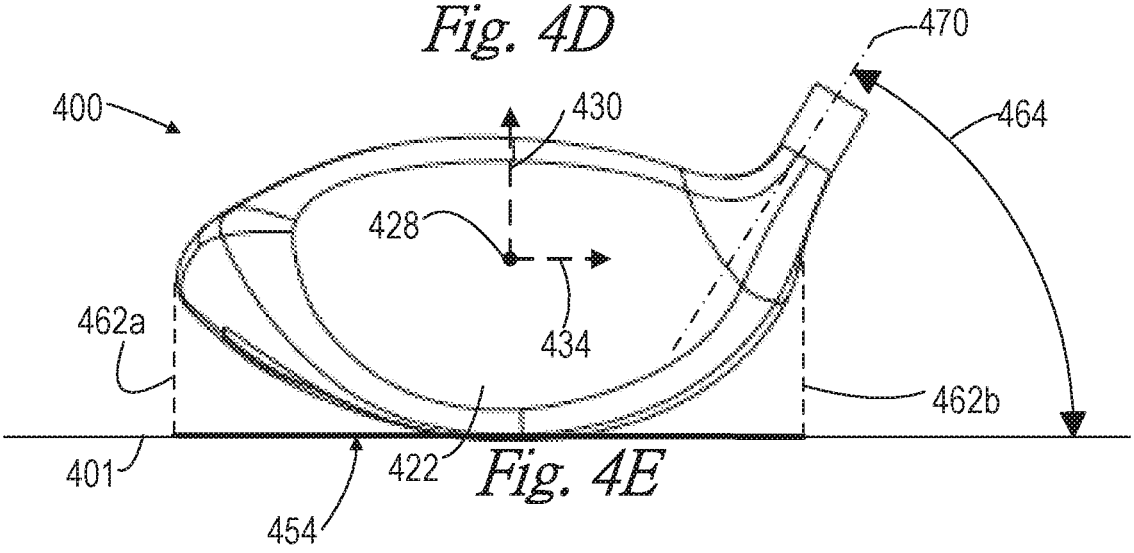

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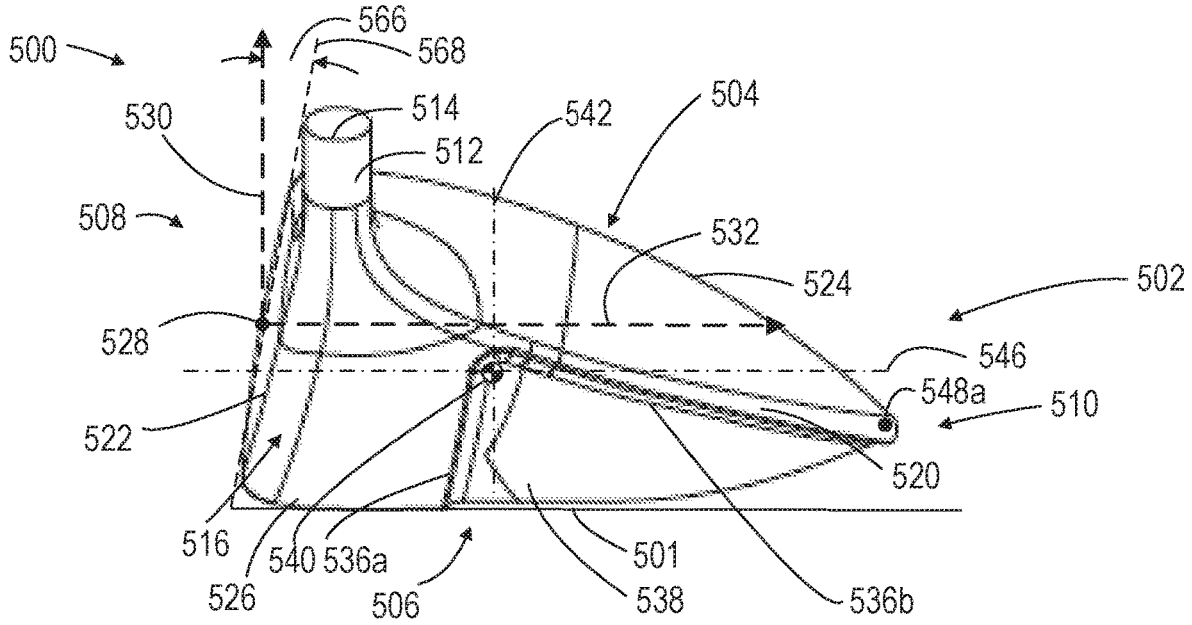
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Fig. 5A

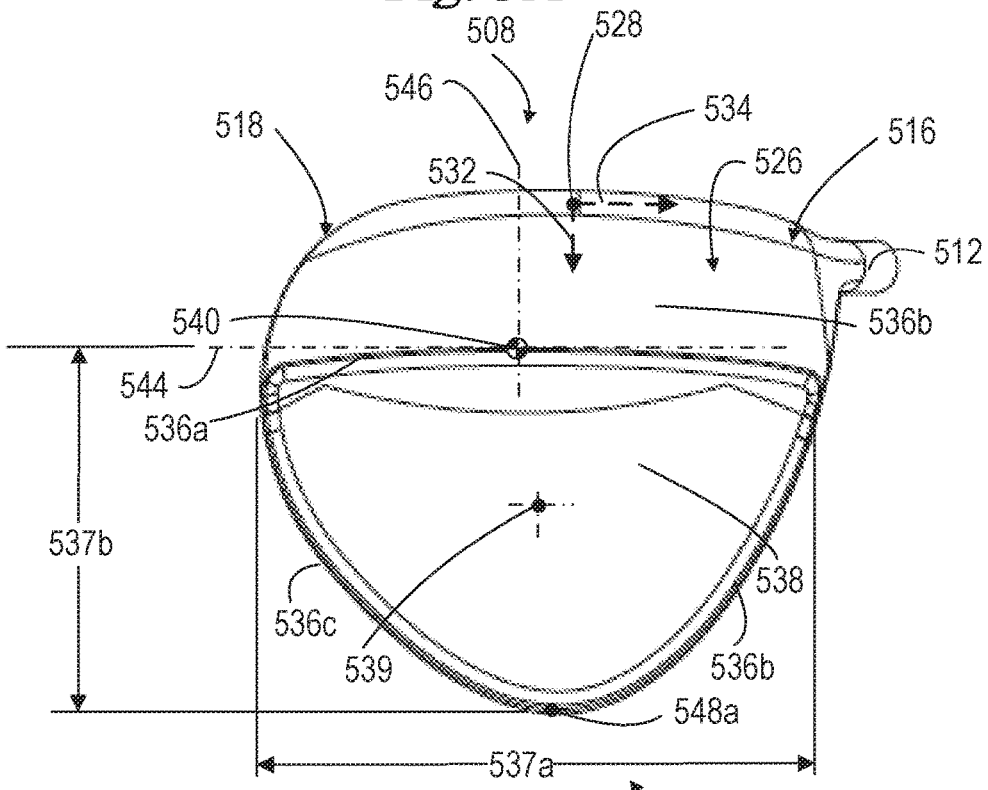
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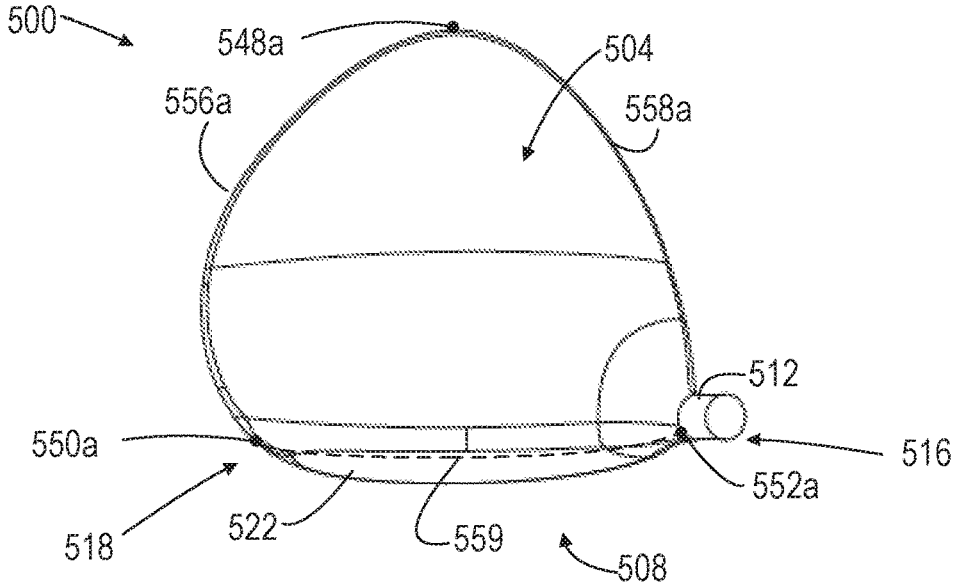
Fig. 5B



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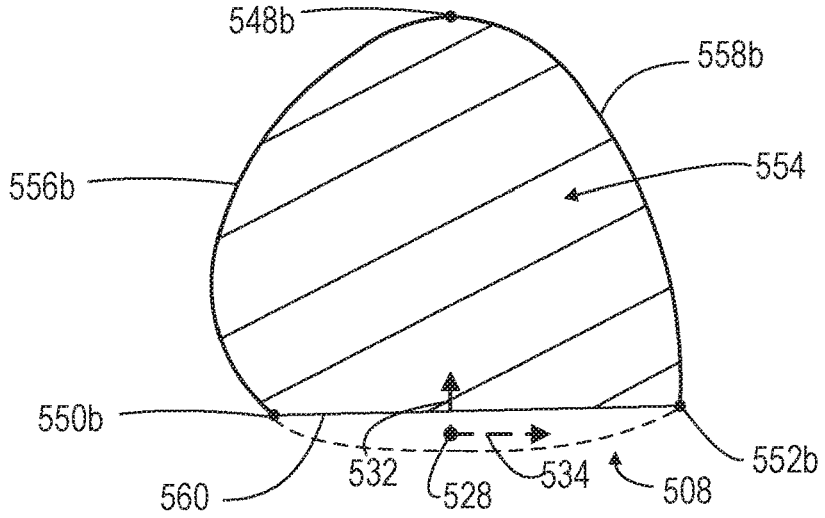

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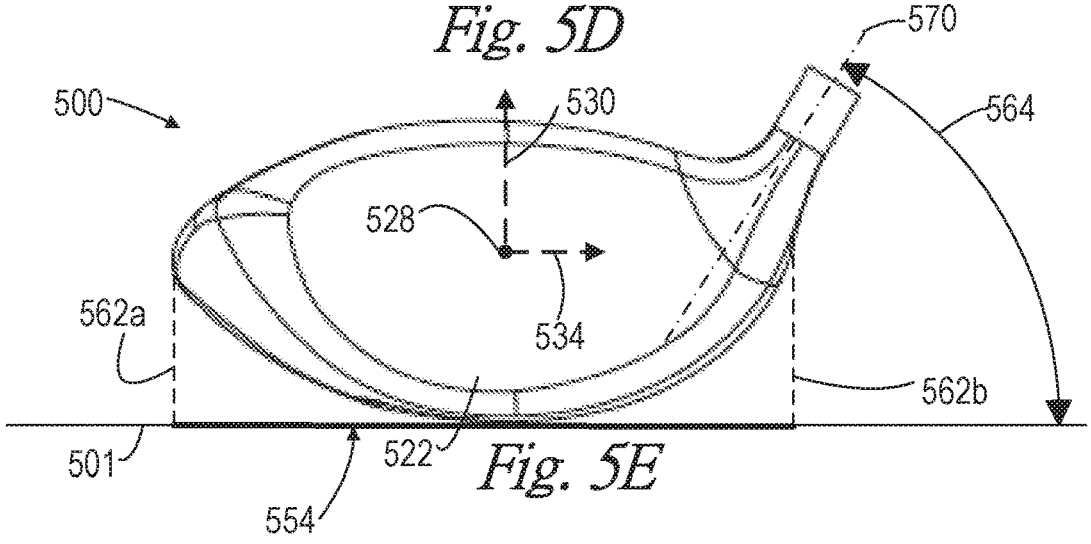

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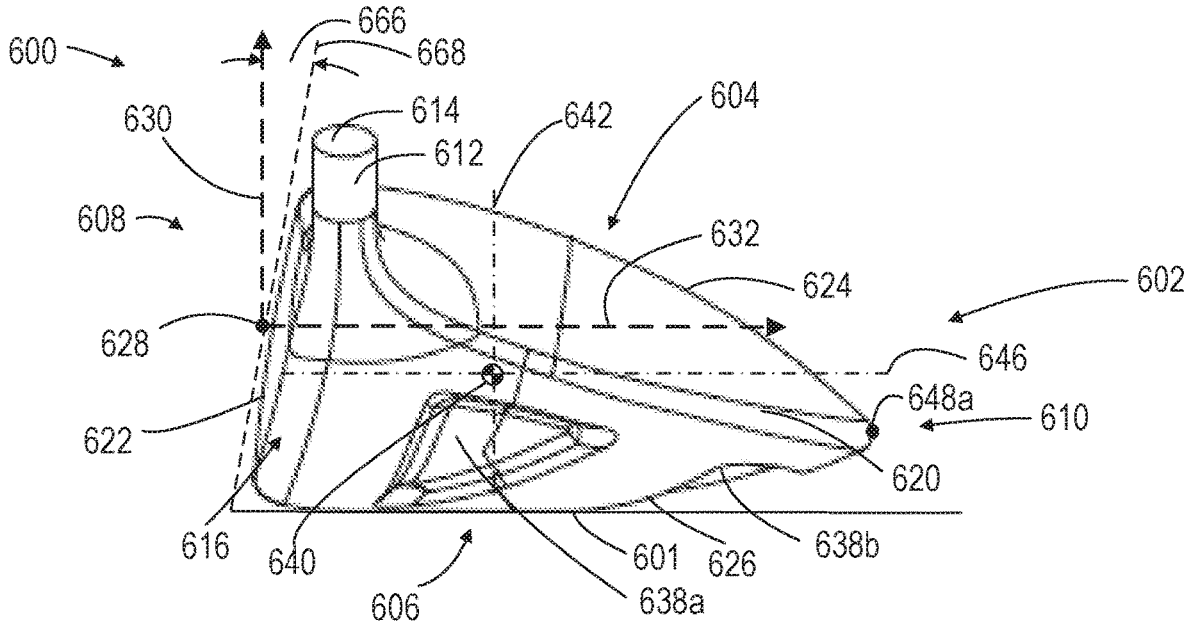
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Fig. 6A

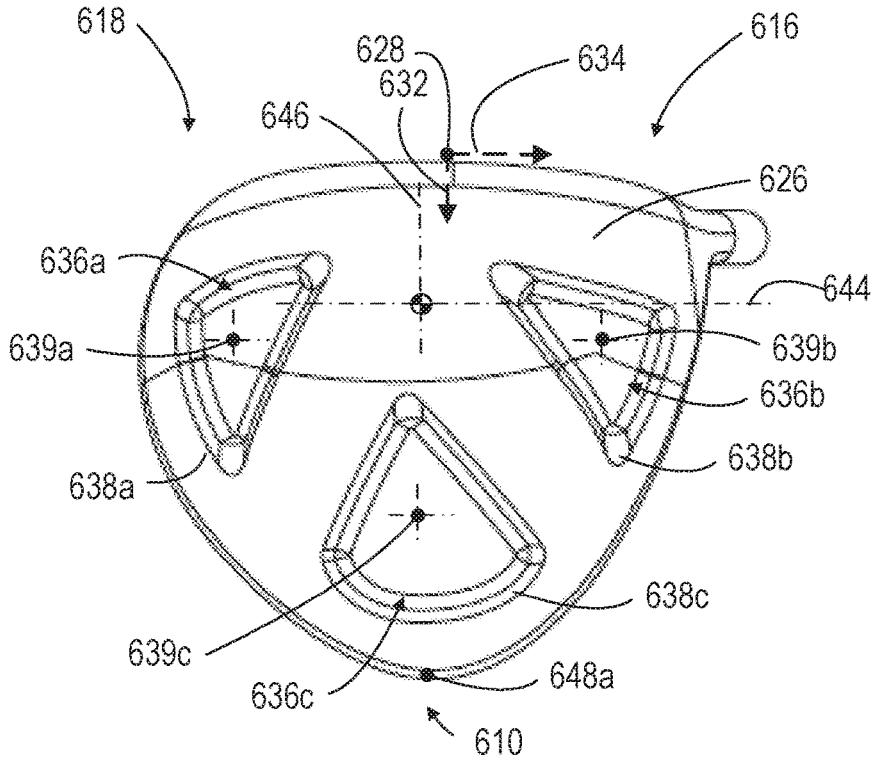
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Fig. 6B

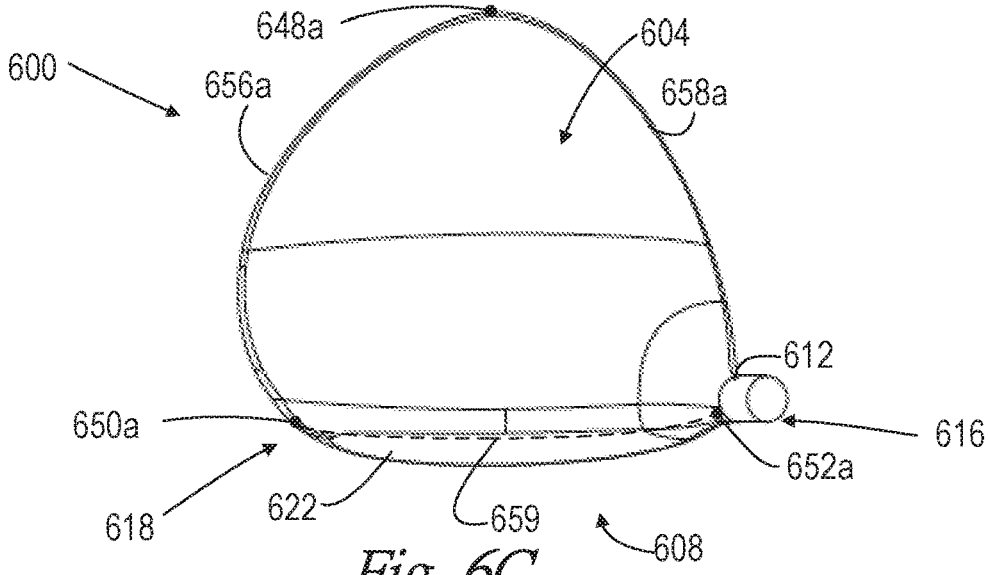

Fig. 6C

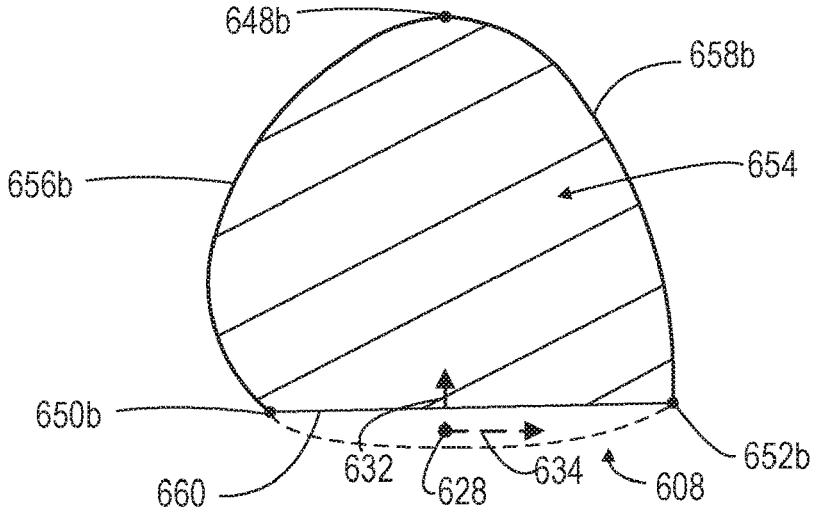

Fig. 6D

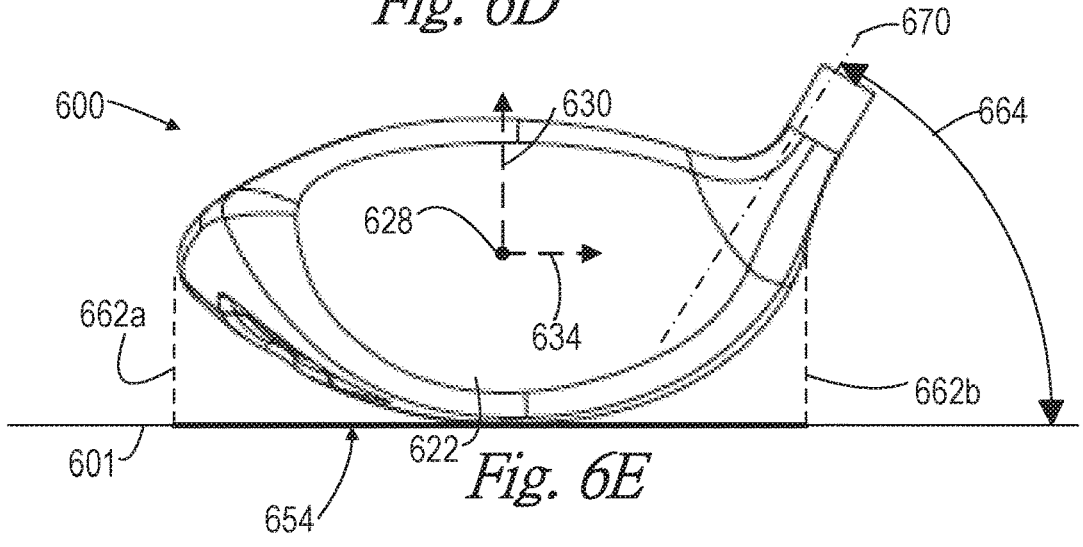

Fig. 6E

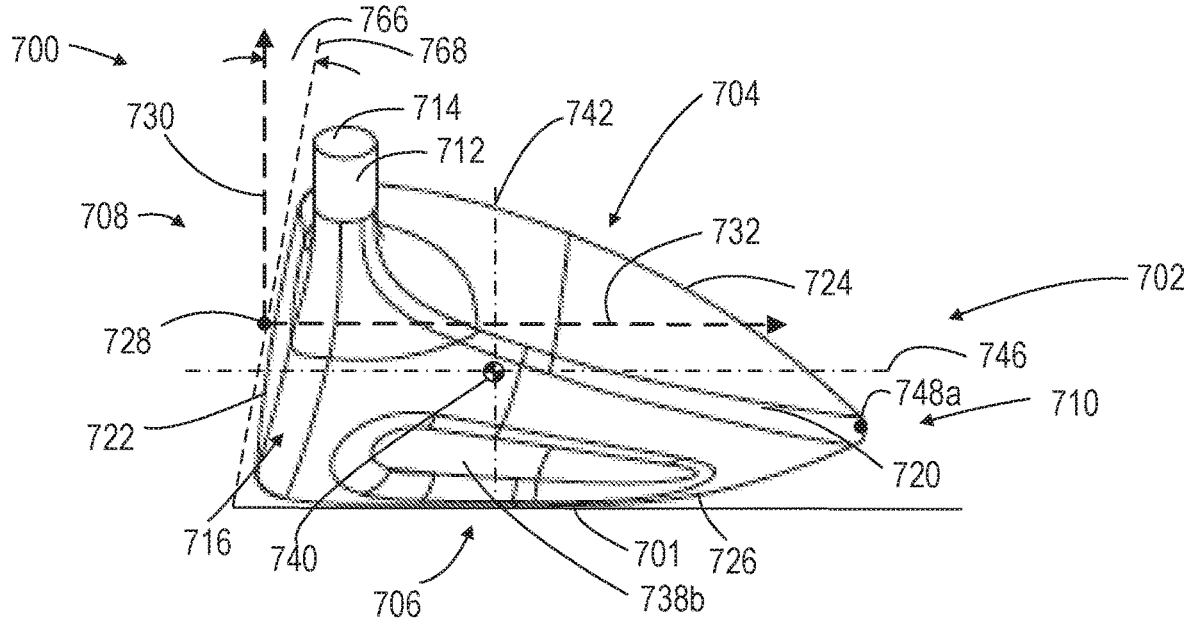
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Fig. 7A

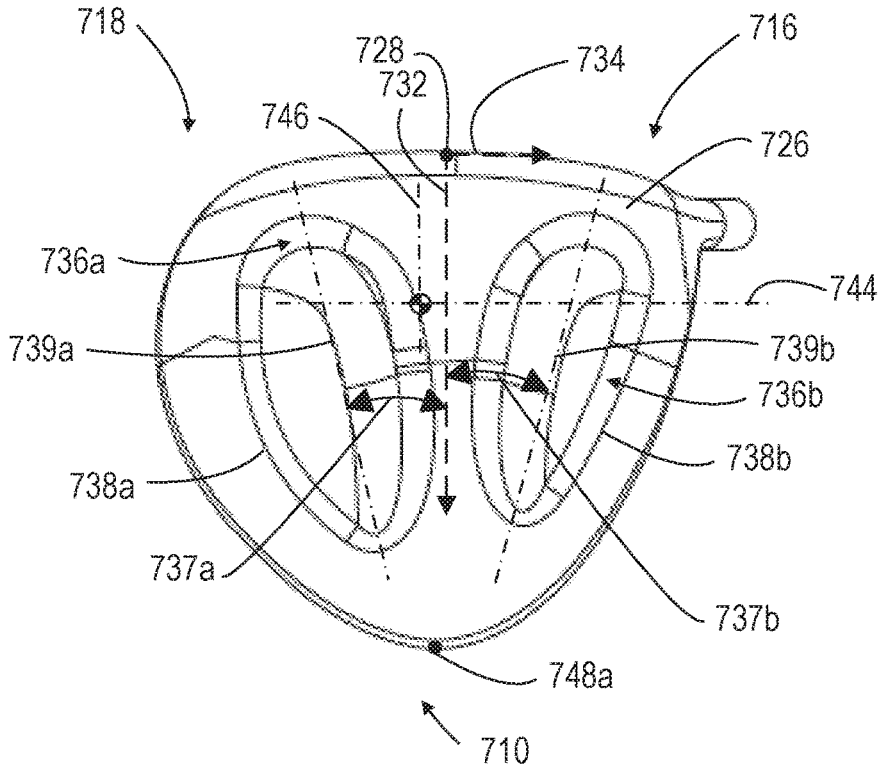
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Fig. 7B

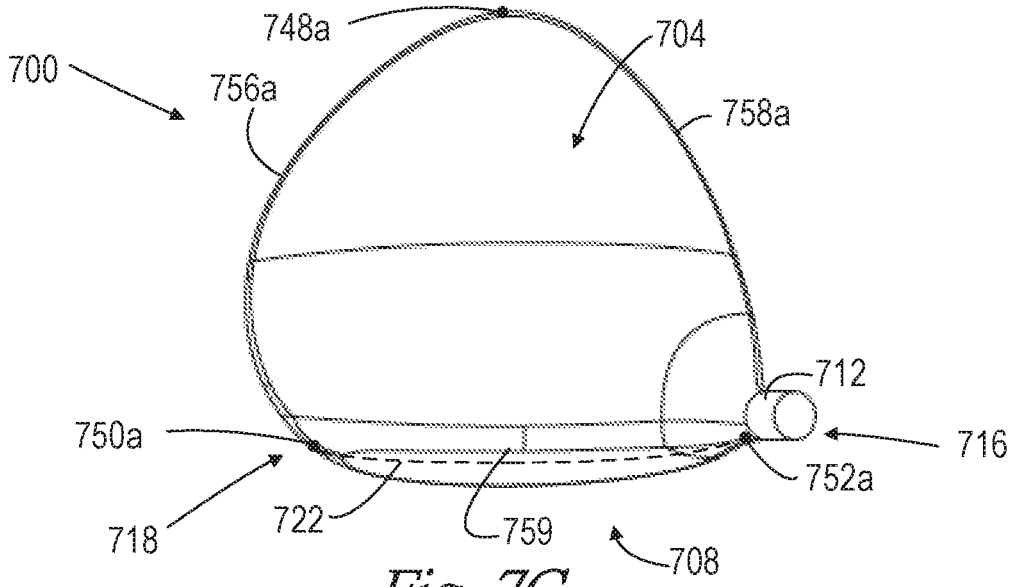

Fig. 7C

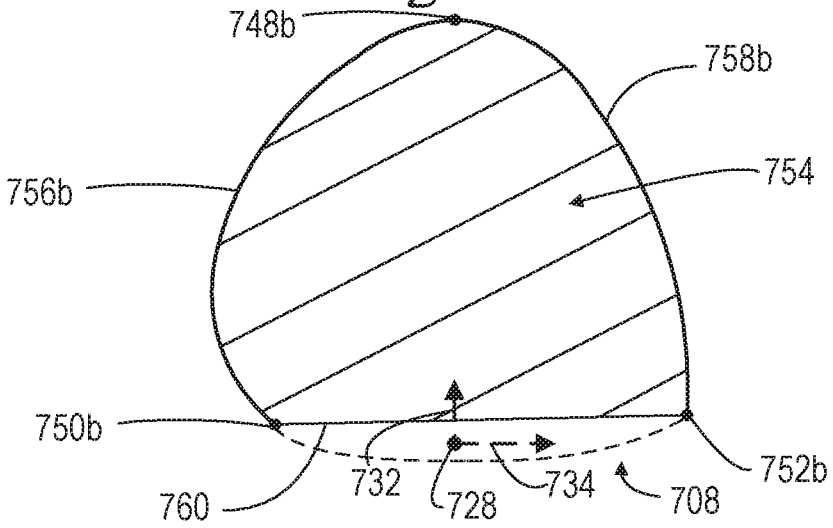

Fig. 7D

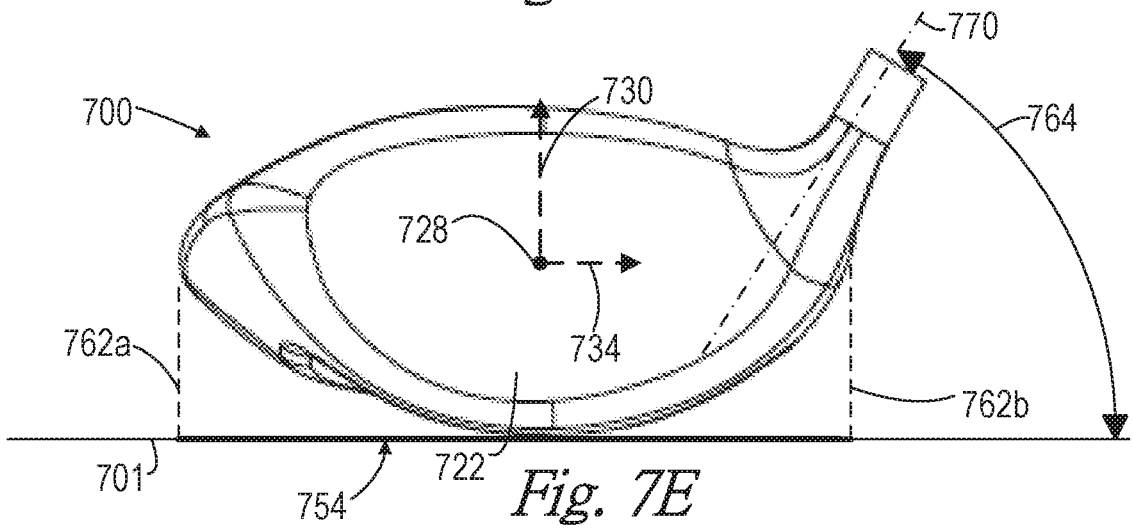

Fig. 7E

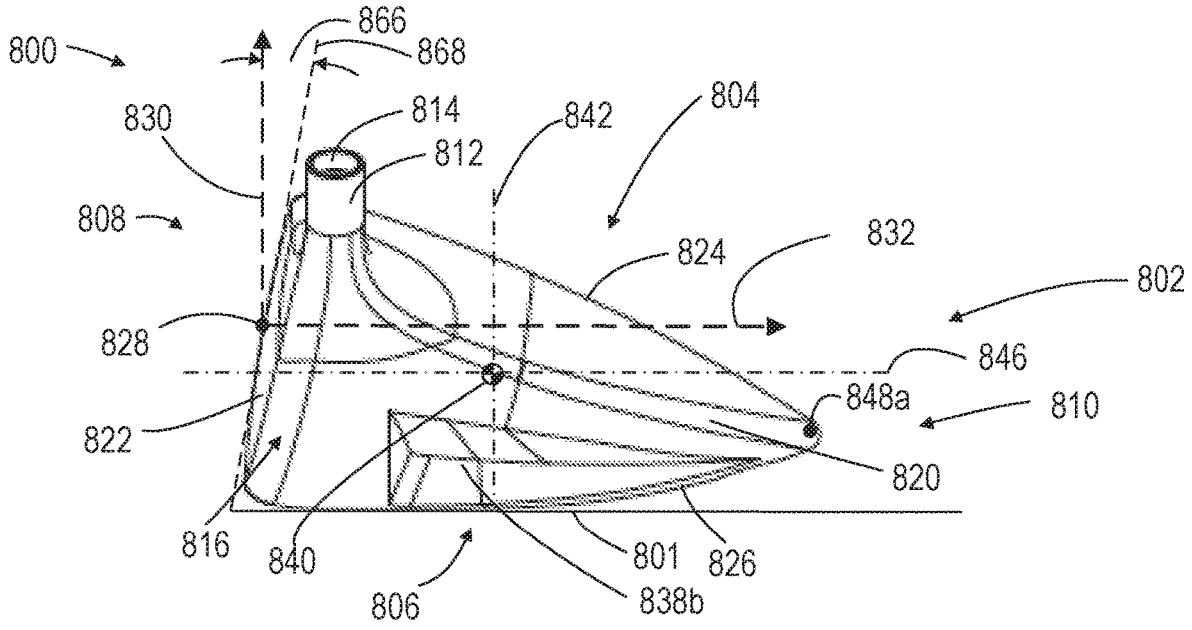
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Fig. 8A

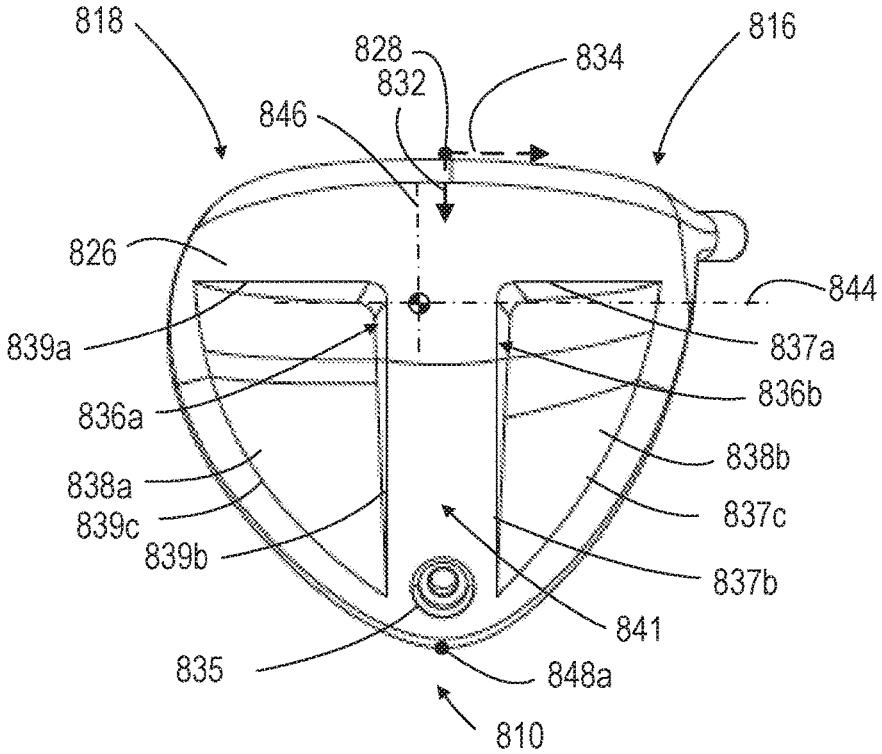
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Fig. 8B

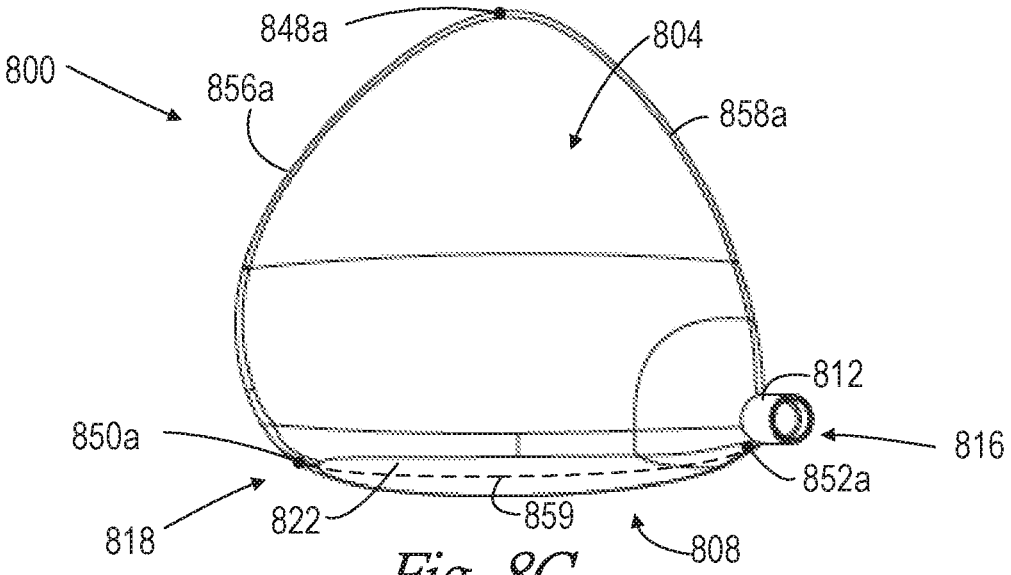

Fig. 8C

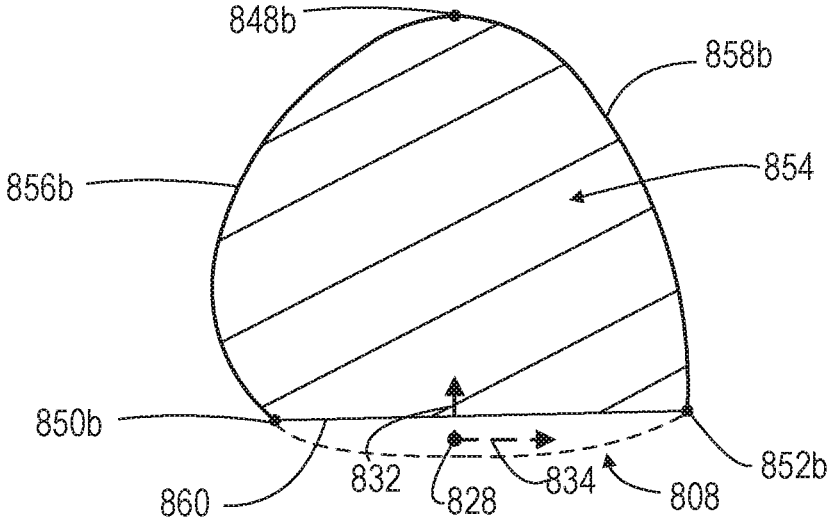

Fig. 8D

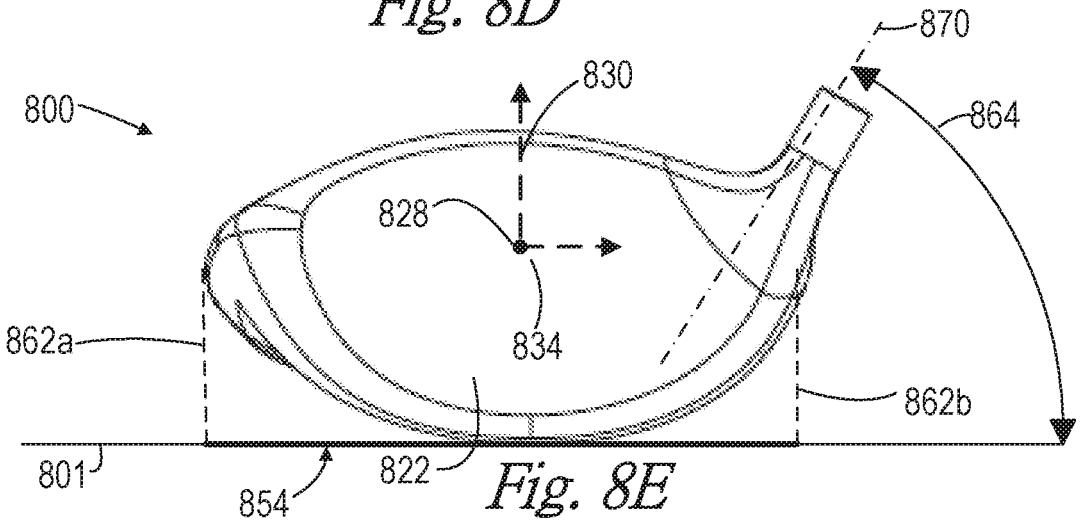

Fig. 8E

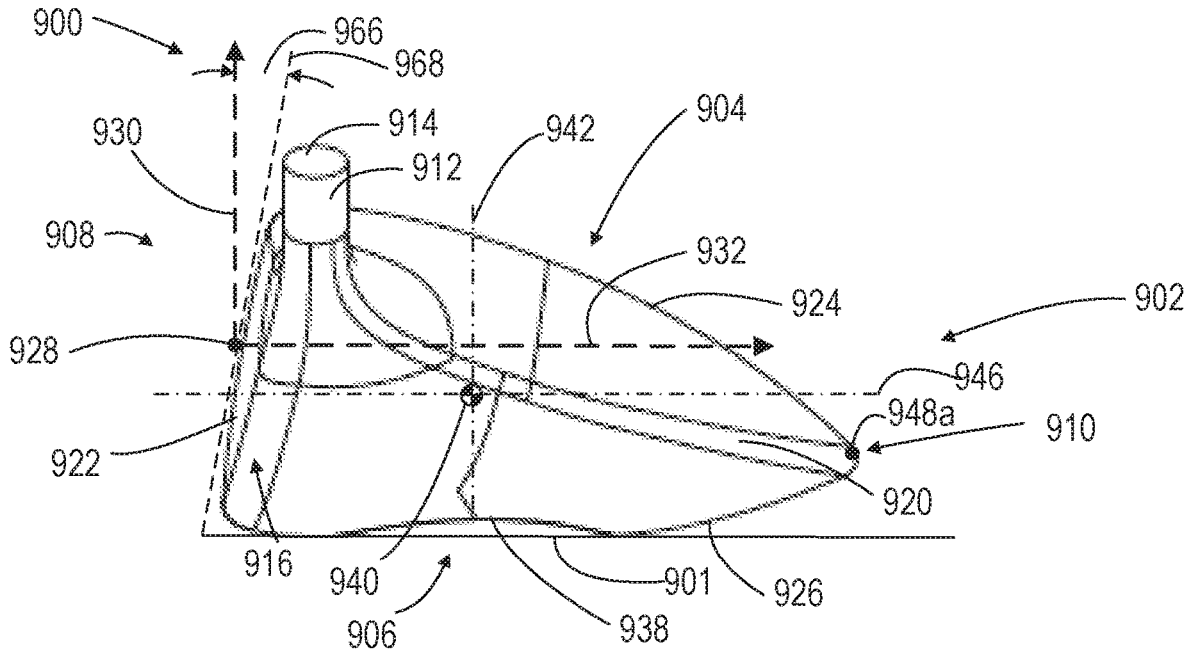
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Fig. 9A

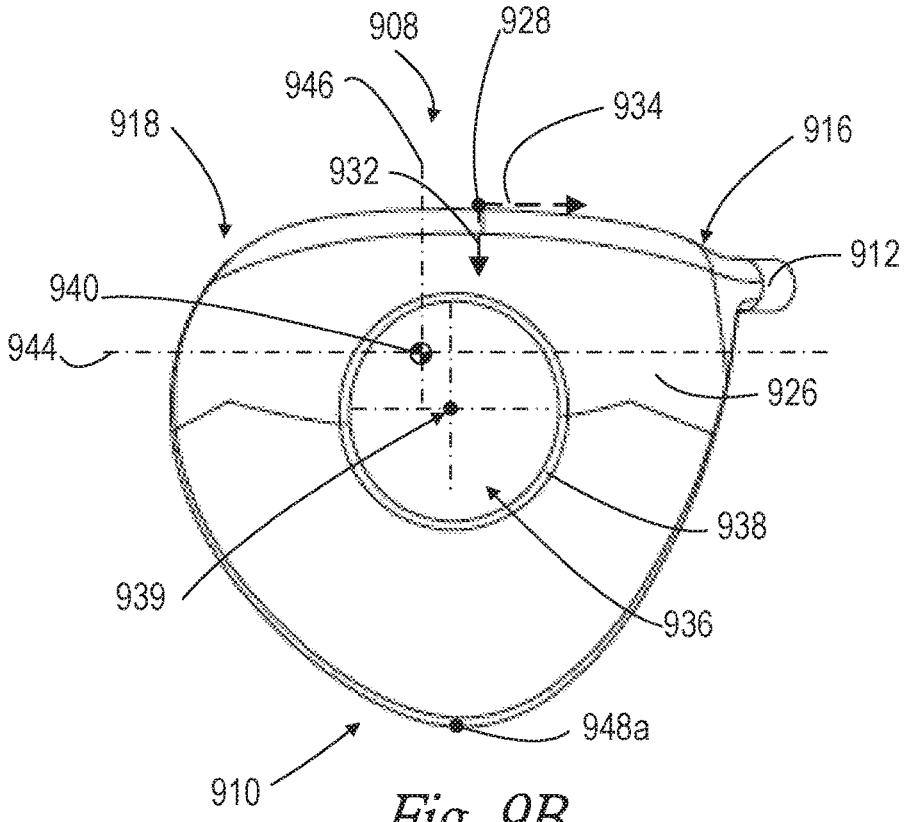
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Fig. 9B

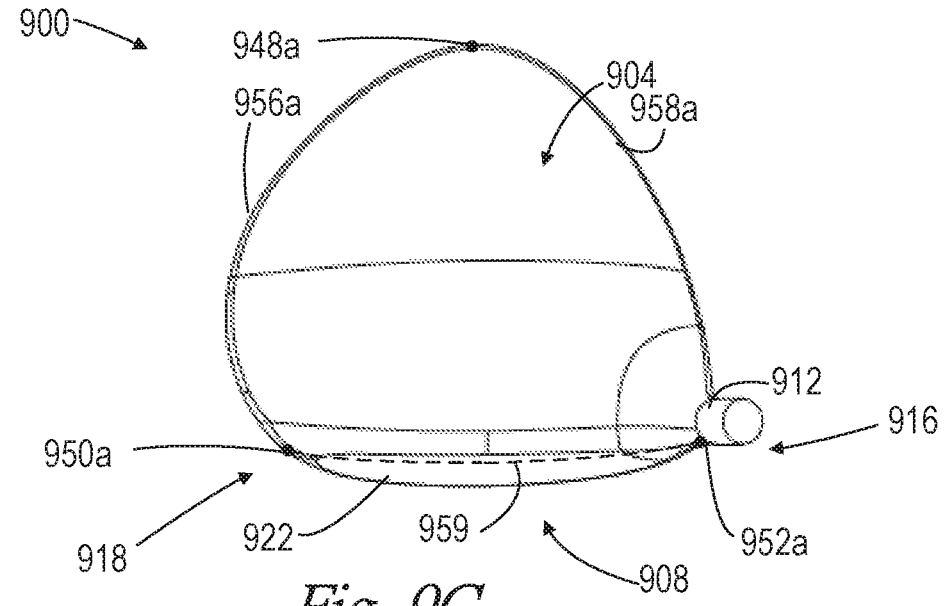

Fig. 9C

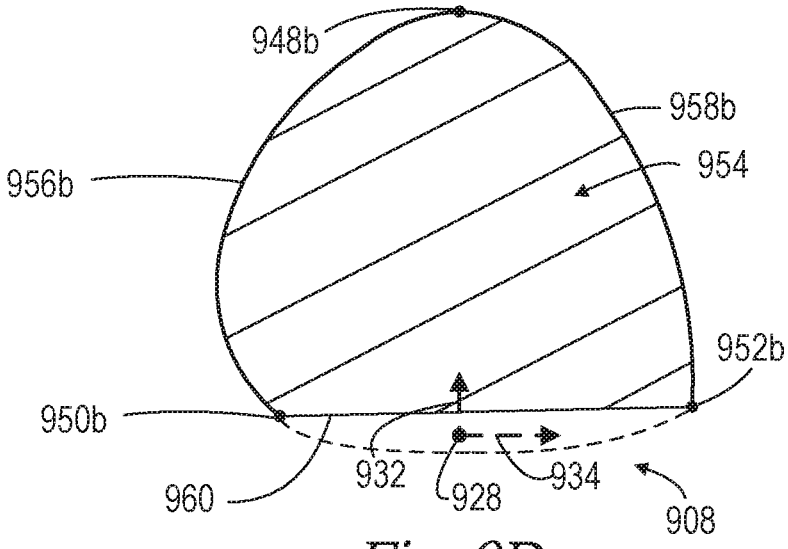

Fig. 9D

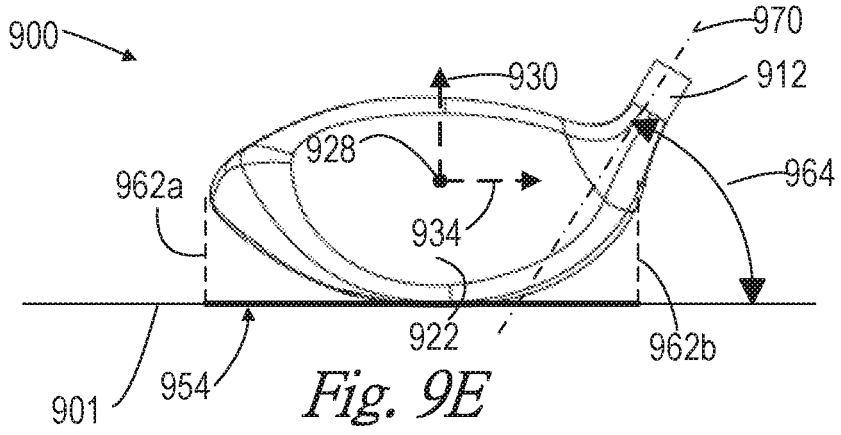

Fig. 9E

GOLF CLUB HEAD

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 15/980,552, filed on May 15, 2018, which is a continuation of U.S. patent application Ser. No. 15/177,586, filed Jun. 9, 2016, which is a continuation of U.S. patent application Ser. No. 14/048,610, filed Oct. 8, 2013, now U.S. Pat. No. 9,387,371, which is a continuation of U.S. patent application Ser. No. 13/741,193, filed Jan. 14, 2013, now U.S. Pat. No. 8,579,722, which is a continuation of U.S. patent application Ser. No. 13/447,994, filed Apr. 16, 2012, now U.S. Pat. No. 8,353,782, which is a continuation of U.S. patent application Ser. No. 13/195,467, filed Aug. 1, 2011, now U.S. Pat. No. 8,157,671, which is a continuation of U.S. patent application Ser. No. 12/316,584, filed Dec. 11, 2008, now U.S. Pat. No. 8,012,038, all of which are incorporated herein by reference.

This application is related to U.S. patent application Ser. Nos. 11/825,138 and 11/870,913, which are incorporated herein by reference. This application also is related to U.S. Pat. Nos. 6,997,820, 7,186,190, 7,267,620, 7,140,974, 6,773,360, 7,166,040, 7,407,447 6,800,038, 6,824,475, 7,066,832, 7,419,441 and 7,628,707, which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

Golf is a game in which a player, using many types of clubs, hits a ball into each hole on a golf course in the lowest possible number of strokes. Golf club head manufacturers and designers seek to improve certain performance characteristics such as forgiveness, playability, feel, and sound. In addition, the aesthetic of the golf club head must be maintained while the performance characteristics are enhanced.

In general, "forgiveness" is defined as the ability of a golf club head to compensate for mis-hits where the golf club head strikes a golf hall outside of the ideal contact location. Furthermore, "playability" can be defined as the ease in which a golfer can use the golf club head for producing accurate golf shots. Moreover, "feel" is generally defined as the sensation a golfer feels through the golf club upon impact, such as a vibration transferring from the golf club to the golfer's hands. The "sound" of the golf club is also important to monitor because certain impact sound frequencies are undesirable to the golfer.

Golf head forgiveness can be directly measured by the moments of inertia of the golf club head. A moment of inertia is the measure of a golf head's resistance to twisting upon impact with a golf ball. Generally, a high moment of inertia value for a golf club head will translate to a lower amount of twisting in the golf club head during "off center" hits. Because the amount of twisting in the golf club head is reduced, the likelihood of producing a straight golf shot has increased thereby increasing forgiveness. In addition, a higher moment of inertia can increase the ball speed upon impact thereby producing a longer golf shot.

The United States Golf Association (USGA) regulations constrain golf club head shapes, sizes, and moments of inertia. Due to theses constraints, golf club manufacturers and designers struggle to produce a club having maximum size and moment of inertia characteristics while maintaining all other golf dub head characteristics.

SUMMARY OF THE DESCRIPTION

In one embodiment, the present disclosure describes a golf club head comprising a heel portion, a toe portion, a crown, a sole, and a face. The foregoing and other objects, features, and advantages of the invention will become more apparent from the following detailed description, which proceeds with reference to the accompanying figures.

According to one aspect of the present invention, a golf club head is provided having a body, a face, a top portion, front portion, back portion, and a bottom portion. The body includes an exterior surface defining a first body volume of at least about 400 cm^3. A face positioned at the front portion of the body is described and the face is configured to receive an impact. A top portion silhouette profile is located along a perimeter of the top portion. The top portion silhouette profile defines the outer bounds of the top portion in an X-direction and Y-direction. Furthermore, at least one indentation located on the bottom portion below the crown silhouette profile and the removal of the at least one indentation from the bottom portion creates a second body volume that is at least 12 cm^3 larger than the first body volume.

In one example of the present invention, the first body volume is about 440 cm^3 to about 470 cm^3. In another example of the present invention, the first body volume is about 450 cm^3 to about 470 cm^3. In yet another example of the present invention, the first body volume is about 460 cm^3 to about 470 cm^3.

In yet another example of the present invention, the first body volume is about 460 cm^3 to about 470 cm^3 and the second body volume is at least about 14 cm^3 larger than the first body volume.

In one example of the present invention, the face has an area of at least about 4,000 mm^2, in another example of the present invention, a heel-toe dimension is between about 119 mm and about 127 mm.

In another example of the present invention, a top-bottom dimension is between about 63 mm and about 71 mm and a front-back dimension is between about 111 mm and about 127 mm.

In another aspect of the present invention, the golf club head has a coefficient of restitution greater than about 0.810 and a moment of inertia about a head center of gravity z-axis of at least about 500 $kg \cdot mm^2$. Furthermore, the moment of inertia about a head center of gravity x-axis of at least about 300 $kg \cdot mm^2$.

According to another aspect of the present invention, the golf club head has a head origin defined as a position on the face plane at a geometric center of the face. The head origin includes an x-axis tangential to the face and is generally parallel to the ground when the head is in an address position. At the address position, a positive x-axis extends towards the heel portion and a y-axis extends perpendicular to the x-axis and is generally parallel to the ground. A positive y-axis extends from the face and through the rearward portion of the body and a z-axis extends perpendicular to the ground, to the x-axis and to the y-axis when the head is ideally positioned. Furthermore, a positive z-axis extends from the origin and generally upward. The golf club head has a center of gravity with an x-axis coordinate between about −2 mm and about 7 mm, a y-axis coordinate between about 30 mm and about 40 mm, and a z-axis coordinate between about −7 mm and about 2 mm.

In one example of the present invention, the golf club head has a center of gravity with a z-axis coordinate being less than about −2 mm.

In another example of the present invention, the golf club head has a center of gravity with a y-axis coordinate being greater than about 15 mm.

In yet another example of the present invention, the golf club head has a center of gravity with a z-axis coordinate

being less than about −2 mm and a y-axis coordinate being greater than about 15 mm. In addition, the golf club head further comprises a moment of inertia about a head center of gravity z-axis of at least about 500 kg·mm^2 and a moment of inertia about a head center of gravity x-axis of at least about 300 kg·mm^2.

In one aspect of the present invention, the golf club head has a first sole mode frequency greater than about 3000 Hz.

In one example of the present invention, the removal of the at least one indentation from the bottom portion creates a second body volume that is between about 12 cm^3 and 20 cm^3 larger than the first body volume.

According to one aspect of the present invention, a golf club head comprises at least one indentation located on the bottom portion. The removal of the at least one indentation from the bottom portion creates a second exterior surface of the body having a second volume, wherein the second volume is about 4%-5% larger than the first volume.

According to another aspect of the present invention, a golf club head comprises at least one indentation located on the bottom portion, wherein the at least one indentation is configured to create a bottom portion volume of greater than about 50% of the total volume.

In one example of the present invention, a golf club head bottom portion volume is greater than about 60% of the total volume.

According to yet another aspect of the present invention, a golf club head comprises a top portion silhouette profile located along a perimeter of the top portion. The top portion silhouette profile defines the outer bounds of the top portion in an X-direction and Y-direction defining an area of at least about 11,000 mm^2. The crown silhouette profile area extends substantially in an X-direction and a Y-direction.

In one example of the present invention, at least one indentation is located within the bottom portion of the golf club head and is configured to maintain the crown silhouette profile area of between at least about 11,500 mm^2.

In another example of the present invention, at least one indentation is located within the sole and the top portion silhouette profile is a non-triangular shape.

In another example of the present invention, the perimeter of the crown silhouette profile area is defined by the outermost points of the top portion in the X-direction and Y-direction and the face has a face area size of at least about 4,000 mm^2.

According to one aspect of the present invention, a top portion silhouette profile is located along a perimeter of the top portion. The top portion silhouette profile defines the outer bounds of the top portion in an X-direction and Y-direction and has a top portion surface area. The bottom portion has a bottom surface area below the top portion silhouette profile, where the top portion surface area divided by the bottom portion surface areas is equal to or less than a ratio of about 0.96.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is illustrated by way of example and not limitation in the figures of the accompanying drawings in which like references indicate similar elements.

FIG. **1**A is an elevated side view of a golf club head showing a golf club bead origin coordinate system and a center-of-gravity coordinate system according to a first embodiment.

FIG. **1**B is a bottom perspective view of the golf club head of FIG. **1**A showing the golf club head origin coordinate system and the center-of-gravity coordinate system.

FIG. **1**C is a top view of the golf club head of FIG. **1**A.

FIG. **1**D is a projected crown silhouette of the golf club head in FIG. **1**C.

FIG. **1**E is an elevated front view of the golf club head of FIG. **1**A.

FIG. **2**A is an elevated side view of a golf club head showing a golf club head origin coordinate system and a center-of-gravity coordinate system according to a second embodiment.

FIG. **2**B is a bottom perspective view of the golf club head of FIG. **2**A showing the golf club head origin coordinate system and the center-of-gravity coordinate system.

FIG. **2**C is a top view of the golf club head of FIG. **2**A.

FIG. **2**D is a projected crown silhouette of the golf club head in FIG. **2**C.

FIG. **2**E is an elevated front view of the golf club head of FIG. **2**A.

FIG. **3**A is an elevated side view of a golf club head showing a golf club head origin coordinate system and a center-of-gravity coordinate system according to a third embodiment.

FIG. **3**B is a bottom perspective view of the golf club head of FIG. **3**A showing the golf club head origin coordinate system and the center-of-gravity coordinate system.

FIG. **3**C is a top view of the golf club head of FIG. **3**A.

FIG. **3**D is a projected crown silhouette of the golf club head in FIG. **3**C.

FIG. **3**E is an elevated front view of the golf club head of FIG. **3**A.

FIG. **4**A is an elevated side view of a golf club head showing a golf club head origin coordinate system and a center-of-gravity coordinate system according to a fourth embodiment.

FIG. **4**B is a bottom perspective view of the golf club head of FIG. **4**A showing the golf club head origin coordinate system and the center-of-gravity coordinate system.

FIG. **4**C is a top view of the golf club head of FIG. **4**A.

FIG. **4**D is a projected crown silhouette of the golf club head in FIG. **4**C.

FIG. **4**E is an elevated front view of the golf club head of FIG. **4**A.

FIG. **5**A is an elevated side view of a golf club head showing a golf club bead origin coordinate system and a center-of-gravity coordinate system according to a fifth embodiment.

FIG. **5**B is a bottom perspective view of the golf club head of FIG. **5**A showing the golf club head origin coordinate system and the center-of-gravity coordinate system.

FIG. **5**C is a top view of the golf club head of FIG. **5**A.

FIG. **5**D is a projected crown silhouette of the golf club head in FIG. **5**C.

FIG. **5**E is an elevated front view of the golf club head of FIG. **5**A.

FIG. **6**A is an elevated side view of a golf club head showing a golf club head origin coordinate system and a center-of-gravity coordinate system according to a sixth embodiment.

FIG. **6**B is a bottom perspective of the golf club tread of FIG. **6**A showing the golf club head origin coordinate system and the center-of-gravity coordinate system.

FIG. **6**C is a top view of the golf club head of FIG. **6**A.

FIG. **6**D is a projected crown silhouette of the golf club head in FIG. **6**C.

FIG. **6**E is an elevated front view of the golf club head of FIG. **6**A.

FIG. **7**A is an elevated side view of a golf club head showing a golf club head origin coordinate system and a center-of-gravity coordinate system according to a seventh embodiment.

FIG. **7**B is a bottom perspective view of the golf club head of FIG. **7**A showing the golf club head origin coordinate system and the center-of-gravity coordinate system.

FIG. **7**C is a top view of the golf club head of FIG. **7**A.

FIG. **7**D is a projected crown silhouette of the golf club head in FIG. **7**C.

FIG. **7**E is an elevated front view of the golf club head of FIG. **7**A.

FIG. **8**A is an elevated side view of a golf club head showing a golf club head origin coordinate system and a center-of-gravity coordinate system according to an eighth embodiment.

FIG. **8**B is a bottom perspective view of the golf club head of FIG. **8**A showing the golf club head origin coordinate system and the center-of-gravity coordinate system.

FIG. **8**C is a top view of the golf club head of FIG. **8**A.

FIG. **8**D is a projected crown silhouette of the golf club head in FIG. **8**C.

FIG. **8**E is an elevated front view of the golf club head of FIG. **8**A.

FIG. **9**A is an elevated side view of a golf club head showing a golf club head origin coordinate system and a center-of-gravity coordinate system according to a ninth embodiment.

FIG. **9**B is a bottom perspective view of the golf club head of FIG. **9**A showing the golf club head origin coordinate system and the center-of-gravity coordinate system.

FIG. **9**C is a top view of the golf club head of FIG. **9**A.

FIG. **9**D is a projected crown silhouette of the golf club head in FIG. **9**C.

FIG. **9**E is an elevated front view of the golf club head of FIG. **9**A.

DETAILED DESCRIPTION

Various embodiments and aspects of the inventions will be described with reference to details discussed below, and the accompanying drawings will illustrate the various embodiments. The following description and drawings are illustrative of the invention and are not to be construed as limiting the invention. Numerous specific details are described to provide a thorough understanding of various embodiments of the present invention. However, in certain instances, well-known or conventional details are not described in order to provide a concise discussion of embodiments of the present inventions.

Embodiments of a golf club head providing desired center-of-gravity (hereinafter, "CG") properties and increased moments of inertia (hereinafter, "MOI") and projected crown silhouette profiles are described herein. In some embodiments, the golf club head has an optimal shape for providing maximum golf shot forgiveness given a maximum head volume, a maximum head face area, and a maximum head depth according to desired values of these parameters, and allowing for other considerations such as the physical attachment of the golf club head to a golf club and golf club aesthetics.

Forgiveness on a golf shot is generally maximized by configuring the golf club head such that the CG of the golf club head is optimally located and the MOI of the golf club head is maximized.

In certain embodiments, the golf club head has a shape with dimensions at or near at least some of the golf club head dimensional constraints set by current USGA regulations. In such embodiments, the golf club head features fall within a predetermined golf head shape range that results in a desired CG location and increased MOI, and thus more forgiveness on off center hits than conventional golf club heads.

In the embodiments described herein, the "face size" or "striking surface area" is defined according to a specific procedure described herein. A front wall extended surface is first defined which is the external face surface that is extended outward (extrapolated) using the average bulge radius (heel-to-toe) and average roll radius (crown-to-sole). The bulge radius is calculated using five equidistant points of measurement fitted across a 2.5 inch segment along the x-axis (symmetric about the center point). The roll radius is calculated by three equidistant points fitted across a 1.5 inch segment along the y-axis (also symmetric about the center point).

The front wall extended surface is then offset by a distance of 0.5 mm towards the center of the head in a direction along an axis that is parallel to the face surface normal vector at the center of the face. The center of the face is defined according to USGA "Procedure for Measuring the Flexibility of a Golf Clubhead", Revision 2.0, Mar. 25, 2005.

A face front wall profile shape curve (herein, "S_f") is defined as the intersection of the external surface of the head with the offset extended front wall surface. Furthermore, the hosel region of the face front wall profile shape curve is trimmed by finding the intersection point (herein, "P_a") of Sf with a 30 mm diameter cylindrical surface that is co-axial with the shaft (or hosel) axis. A line is drawn from the intersection point, P_a, in a direction normal to the hosel/shaft axis which intersects the curve S_f at a second point (herein, "P_b"). The two points, P_a and P_b, define two trimmed points of S_f. The line drawn from P_a to P_b defines the edge of the "face size" as defined in the present application.

Therefore, the "face size" is a projected area normal to a front wall plane which is tangent to the face surface at the geometric center of the face using the method defined in the USGA "Procedure for Measuring the Flexibility of a Golf Clubhead", Revision 2.0, Mar. 25, 2005.

FIG. **1**A shows a wood-type (e.g., driver or fairway wood) golf club head **100** including a hollow body **102** having a top portion **104**, a bottom portion **106**, a front portion **108**, and a back portion **110**. The club head **100** also includes a hosel **112** which defines a hosel bore **114** and is connected with the hollow body **102**. The hollow body **102** further includes a heel portion **116** and a toe portion **118**. A striking surface **122** is located on the front portion **108** of the golf club head **100**. In some embodiments, the striking surface **122** can include a bulge and roll curvature or a face plate. The striking surface **122** has a face plane **168** that forms a face angle **166**.

In some embodiments of the present invention, the striking surface **122** is made of a composite material as described in U.S. patent application Ser. No. 10/442,348 (now U.S. Pat. No. 7,267,620), Ser. No. 10/831,496 (now U.S. Pat. No. 7,140,974), Ser. Nos. 11/642,310, 11/825,138, and 12/156,947, which are incorporated herein by reference. The composite material can be manufactured according to the methods described in U.S. patent application Ser. No. 11/825,138.

In other embodiments, the striking surface **122** is made from a metal alloy (e.g., titanium, steel, aluminum, and/or magnesium), ceramic material, or a combination of composite, metal alloy, and/or ceramic materials. Moreover, the striking face **122** can be a striking plate having a variable

thickness as described in U.S. Pat. Nos. 6,997,820, 6,800,038, 6,824,475, and 7,066,832 which are incorporated herein by reference.

The golf dub head **100** also has a first body volume, typically measured in cubic centimeters (cm^3), equal to the volumetric displacement of the club head **100**, as will be discussed in further detail below.

FIGS. **1-9** generally show a club head origin coordinate system being provided such hat the location of various features of the club head (including, e.g., a club bead CG) can be determined. In FIG. **1**A, a club head origin point **128** is represented on the club head **100**. The club head origin point **128** is positioned at the ideal impact location which can be a geometric center of the striking surface **122**.

The head origin coordinate system is defined with respect to the head origin point **128** and includes a Z-axis **130**, an X-axis **134**, and a Y-axis **132**. The Z-axis **130** extends through the head origin point **128** in a generally vertical direction relative the ground **101** when the club head **100** is at an address position. Furthermore, the Z-axis **130** extends in a positive direction from the origin point **128** toward the top portion **104** of the golf club head **100**.

The X-axis **134** extends through the head origin point **128** in a toe-to-heel direction substantially parallel or tangential to the striking surface **122** at the ideal impact location. The X-axis **130** extends in a positive direction from the origin point **128** to the heel **116** of the club head **100** and is perpendicular to the Z-axis **130** and Y-axis **132**.

The Y-axis **132** extends through the head origin point **128** in a front-to-back direction and is generally perpendicular to the X-axis **134** and Z-axis **130**. The Y-axis **132** extends in a positive direction from the origin point **128** towards the rear portion or back portion **110** of the club head **100**.

The top portion **104** includes a crown **124** that extends substantially in an X-direction and Y-direction and has a top portion volume defined by the top portion **104**. Similarly, the bottom portion **106** has a bottom portion volume. The bottom portion **106** also includes a sole area **126** that substantially faces the ground **101** at the address position of the golf club head **100** and also extends primarily in an X and Y-direction.

The top portion volume and the bottom portion volume are combined to create a total first body volume. It is understood that the top **104** and bottom **106** portions are three dimensional objects that also extend in the Z-direction **130**.

Moreover, the crown **124** is defined as an upper portion of the club head **100** above a peripheral outline of the club head **100** as viewed from a top-down direction and includes a region rearwards of the top most portion of the from portion **108** that contains the ball striking surface **122**. In one embodiment, a skirt region can be located on a side portion **120** of the club head **100** and can include regions within both the top portion **104** and bottom portion **106**. In some embodiments, a skirt region is not present or pronounced.

The top **104** and bottom **106** portions can be integrally formed using techniques such as molding, cold forming, casting, and/or forging and the striking face can be attached to the crown, sole, and skirt (if any) through bonding, welding, or any known method of attachment. For example, a face plate can be attached to the body **100** as described in U.S. patent application Ser. No. 10/442348 (now U.S. Pat. No. 7,267,620) and Ser. No. 10/831,496 (now U.S. Pat. No. 7,140,974), as previously mentioned above. The body **100** can be made from a metal alloy such as titanium, steel, aluminum, and or magnesium. Furthermore, the body **100** can be made from a composite material, ceramic material, or any combination thereof. The body **100** can have a thin-walled construction as described in U.S. patent application Ser. No. 11/067,475, now issued U.S. Pat. No. 7,186,190, which is incorporated herein by reference.

Referring to FIGS. **1-9**, the golf club heads described herein each have a maximum club head height (H, top-bottom), width (W, heel-toe) and depth (D, front-back). The maximum height, H, is defined as the distance between the lowest and highest points on the outer surface of the golf club head body measured along an axis parallel to the origin Z-axis **130** when the club head is at a proper address position. The maximum depth, D, is defined as the distance between the forward-most and rearward-most points on the surface of the body measured along an axis parallel to the origin Y-axis **132** when the head is at a proper address position. The maximum width, W, is defined as the distance between the farthest distal toe point and closest proximal heel point on the surface of the body measured along an axis parallel to the origin X-axis **134** when the head is at a proper address position.

The height, H, width, W, and depth D of the club head in the embodiments herein are measured according to the United States Golf Association "Procedure for Measuring the Club Head Size of Wood Clubs" revision 1.0 and Rules of Golf, Appendix II(4)(b)(i).

Golf club head moments of inertia are defined about three axes extending through the golf club head CG **140** including: a CG z-axis **142** extending through the CG **140** in a generally vertical direction relative to the ground **101** when the club head **100** is at address position, a CG x-axis **144** extending through the CG **140** in a heel-to-toe direction generally parallel to the striking surface **122** and generally perpendicular to the CG z-axis **142**, and a CG y-axis **146** extending through the CG **140** in a front-to-back direction and generally perpendicular to the CG x-axis **144** and the CG z-axis **142**. The CG x-axis **144** and the CG y-axis **146** both extend in a generally horizontal direction relative to the ground **101** when the club head **100** is at the address position. Specific CG location values are discussed in further detail below with respect to certain exemplary embodiments.

The moment of inertia about the golf club head CG x-axis **144** is calculated by the following equation:

$$I_{CGz}=\int(y^2+z^2)dm$$

In the above equation, y is the distance from a golf club head CG xz-plane to an infinitesimal mass dm and z is the distance from a golf club head CG xy-plane to the infinitesimal mass dm. The golf club head CG xz-plane is a plane defined by the CG x-axis **144** and the CG z-axis **142**. The CG xy-plane is a plane defined by the CG x-axis **144** and the CG y-axis **146**.

Moreover, a moment of inertia about the golf club head CG z-axis **142** is calculated by the following equation:

$$I_{CGz}=\int(x^2+y^2)dm$$

In the equation above, x is the distance from a golf club head CG yz-plane to an infinitesimal mass dm and y is the distance from the golf club head CG xz-plane to the infinitesimal mass dm. The golf club head CG yz-plane is a plane defined by the CG y-axis **146** and the CG z-axis **142**. Specific moment of inertia values for certain exemplary embodiments are discussed further below.

FIG. **1**B shows a bottom view of the bottom portion **106** having a first indentation **138***a* and a second indentation **138***b* located on the bottom portion **106** of the club head **100**. The first indentation **138***a* is located near the toe portion **118**

and the second indentation **138***b* is located near the heel portion **116** of the club head **100**. In one exemplary embodiment, the first **138***a* and second **138***b* indentations are generally triangular in shape and arranged so that the sole **126** forms a T-shape. In one embodiment, the first **138***a* and second **138***b* indentations axe mirrored across the Y-axis **132** and are about the same shape and size.

The first indentation **138***a* has a first edge **139***a*, a second edge **139***b*, and a third edge **139***c*. The second indentation **138***b* also has a first edge **137***a*, a second edge **137***b*, and a third edge **137***c*. The first edges **138***a*,**137***a* of both indentations extend in an X and Y-direction and are generally curved with respect to the X-axis **134**. The second edges **138***b*,**137***b* of both indentations extend primarily in a Y-direction and are generally curved with respect to the Y-axis **132**. The third edge **139***c* of the first indentation **138***a* is a curved edge in the X-Y plane that generally follows a silhouette profile near the toe side **118** of the club head **100**. The third edge **137***c* of the second indentation **138***b* is also a curved edge in the X-Y plane that generally follows a silhouette profile near the heel side **116** of the club head **100**.

In each indentation **138***a*,**138***b*, a convex indentation wall **136***a*,**136***b* extends from the first edge **139***a*,**137***a* toward the top portion **104** or crown **124** creating a fourth edge **143***a*, **143***b* located within the indentations **138***a*,**138***b*. The fourth edge **143***a*,**143***b* represents the intersection between the indentation wall, **136***a*,**136***b* and a bottom surface of the crown **124**. Thus, a bottom surface area of the crown **124** is exposed within each indentation **138***a*,**138***b* between the fourth edge **143***a*,**143***b* and the third edge **137***c*,**139***c*.

The convex indentation wall **136***a*,**136***b* ensures that the cavity of the club head **100** maintains a certain volume which can affect the sound frequency of the club head **100** upon direct impact with a golf ball. In one embodiment, the frequency of the sole upon direct impact with a golf ball has a first sole mode greater than 3000 Hz. In one exemplary embodiment, the first sole mode frequency is about 3212 Hz while the second and third modes are about 3297 Hz and 3427 Hz, respectively. In certain preferred embodiments, the first sole mode frequency is at between about 3200 to 3500 Hz.

The first **138***a* and second **138***b* indentations are separated by a plateau or center sole portion **141** that extends in a direction parallel to the Y-axis **132**. In one exemplary embodiment, the width (along the X-axis **134**) of the center sole portion **141** is about 22 mm to about 31 mm between the two indentations **138***a*,**138***b*. Furthermore, the width (along the X-axis **134**) of each indentation **138***a*,**138***b* is about 50 mm to about 57 mm and the length (along the Y-axis **132**) of each indentation **138***a*,**138***b* is about 69 mm. In another embodiment, the width of each indentation **138***a*,**138***b* is about 40 mm and the length of each indentation **138***a*,**138***b* is about 65 mm.

The center sole portion **141** also contains a movable weight port **135** located on the sole **126** near the back portion **110** where a movable weight may be inserted or removed to change characteristics of the CG location, as described in U.S. patent application Ser. No. 10/290,817 (U.S. Pat. No. 6,773,360), Ser. No. 10/785,692 (U.S. Pat. No. 7,166,040), Ser. Nos. 11/025,469, 11/067,475 (U.S. Pat. No. 7,186,190), Ser. No. 11/066,720 (U.S. Pat. No. 7,407,447), and Ser. No. 11/065,772 (U.S. Pat. No. 7,419,441), which are hereby incorporated by reference in their entirety.

In one embodiment, the indentations **138***a*,**138***b* remove a total of 13 cm^3 from a total volume of the club head **100** thereby allowing the saved volume to be reallocated in other regions of the club head **100**. For example, the total volume of the club head **100** can be a first body volume of about 461 cm^3 before indentation removal and having a second body volume of about 474 cm^3 after indentation removal thus providing a 13 cm^3 difference.

In another embodiment, the indentations **138***a*,**138***b* remove about of 15 cm^3 from the total volume of the club head **100**. In other words, the removal of the indentations **138***a*,**138***b* would increase the volume of the head **100** by about 13 to 15 cubic centimeters (cm^3) to create a second body volume. It is understood that a measuring tolerance of about +/−3 cm^3 may he taken into consideration.

In one embodiment, the second body volume (without indentations, i.e. complete indentation removal) is about 4-5% larger than the first body volume (with indentations). In another embodiment, the bottom portion volume is about 71% of the total volume of the club head and the top portion is about 29% of the total volume. In one example, the total volume is about 461 cm^3 and the top volume is about 133 cm^3 while the bottom volume is about 329 cm^3.

The removal of the small indentations discussed throughout the various embodiments of the present invention are accomplished by filling the small indentations with a material (e.g. clay or dough) and covering the small indentations with tape so as to produce a relatively fiat plane between the edges of the indentations. A user can take a straight edge or knife and move the straight edge across the entire indentation to remove excess clay or dough material prior to taping (herein, "straight edge" filling procedure). However, the small indentations in the present invention are not considered large enough to be filled prior to measuring the total volume of a club head according to the United States Golf Association "Procedure for Measuring the Club Head Size of Wood Clubs" Revision 1.0 procedures. In one embodiment, the contour after filling the small indentation creates a continuous plane between the edges of the small indentation so that the small indentation is removed or unnoticeable to the user.

In another embodiment, the removal of the small indentations are accomplished by covering the small it with tape only (without filler material) to create a continuous surface that connects the edges of the small indentations so that the small indentation is removed or unnoticeable to the user.

In an alternative procedure, the sole volume filling methodology may be a mathematical procedure where the second body volume is measured in an alternative equation as:

$$V_h = V_{hf} - 15\ cm^3$$

In the above equation, V_h is the second body volume and V_{hf} is the volume of the club head after the filling of a large cavity according to the straight edge filling procedure, previously described. Thus, the second body volume could be defined purely as a mathematical expression subtracting 15 cm^3 from the filled volume of a club head.

However, the second body volume that is described in the various embodiments of the present invention do not utilize the mathematical procedure of calculating a second body volume. The second body volume measurements described within the present invention are obtained by the straight edge filling procedure as described above.

The sole **126** of the bottom portion **106** is defined as a lower portion of the club head **100** extending upwards from a lowest point of the club head when the club head is positioned at a proper address position relative to a golf ball on a ground surface **101**. In some exemplary embodiments, the sole **126** extends about 50-60% of the distance from the lowest point of the club head to the crown **124**. In further exemplary embodiments, the sole extends upward in the

Z-direction about 15 mm for a driver and between about 10 mm and 12 mm for a fairway wood. The sole **126** can include the entire bottom portion **106** or partially cover a bottom region of the bottom portion **106**. The sole **126** and bottom portion **106** are located below the top portion **104** in a negative Z-direction.

FIG. **1**C shows a top view of the club head **100** including the top portion **104**, striking surface **122**, and the hose **112**. The X-axis **134** and the Y-axis **132** extend from the origin point **128** as previously mentioned (not shown for clarity). A first point **148***a*, a second point **150***a*, and a third point **152***a* are located about the perimeter of the top portion **104**. The first point **148***a* is a rearward-most point on the surface of the body measured along an axis parallel to the origin Y-axis **132** when the head **100** is at a proper address position. The second point **150***a* is an intersection point defining the intersection between the front portion **108**, the top portion **104**, and the bottom portion **106** that is located near the toe portion **118** of the club head **100**. The third point **152***a* is an intersection point defining the intersection between the between the front portion **108**, the top portion **104**, and the bottom portion **106** that is located near the heel portion **116** of the club head **100**. In one embodiment, the third point **152***a* defines an intersection that excludes or ignores a majority of the hosel **112**.

A top portion silhouette profile includes a first contour **156***a*, a second contour **158***a*, and a third segment **159** being located along a perimeter of the top portion **104** defining the outer bounds of the top portion **104** in substantially an X-direction **134** and Y-direction **132**.

The first contour **156***a* extends along an outer toe edge of the club head **100** between the first point **148***a* and second point **150***a*. The second contour **158***a* extends along an outer heel edge of the club head **100** between the first point **148***a* and third point **152***a*. The third segment **159** defining the top portion silhouette profile is a straight line (with respect to the X-axis **134** and Z-axis **130**, i.e. viewed from the X-Z plane) along the surface of the front portion **108** or striking surface **122** that connects the second point **150***a* and the third point **152***a*. The first contour **156***a*, second contour **158***a*, and third segment **159** are substantially coplanar.

In certain embodiments, a plane between the top portion **104** and bottom portion **106** that contains the first point **148***a*, second point **150***a*, third point **152***a*, first contour **156***a*, second contour **158***a*, and third segment **159** can be referenced as a dividing plane for measuring a top portion volume and a bottom portion volume. In addition, the same dividing plane is used for measuring a top portion surface area S_t or bottom portion surface area S_b. A top and bottom portion volume is measured according to the weighed water displacement method under United States Golf Association "Procedure for Measuring the Club Head Size of Wood Clubs" Revision 1.0 procedures.

FIG. **1**D shows a projected crown silhouette **154** being the top portion silhouette profile shape that is externally projected on to the ground when looking vertically down at the crown **124** when the head **100** is in the address position.

The projected crown silhouette **154** occupies an area in the X-Y plane as emphasized by the hatched lines in FIG. **1**D. However, the projected crown silhouette **154** excludes the striking surface **122** and front portion **108** as shown in dashed lines. The projected crown silhouette **154** is defined by the first point projection **148***b*, the second point projection **150***b*, the third point projection **152***b*, and a projected portion of the outer perimeter of the top portion **104** on to the ground **101** or an X-Y plane.

As further shown in FIG. **1**D, the projected crown silhouette **154** is defined by three projected segments **156***b*, **158***b*,**160** located between the first **148***b*, second **150***b*, and third **152***b* projected points. The first contour **156***a* and the second contour **158***a* are located along the perimeter of the top portion **104** and correspond to the first projected segment **156***b* and the second projected segment **158***b*, respectively. The projected segments **156***b*,**158***b* are the projected profiles of the crown on to the X-Y plane or ground **101**. The first projected segment **156***b* extends between the first projected point **148***b* and the second projected point **150***b*. The second projected segment **158***b* extends between the first projected point **148***b* and the third projected point **152***b*. The third segment **160** of the profile is a single line segment connecting the second projected point **150***b* and the third projected point **152***b* in the projected X-Y plane. Similar to the first **156***b* and second **158***b* projected segments, the third segment **160** corresponds to an actual crown top line profile contour and is a relatively straight-line boundary drawn between the second projected point **150***b* and third projected point **152***b* running along the top line of the face **122**. In other words, the third segment **160** is a projected line of the boundary between the face **122** and the crown **124**.

In one embodiment, the projected crown silhouette **154** occupies a projected silhouette area of about 11,702 mm^3 in an X-Y plane which excludes the face **122**. The crown silhouette sizes **154** and face sizes **122** described herein are primarily attainable through the removal of volume in the bottom portion **106** of the club head **100**. The volume saved in the bottom portion **106** is reallocated to the top portion **104** of the club head **100** to create a larger and more unique projected crown silhouette **154** or top portion perimeter shape.

FIG. **1**E shows a front view of the club head **100** and striking surface **122** at an address position. Projection lines **162***a*,**162***b* are shown in dashed lines to further illustrate how the crown silhouette is projected on to the ground **101**, as previously described. It is understood that the crown silhouette can be projected on to any X-Y plane, not necessarily the ground **101** only, without departing from the scope of the invention.

A golf club head, such as the club head **100** is at its proper address position when face angle **166** is approximately equal to the golf club head loft and the golf club head lie angle **164** is about equal to 60 degrees. In other words, the address position is generally defined as the position of the club head as it naturally sits on the ground **101** when the shaft is at 60 degrees to the ground.

The face angle **166** is defined between a face plane **168** that is tangent to an ideal impact location **128** on the striking surface **122** and a vertical Z-X plane containing the Z-axis **130** and X-axis **134**. Moreover, the golf club head lie angle **164** is the angle between a longitudinal axis (or hosel axis) **170** of the hosel **112** or shaft and the ground **101** or X-Y plane. It is understood that the ground **101** is assumed to be a level plane.

FIG. **1**E further shows the ideal impact location **128** on the striking surface **122** of the golf club head. In one embodiment, the origin point **128** or ideal impact location is located at the geometric center of the striking surface **122**. The origin point **128** is the intersection of the midpoints of a striking surface height (H_{ss}) and striking surface width (W_{ss}) of the striking surface **122** as measured according to the USGA "Procedure for Measuring the Flexibility of a Golf Clubhead", Revision 2.0.

In certain embodiments, the ball striking surface **122** has the maximum allowable surface area under current USGA

dimensional constraints for golf club heads in order to achieve a desired level of forgiveness and playability. Specifically, the maximum club head height (H) is about 71 mm (2.8") and a maximum width (W) of about 127 mm (5"). In certain embodiments, the height is about 63.5 mm to 71 mm (2.5" to 2.8") and the width is about 119.38 mm to about 127 mm (4.7" to 5.0"). Furthermore, the depth dimension (D) is about 111.76 mm to about 127 mm (4.4" to 5.0"). In one preferred specific exemplary embodiment, the club height, H, is about 70 mm and the club width is about 126 mm while the club length is about 12:5 mm.

In one embodiment, the striking surface **122** may reach the maximum height H and width W dimensions as a direct result of the removal of volume from the bottom portion **106**. In certain embodiments, the striking surface **122** has a surface area between about 4,000 mm^2 and 6,200 mm^2 and, in certain preferred embodiments, the striking surface **122** is at least about 5,000 mm^2. In other embodiments, the ball striking surface **122** may have a maximum height H_{ss} value of about 67 mm to about 71 mm, a maximum width W_{ss} value of about 118 mm to about 127 mm. In another exemplary embodiment, the striking surface **122** area is about 6,192 mm^2, according to the procedure for measuring striking surface area, as previously described.

The golf club head of the implementations shown herein can have a maximum depth D equal to the maximum allowable depth of about 127 mm (5 inches) under current USGA dimensional constraints. Because the moment of inertia of a golf club head about a CG of the head is proportional to the squared distance of a golf club head mass away from the CG, having a maximum depth D value can have a desirable effect on moment of inertia and the CG position of the club head. Thus, the presence of the indentation **138** achieves a large height H, depth D, and width W dimension of the club head **100** while maintaining an advantageous CG location and acceptable MOI values.

Specifically, in some implementations, the CG x-axis coordinate is between about −2 mm and about 7 mm, the CG y-axis coordinate is between about 30 mm and about 40 mm, and the CG z-axis coordinate is between about −7 mm and about 2 mm.

In other embodiments of the present invention, the golf club head **100** can have a CG with a CG x-axis **134** coordinate between about −5 mm and about 10 mm, a CG y-axis **132** coordinate between about 15 mm and about 50 mm, and a CG z-axis **130** coordinate between about −10 mm and about 5 mm. In yet another embodiment, the CG y-axis **132** coordinate is between about 20 mm and about 50 mm.

In one specific exemplary embodiment, the golf club head **100** has a CG with a CG x-axis **134** coordinate of about 2.8 mm, a CG y-axis **132** coordinate of about 31 mm, and a CG z-axis **130** coordinate of about −4.71 mm. In one example, a composite face embodiment can achieve a CG with a CG x-axis **134** coordinate of about 3.0 mm, a CG y-axis **132** coordinate of about 36.5 mm, and a CG z-axis **130** of about −6.0 mm

In certain implementations, the club head **100** can have a moment of inertia about the CG z-axis, I_{CGz}, between about 450 kg·mm^2 and about 650 kg·mm^2, and a moment of inertia about the CG x-axis I_{CGx} between about 300 kg·mm^2 and about 500 kg·mm^2. In one exemplary embodiment, the club head **100** has a moment of inertia about the CG z-axis, I_{CGz}, of about 504 kg·mm^2 and a moment of inertia about the CG x-axis I_{CGx} of about 334 kg·mm^2. In another exemplary embodiment, the striking surface **122** is composed of a composite material previously described and has a moment of inertia about the CG z-axis, I_{CGz}, of about 543 kg·mm^2 and a moment of inertia about the CG x-axis I_{CGx} of about 382 kg·mm^2. In one embodiment, the composite striking surface **122** decreases the total club weight by about 10 g.

In addition, the presence of the indentation **138** in the bottom portion **106** increases the bottom portion surface area S_b located below the top portion silhouette profile **156***a*, **158***a*, **159**. In certain implementations the club head can have a top portion surface area S_t (which includes the face) of about 16,000 to m^2 to 18,000 mm^2 and a bottom portion surface area S_b of about 18,000 mm^2 to about 22,000 mm^2. The surface area ratio S_r of the top portion surface area S_t to the bottom portion surface area S_b is represented by the equation:

$$S_r = \frac{S_t}{S_b}$$

In certain embodiments, the surface ratio S_r can range between about 0.70 to about 0.96, with a preferred range of less than 0.90 and less than 0.80. A lower surface area ratio S_r indicates that the bottom portion has an increased surface area due to the indentations which also provides a volume reduction in the sole area.

In one exemplary embodiment, the top portion **104** surface area S_t is about 17,117 mm^2 and the bottom portion **106** surface area S_b including the indentation **138** is about 21,809 mm^2 resulting in a total surface area of about 38,926 mm^2 and a surface ratio S_r of about 0.78.

FIG. **2**A shows a wood-type (e.g., driver or fairway wood) golf dub head **200** including a hollow body **202** having a top portion **204**, a bottom portion **206**, a front portion **208**, and a back portion **210**. A hosel **212** which defines a hosel bore **214** is connected with the hollow body **202**. The body **202** further includes a heel portion **216** and a toe portion **218**.

FIG. **2**A further shows a side portion **220**, a striking surface **222**, a crown **224**, a sole **226**, an origin point **228**, a Z-axis **230**, a Y-axis **232**, an X-axis **234**, a rearward-most first point **248***a*, a CG point **240**, a CG z-axis **242**, a CG x-axis **244**, a and a CG y-axis **246**, as previously described.

FIG. **2**B shows a first indentation **238***a*, a second indentation **238***b*, and a third indentation **238***c* being located on the bottom portion **206** of the club head **200**. The three indentations **238***a*,**238***b*,**238***c* having a first geometric center point **239***a*, a second geometric center point **239***b*, and a third geometric center point **239***c*, respectively. In one embodiment, the indentations each have a diameter of about 40 mm. Furthermore, each indentation **238***a*,**238***b*,**238***c* has a respective concave surface **236***a*,**236***b*,**236***c* extending below the top surface of the bottom portion **206**. The first indentation **238***a* is located near the toe portion **218** and the second indentation **238***b* is located near the heel portion **218** of the club head **200**. The third indentation **238***c* is located near a back portion **210** of the bottom portion **206** and the first **238***a* and second **238***b* indentations am located near the front portion **208** of the bottom portion **206**. In one embodiment, the three indentations **238***a*, **238***b*, **238***c* are located in the sole **226** region and the respective geometric center points **239***a*,**239***b*,**239***c* of the indentations form a triangular shape arrangement that substantially points in a rearward direction or positive Y-direction **232** toward the rear portion **102** of the club head.

In one embodiment, the triangular shape formed by the geometric center points **239***a*,**239***b*,**239***c* has a first segment **272***a* between the first **238***a* and second **238***b* indentation of about 85 mm. The triangular shape further has a second

segment **272***b* between the second **238***b* and third **238***c* indentation of about 70 mm and a third segment **272***c* of about 70 mm between the third **238** and first indentation **238***a*. In one embodiment, the angle between the first **272***a* and third **272***c* segment is about 52.6° and the angle between the first **272***a* and second **272***b* segment is also about 52.6°. Moreover, the angle between the second **272***b* and third **272***c* segment is about 74.7°.

In one embodiment, the three indentations **238***a*, **238***b*, **238***c* remove a total of about 14-15 cm^3 from a total volume of the club head **200** allowing the saved volume to be reallocated in other regions of the club head **200**, such as the face **222** and the top portion **204**. In another embodiment, each indentation removes about of 4.6 cm^3 from the total volume of the club head **200**. In other words, the removal of the indentations **238** would increase the volume of the head **200** by about 14 cubic centimeters (cm^3) to create a second body volume. In one example, the first body volume is about 458 cm^3 and the second body volume (without indentations) is about 472 cm^3 when using the water displacement test previously described.

In one embodiment, the second body volume (without indentations) is about 4-5% larger than the first body volume (with indentations). In another embodiment, the bottom portion volume is about 54% of the total volume of the first body volume of the club head which is about 464 cm^3. Furthermore, the top portion volume is about 213 cm^3 and the bottom portion volume is about 251 cm^3.

FIG. **2**C shows a top view of the club head **200** including the top portion **204**, striking surface **222**, and the hosel **212**. The X-axis **234** and the Y-axis **232** extend from the origin point **228** as previously mentioned. A first point **248***a*, a second point **250***a*, and a third point **252***a* are located about the perimeter of the top portion **204** as previously described.

Again, a top portion silhouette profile is shown including a first contour **256***a*, a second contour **258***a*, and a third segment **259** is located along a perimeter of the top portion **204** defining the outer bounds of the top portion **204** in substantially an X-direction **234** and Y-direction **232**.

The first contour **256***a* extends along an outer toe edge of the club head **200** between the first point **248***a* and second point **250***a*. The second contour **258***a* extends along an outer heel edge of the club head **200** between the first point **248***a* and third point **252***a*. The third segment **259** defining the top portion silhouette profile is a line along the surface of the front portion **208** or striking surface **222** that connects the second point **250***a* and the third point **252***a*. The first contour **256***a*, second contour **258***a*, and third segment **259** are substantially coplanar.

FIG. **2**D shows a projected crown silhouette **254** being the top portion silhouette profile shape that is externally projected on to the ground when looking vertically down at the crown **224** when the head **200** is in the address position, as previously described. As noted above, the crown silhouette **254** is defined by three projected points **248***b*,**250***b*,**252***b* and three segments **256***b*,**258***b*,**260** shown in an X-Y plane or ground **201** plane as previously described. In one embodiment, the projected crown silhouette **254** occupies a projected silhouette area of 11,975 mm^3 in an X-Y plane while having a width W, height H, and depth D dimension of 124 mm, 65 mm, and 123 mm, respectively.

Furthermore, the golf club head **200** has a CG with a CG x-axis **234** coordinate, a CG y-axis **232** coordinate, and a CG z-axis **230** coordinate within the ranges described previously. The CG location is measured from the origin point **228**.

Furthermore, the club head **200** has a moment of inertia about the CG z-axis, I_{CGz}, and the CG x-axis I_{CGx} that are within the range of values previously described.

In one exemplary embodiment, the top portion **204** surface area S_t is about 17,792 mm^2 and the bottom portion **206** surface area S_b including the indentation **238** is about 18,752 mm^2 resulting in a total surface area of about 36,544 mm^2 and a surface ratio S_r of about 0.95.

FIG. **2**E shows a front view of the club head **200** and striking surface **222** at an address position having a hosel longitudinal axis **270** and angle **264**. Again, projection lines **262***a*,**262***b* are shown in dashed lines to further illustrate how the crown silhouette **254** is projected on to the ground **201**, as previously described.

In one embodiment, the ball striking surface **222** may have a maximum height H value of about 67 mm to about 71 mm, a maximum width W value of about 118 mm to about 127 mm and a corresponding ball striking surface **222** area of about 4,793 mm^2.

FIG. **3**A shows a wood-type (e.g., driver or fairway wood) golf club head **300** including a hollow body **302** having a top portion **304**, a bottom portion **306**, a front portion **308**, and a back portion **310**. A hosel **312** which defines a hosel bore **314** is connected with the hollow body **302**, The body **302** further includes a heel portion **316** and a toe portion **318**.

FIG. **3**A further shows a side portion **320**, a striking surface **322**, a crown **324**, a sole **326**, an origin point **328**, a Z-axis **330**, a Y-axis **332**, an X-axis **334**, a rearward-most point **348***a*, a CG point **340**, a CG z-axis **342**, a CG x-axis **344**, a and CG y-axis **346**, as previously described.

FIG. **3**B shows a first indentation **338***a*, a second indentation **338***b*, a third indentation **338***c*, a fourth indentation **338***d*, fifth indentation **338***e*, sixth indentation **338***f*, seventh indentation **338***g*, and eighth indentation **338***h* being located on the bottom portion **306** of the club head **300**. In one embodiment, the indentations are located exclusively on the bottom portion **306** of the club head **300** and each have a diameter of about 25 mm. Each indentation has a respective geometric center point **339***a*,**339***b*,**339***c*,**339***d*,**339***e*,**339***f*, **339***g*,**339***h* and includes a corresponding concave surface **336***a*,**336***b*,**336***c*,**336***d*,**336***e*,**336***f*,**336***g*,**336***h* that extends into the bottom portion **306** or sole **326** of the club head **300**.

FIG. **3**B further shows the indentations being configured in three rows substantially parallel to the X-direction **334**. A first row contains four indentations **338***a*,**338***b*,**338***c*,**338***d* having the first indentation **338***a* being located near a toe portion **318** and the fourth indentation **338***d* being located near the heel portion **316**. A second row contains three indentations **338***e*,**338***f*,**338***g* and a third row contains one indentation **338***h* located near the rearward-most point **348***a*. Thus, the arrangement of the first, second, and third rows of indentations form a generally triangular arrangement of indentations on the bottom portion **306** or sole **326**.

In one embodiment, the indentations **338***a*,**338***b*,**338***c*, **338***d*,**338***e*,**338***f*,**338***g*, **338***h* are equally spaced in the X-direction **334** from one another across the surface of the bottom portion **306**. In addition, the first, second, and third rows are equally spaced from one another across the surface of the bottom portion **306**. It is understood that the indentations can vary in spacing with respect to each other and need not be equidistant.

In one embodiment, the eight indentations **338***a*,**338***b*, **338***c*,**338***d*,**338***e*, **338***f*,**338***g*, **338***h* remove a total of about 15 to 16 cm^3 from a total volume of the club head **300** allowing the saved volume to be reallocated in other regions of the club head **300**. In another embodiment, each indentation removes about of 1.875 cm^3 from the total volume of the

club head **300**. In other words, the removal of the indentations **338** would increase the volume of the head **300** by about 15 cm^3 to create a second body volume. The first body volume can be about 459 cm^3 and the second body volume can he about 475 cm^3 according to the water displacement method.

In one embodiment, the second body volume (without indentations) is about 4-5% larger than the first body volume (with indentations). In another embodiment, the bottom portion volume is about 56% of the total volume of the club head. Furthermore, the top portion volume can be about 205 cm^3 and the bottom portion volume can be about 259 cm^3 resulting in a total volume of about 463 cm^3.

FIG. **3**C shows a top view of the club head **300** including the top portion **304**, striking surface **322**, and the hosel **312**. The X-axis **334** and the Y-axis **332** extend from the origin point **328** as previously mentioned. The club head **300** also has a first point **348***a*, a second point **350***a*, and a third point **352***a* located about the perimeter of the top portion **304** as previously described.

Again, a top portion silhouette profile is shown including a first contour **356***a*, a second contour **358***a*, and a third segment **359** is located along a perimeter of the top portion **304** defining the outer bounds of the top portion **304** in substantially an X-direction **334** and Y-direction **332** as previously described. Again, in one embodiment, the first contour **356***a*, second contour **358***a*, and third segment **359** are substantially coplanar.

FIG. **3**D shows a projected crown silhouette **354** being the top portion silhouette profile shape that is externally projected on to the ground when looking vertically down at the crown **324** when the head **300** is in the address position as previously described. As noted above, the crown silhouette **354** is defined by three projected points **348***b*,**350***b*,**352***b* and three segments **356***b*,**358***b*,**360** shown in an X-Y plane or ground **301** plane. In one embodiment, the projected crown silhouette occupies a projected silhouette area **354** of about 11,999 mm^2 in an X-Y plane.

Furthermore, the golf club head **300** has a CG with a CG x-axis **334** coordinate, a CG y-axis **332** coordinate, and a CG z-axis **330** coordinate within the ranges described above. In addition, the club head **300** has a moment of inertia about the CG z-axis, I_{CGz}, and a moment of inertia about the CG x-axis I_{CGx} that are within the ranges described above.

In one exemplary embodiment, the top portion **304** surface area S_t is about 17,562 mm^2 and the bottom portion **306** surface area S_b including the indentation **338** is about 19,654 mm^2 resulting in a total surface area of about 37,216 mm^2 and a surface ratio S_r of about 0.89.

FIG. **3**E shows a front view of the club head **300** and striking surface **322** at an address position having a hosel longitudinal axis **370** and angle **364**. Again, projection lines **362***a*,**362***b* are shown in dashed lines to further illustrate how the crown silhouette **354** is projected on to the ground **301**, as previously described.

In one embodiment, the ball striking surface **322** may have a maximum height H value of about 67 mm to about 71 mm, a maximum width W value of about 118 mm to about 127 mm and a corresponding ball striking surface **322** area of about 4,793 mm^2.

FIG. **4**A shows a wood-type (e.g., driver or fairway wood) golf club head **400** including a hollow body **402** having a top portion **404**, a bottom portion **406**, a front portion **408**, and a back portion **410**. A hosel **412** which defines a hosel bore **414** is connected with the hollow body **402**. The body **402** further includes a heel portion **416** and a toe portion **418**.

FIG. **4**A further shows a side view of a club bead **400** having a side portion **420**, a striking surface **422**, a crown **424**, a sole **426**, an origin point **428**, a Z-axis **430**, a Y-axis **432**, an X-axis **434**, a rearward-most point **448***a*, a CG point **440**, a CG z-axis **442**, a CG x-axis **444**, a and a CG y-axis **446**, as previously described.

FIG. **4**B shows a bottom view having an indented channel or groove **438** located on the bottom portion **406** of the club bead **400**. In one exemplary embodiment, the indented groove **438** creates an indentation **438** having a width **437***a* of about 100 mm to 120 mm in the X-direction **434** and a length **437***b* of abo a 50 mm to 60 mm in the Y-direction **432**. Thus, the groove indentation **438** extends primarily in the X-direction **434**.

The groove indentation **438** is generally defined by four indentation edges **436***a*,**436***b*,**436***c*,**436***d*, The first indentation edge **436***a* and third indentation edge **436***c* extends parallel to the Y-axis **432**. The second **436***b* and fourth **436***d* indentation edges are curved segments extending primarily in the X-direction **434** to connect the first **436***a* and third **436***c* indentation edges.

In one embodiment, the groove indentation **438** is centrally located on the bottom portion **406** or sole **426** only. Referring to FIG. **4**A, the groove indentation **438** has a slightly convex shaped initial side profile contour moving from the second **436***b* and fourth **436***d* indentation edge toward the center **439** of the groove indentation **438**. The side profile of the groove indention **438**, within a Y-Z plane, transitions from the initial convex profile contour to a concave indentation profile contour located at the deepest point of the groove indentation **438**. It is understood that the groove indentation **438** can be a different shape configuration such as an elongated oval or substantially square shape without departing from the scope of the invention.

In certain embodiments, the groove indentation **438** removes a total of about 10 cm^3 to 17 cm^3 from a total volume of the club head **400** thereby allowing the saved volume to be reallocated in other regions of the club head **400**. In another embodiment, the groove indentation **438** removes about of 15 cm^3 from the total volume of the club head **400**. In other words, the removal of the groove indentation **438** would increase the volume of the head **400** by about 15 cm^3 to create a second body volume. In some embodiments, the second body volume (without indentations) is about 4-5% larger than the first body volume (with indentations). In certain embodiments, the bottom portion volume is about 53% to about 71% of the total volume of the club head. In one exemplary embodiment, the bottom portion volume is about 326 cm^3, the top portion volume is about 135 cm^3, and the total volume is about 461 cm^3. In another embodiment, the bottom portion volume is about 253 cm^3, the top portion volume is about 211 cm^3, and the total volume is about 464 cm^3.

FIG. **4**C shows a top view of the club head **400** including the top portion **404**, striking surface **422**, and the hosel **412**. The X-axis **434** and the Y-axis **432** extend from the origin point **428** as previously mentioned. The club head **400** also has a first point **448***a*, a second point **450***a*, and a third point **452***a* located about the perimeter of the top portion **404** as previously described.

Again, a top portion silhouette profile is shown including a first contour **456***a*, a second contour **458***a*, and a third segment **459** is located along a perimeter of the top portion **404** defining the outer bounds of the top portion **404** in substantially an X-direction **434** and Y-direction **432** as

previously described. Again, the first contour **456***a*, second contour **458***a*, and third segment **459** are substantially coplanar in one embodiment.

FIG. **4**D shows a projected crown silhouette **454** being the top portion silhouette profile shape that is externally projected on to the ground when looking vertically down at the crown **424** when the head **400** is in the address position, as previously described. As noted above, the crown silhouette **454** is defined by three projected points **448***b*,**450***b*,**452***b* and three segments **456***b*,**458***b*,**460** shown in an X-Y plane or ground **401** plane. In one embodiment, the projected crown silhouette **454** occupies a projected silhouette area of about 12,120 mm^2 in an X-Y plane while having a width W, height H, and depth D dimension of about 125 mm, 65 mm, and 123 mm, respectively. In addition, the face size includes a striking surface **422** area of about 4,793 mm^2. In another embodiment, the projected crown silhouette **454** occupies a projected silhouette area of about 11.702 mm^2 while having a width W, height H, and depth D dimension of about 126 mm, 70 mm, and 125 mm, respectively. Furthermore, the face size includes a striking surface **422** area of about 5,531 mm^2.

Furthermore, the golf club head **400** has a CG with a CG x-axis **434** coordinate of about 2.9 mm, a CG y-axis **432** coordinate of about 31.8 mm, and a CG z-axis **430** coordinate of about −4.87 mm. It is understood than other CG locations within the above described ranges can be achievable. In one example, a composite face embodiment can achieve a CG with a CG x-axis **434** coordinate of about 3.1 mm, a CG y-axis **432** coordinate of about 37.3 mm, and a CG z-axis **430** of about −6.1 mm.

In one exemplary embodiment, the club head **400** has a moment of inertia about the CG z-axis, I_{CGz}, of about 523 kg·mm^2 and a moment of inertia about the CG x-axis I_{CGx} of about 356 kg·mm^2. Again, if a composite face already described above is utilized, the I_{CGz} is about 560 kg·mm^2 and the I_{CGx} is about 401 kg·mm^2. Furthermore, the club head **400** can have a first sole mode frequency greater than 3,000 Hz as previously described.

In one exemplary embodiment, the top portion **404** surface area S_t is about 17,745 mm^2 and the bottom portion **406** surface area S_b including the indentation **438** is about 18,727 mm^2 resulting in a total surface area of about 36,472 mm^2 and a surface ratio S_r of about 0.95.

In another exemplary embodiment, the top portion **404** surface area S_t is about 16,089 mm^2 and the bottom portion **406** surface area S_b including the indentation **438** is about 21,738 mm^2 resulting in a total surface area of about 37,827 mm^2 and a surface ratio S_r of about 0.74.

FIG. **4**E shows a front view of the club head **400** and striking surface **422** at an address position having a hosel longitudinal axis **470** and angle **464**. Again, projection lines **462***a*,**462***b* are shown in dashed lines to further illustrate how the crown silhouette **454** is projected on to the ground **401**, as previously described.

FIG. **5**A shows a wood-type (e.g., driver or fairway wood) golf club head **500** including a hollow body **502** having a top portion **504**, a bottom portion **506**, a front portion **508**, and a back portion **510**. A hosel **512** which defines a hosel bore **514** is connected with the hollow body **502**. The body **502** further includes a heel portion **516** and a toe portion **518**.

FIG. **5**A further shows a side view of a club head **500** having a side portion **520**, a striking surface **522**, a crown **524**, a first sole **526**, an origin point **528**, a Z-axis **530**, a Y-axis **532**, an X-axis **534**, a rearward-most point **548***a*, a CG point **540**, a CG z-axis **542**, a CG x-axis **544**, a and a CG y-axis **546**, as previously described.

FIG. **5**B shows a bottom view having a double sole configuration including a first sole **526** and a second sole **538** located on the bottom portion **506** of the club head **500**. In one exemplary embodiment, the second sole **538** creates an indentation **538** having a width **537***a* of about 125 mm in the X, direction **534** and a length **537***b* of about 85 mm in the Y-direction **532**. The indentation **538** can have a depth of about 2 to 3 mm below the surface of the first sole **526**. Thus, the indentation **538** extends primarily in the X and Y directions.

The second sole **538** is generally defined by three edges **536***a*,**536***b*,**536***c* around the perimeter of the second sole **538**. The first edge **536***a* extends generally parallel to the X-axis **534** between a heel portion **516** and toe portion **518**. A second edge **536***b* of the second sole **538** extends from an endpoint of the first edge **536***a* near the heel portion **516** to the rearward-most point **548***a* of the club head **500**. A third edge **536***c* of the second sole **538** extends from an endpoint of the first edge **536***a* near the toe portion **518** to the rearward-most point **548***a* of the club head **500**. In one embodiment, the second edge **536***a* and third edge **536***c* closely follow a first **556***a* and second **558***b* silhouette contour line discussed in further detail below.

In one exemplary embodiment, the second sole **538** primarily occupies the surface area of the bottom portion **506** from the second sole first edge **536***a* to the rearward-most point **548***a* of the club head **500**. The second sole **538** does not extend into the top portion **504** of the club head **500**. In other words, the second sole **538** is located on the bottom portion **506** or sole **526** only.

In one embodiment, the second sole **538** removes a total of about 9 cm^3 from a total volume of the club head **500** thereby allowing the saved volume to be reallocated in other regions of the club head **500**. For example, the first body volume can be about 455 cm^3 and have a second body volume after indentation removal of about 464 cm^3.

In certain embodiments, the second sole **538** removes about 12 cm^3 to about 15 cm^3 from the total volume of the club head **500**. In other words, the removal of the second sole **538** would increase the volume of the head **500** by about 12 cm^3 to about 15 cm^3 to create a second body volume. In one embodiment, the second body volume (without the second sole) is about 4-5% larger than the first body volume the second sole). In another embodiment, the bottom portion volume is about 54% of the total volume of the club head. The total volume of the club head **500** can be about 462 cm^3 and the top portion **504** volume is about 212 cm^3 while the bottom portion volume is about 250 cm^3.

FIG. **5**C shows a top view of the club head **500** including the top portion **504**, striking surface **522**, and the hosel **512**. The X-axis **534** and the Y-axis **532** extend from the origin point **528** as previously mentioned. The club head **500** also has a first point **548***a*, a second point **550***a*, and a third point **552***a* located about the perimeter of the top portion **504** as previously described.

Again, a top portion silhouette profile is shown including a first contour **556***a*, a second contour **558***a*, and a third segment **559** is located along a perimeter of the top portion **504** defining the outer bounds of the top portion **504** in substantially an X-direction **534** and Y-direction **532** as previously described. Again, the first contour **556***a*, second contour **558***a*, and third segment **559** are substantially coplanar in one embodiment.

FIG. **5**D shows a projected crown silhouette **554** being the top portion silhouette profile shape that is externally projected on to the ground when looking vertically down at the crown **524** when the head **500** is in the address position, as

previously described. As noted above, the projected crown silhouette **554** is defined by three projected points **548***b*, **550***b*,**552***b* and three segments **556***b*,**558***b*,**560** shown in an X-Y plane or ground **501** plane. In one embodiment, the projected crown silhouette **554** occupies a projected silhouette area of 12,150 cm^3 in an X-Y plane while having a width W, height H, and depth D dimension of about 125 mm, 65 mm, 123 mm, respectively. In addition, a large face size greater than 4,000 mm^2 is achieved, such as 4,793 mm^2.

Furthermore, the golf club head **500** has a CG with a CG x-axis **534** coordinate, a CG y-axis **532** coordinate, and a CG z-axis **530** coordinate within the ranges described herein.

In one exemplary embodiment, the club head **500** has a moment of inertia about the CG z-axis, I_{CGz}, and a moment of inertia about the CG x-axis I_{CGx} that are within the ranges described herein.

In one exemplary embodiment, the top portion **504** surface area S_t is about 17,787 mm^2 and the bottom portion **506** surface area S_b including the indentation **538** is about 18,526 mm^2 resulting in a total surface area of about 36,313 mm^2 and a surface ratio S_r of about 0.96.

FIG. **5**E shows a front view of the club head **500** and striking surface **522** at an address position having a hosel longitudinal axis **570** and angle **564**. Again, projection lines **562***a*,**562***b* are shown in dashed lines to further illustrate how the crown silhouette **554** is projected on to the ground **501**, as previously described.

FIG. **6**A shows a wood-type (e.g., driver or fairway wood) golf club head **600** including a hollow body **602** having a top portion **604**, a bottom portion **606**, a front portion **608**, and a back portion **610**. A hosel **612** which defines a hosel bore **614** is connected with the hollow body **602**. The body **602** further includes a heel portion **616** and a toe portion **618**.

FIG. **6**A further shows a side view of a club head **600** having a side portion **620**, a striking surface **622**, a crown **624**, a sole **626**, an origin point **628**, a Z-axis **630**, a Y-axis **632**, an X-axis **634**, a rearward-most point **648***a*, a CG point **640**, a CG z-axis **642**, a CG x-axis **644**, a and a CG y-axis **646**, as previously described.

FIG. **6**B shows a bottom view having three indentations **638***a*,**638***b*,**638***c* located on the bottom portion **606** of the club head **600**. In one exemplary embodiment, the three indentation **638***a*,**638***b*,**638***c* create a K-shaped sole **626**. The first indentation **638***a* has a wedge shape or triangular shape located near the toe portion **618** and pointing in a rearward direction toward the back portion **610** of the sole **626**. The second indentation **638***b* has a wedge shape or triangular shape located near the heel portion **616** and pointing in a rearward direction toward the back portion **610** of the sole **626**. The third indentation **638***c* has a wedge shape or triangular shape located near the hack portion **610** and pointing in a forward direction toward the front portion **608** of the sole **626**. A portion of the third indentation **638***c* can be curved to accommodate the perimeter shape of the sole **626**. In one embodiment, the indentations **638***a*,**638***b*,**638***c* are located on the bottom portion **606** or sole **626** only. The three indentations **638***a*,**638***b*,**638***c* include three edges that create indentation sidewalls **636***a*,**636***b*,**636***c* below the surface of the sole **626** into the body **602**. In one embodiment, the three indentations **638***a*,**638***b*,**638***c* are about 6 mm to 8 mm deep below the surface of the sole **626**.

In certain embodiments, the indentations **638***a*,**638***b*,**638***c* remove a total of about 12 cm^3 to about 18 cm^3 from a total volume of the club head **600** thereby allowing the saved volume to be reallocated in other regions of the club head **600**. For example, the first body volume can be about 460 cm^3 prior to indentation removal and have a second body volume of about 478 cm^3 after indentation removal. In another embodiment, the indentations **638***a*,**638***b*,**638***c* remove at most about of 15 cm^3 from the total volume of the club head **600**. In other words, the removal of the indentations **638***a*,**638***b*,**638***c* can increase the volume of the head **600** by about 15 cm^3 to create a second body volume. In one embodiment, the second body volume (without indentations) is about 4-5% larger than the first body volume (with indentations). In another embodiment, the bottom portion volume is about 53% of the total volume of the club head. The top portion **604** can have a volume of about 218 cm^3 and the bottom portion can have a volume of about 246 cm^3 resulting in a total volume of about 464 cm^3.

FIG. **6**C shows a top view of the club head **600** including the top portion **604**, striking surface **622**, and the hosel **612**. The X-axis **634** and the Y-axis **632** extend from the origin point **628** as previously mentioned. The club head **600** also has a first point **648***a*, a second point **650***a*, and a third point **652***a* located about the perimeter of the top portion **604** as previously described.

Again, a top portion silhouette profile is shown including a first contour **656***a*, a second contour **658***a*, and a third segment **659** is located along a perimeter of the top portion **604** defining the outer bounds of the top portion **604** in substantially an X-direction **634** and Y-direction **632** as previously described. In one embodiment, the first contour **656***a*, second contour **658***a*, and third segment **659** are substantially coplanar in one embodiment.

FIG. **6**D shows a projected crown silhouette **654** being the top portion silhouette profile shape that is externally projected on to the ground when looking vertically down at the crown **624** when the head **600** is in the address position, as previously described. As noted above, the projected crown silhouette **654** is defined by three projected points **648***b*, **650***b*,**652***b* and three segments **656***b*,**658***b*,**660** shown in an X-Y plane or ground **601** plane. In one embodiment, the projected crown silhouette **654** occupies a projected silhouette area of about 12,139 mm^2 in an X-Y plane while having a width W, height H, and depth D dimension of about 125 mm, 65 mm, and 123 mm, respectively, In addition, the striking surface **622** face size can be about 4,793 mm^2.

Furthermore, the golf club head **600** has a with a CG x-axis **634** coordinate, a CG y-axis **632** coordinate, and a CG z-axis **630** coordinate within the ranges described herein.

In one exemplary embodiment, the club head **600** has a moment of inertia about the CG z-axis, I_{CGz}, and a moment of inertia about the CG x-axis I_{CGx} within the ranges described herein.

In one exemplary embodiment, the top portion **604** surface area S_t is about 17,947 mm^2 and the bottom portion **606** surface area S_b including the indentation **638** is about 19,353 mm^2 resulting in a total surface area of about 37,301 17,947 mm^2 and a surface ratio S_r of about 0.93.

FIG. **6**E shows a front view of the club head **600** and striking surface **622** at an address position having a hosel longitudinal axis **670** and angle **664**. Again, projection lines **662***a*,**662***b* are shown in dashed lines to further illustrate how the crown silhouette is projected on to the ground **601**, as previously described.

FIG. **7**A shows a wood-type (e.g., driver or fairway wood) golf club head **700** including a hollow body **702** having a top portion **704**, a bottom portion **706**, a front portion **708**, and a back portion **710**. A hosel **712** which defines a hosel bore **714** is connected with the hollow body **702**. The body **702** further includes a heel portion **716** and a toe portion **718**.

FIG. **7**A further shows a side view of a club head **700** having a side portion **720**, a striking surface **722**, a crown

724, a sole 726, an origin point 728, a Z-axis 730, a Y-axis 732, an X-axis 734, a rearward-most point 748*a*, a CG point 740, a CG z-axis 742, a CG x-axis 744, a and a CG y-axis 746, as previously described.

FIG. 7B shows a bottom view of the bottom portion 706 having a first indentation 738*a* and a second indentation 738 located on the bottom portion 706 of the club head 700. The first indentation 738*a* is located near the toe portion 718 and the second indentation 738*b* is located near the heel portion 716. In one exemplary embodiment, the first 738*a* and second 738*b* indentation are an egg shape or tear dropped shape having side walls 736*a*,736*b* that extend below the surface of the sole 726 into the body 702. It is understood that the indentations 738*a*,738*b* can be an elliptical shape. The first 738*a* and second 738*b* indentation are positioned in a V-shaped arrangement where the end points of the indentations 738*a*,738*b* are closer together near the back portion 710 of the club head when compared to the opposite end points of the indentations near the front portion 708.

In addition, the first indention 738*a* has a major axis 739*a* and the second indentation has a second major axis 739*b* that form a first angle 737*a* and a second angle 737*b* with the Y-axis 732, respectively. Thus, the indentations 738*a*,738*b* extend primarily in the Y-direction 732. In one exemplary embodiment, the first indentation 738*a* is slightly larger in size than the second indentation 738*b*, and the indentations 738*a*,738*b* are exclusively located on the bottom portion 706 or sole 726 only. Furthermore, each indentation 738*a*,738*b* can have a maximum Y-direction 732 dimension of about 75 mm, a maximum X-direction 734 dimension of about 40 mm, and a maximum depth of about 7 mm to about 9 mm below the surface of the sole 726.

In certain embodiments, the indentation 738 removes a total of about 12 cm^3 to about 15 cm^3 from a total volume of the club head 700 thereby allowing the saved volume to be reallocated in other regions of the club head 700. In one embodiment, the indentation 738 removes about 12 cm^3 from the total volume of the club head 700. In other words, the removal of the indentation 738 would increase the volume of the head 700 by about 12 cm^3 to create a second body volume. For example, the first body volume can be about 457 cm^3 and the second body volume can he about 469 cm^3 after indentation removal. In one embodiment, the second body volume (without indentations) is about 4-5% larger than the first body volume (with indentations). In another embodiment, the bottom portion volume is about 54% of the total volume of the club head. Furthermore, the top portion is about 214 cm^3 and the bottom portion is about 249 cm^3 resulting in a total volume of about 463 cm^3.

FIG. 7C shows a top view of the club bead 700 including the top portion 704, striking surface 722, and the hosel 712. The X-axis 734 and the Y-axis 732 extend from the origin point 728 as previously mentioned. The club head 700 also has a first point 748*a*, a second point 750*a*, and a third point 752*a* located about the perimeter of the top portion 704 as previously described.

Again, a top portion silhouette profile is shown including a first contour 756*a*, a second contour 758*a*, and a third segment 759 is located along a perimeter of the top portion 704 defining the outer bounds of the top portion 704 in substantially art X-direction 734 and Y-direction 732 as previously described. Again, the first contour 756*a*, second contour 758*a*, and third segment 759 are substantially coplanar in one embodiment.

FIG. 7D shows a projected crown silhouette 754 being the top portion silhouette profile shape that is externally projected on to the ground when looking vertically down at the crown 724 when the head 700 is in the address position, as previously described. As noted above, the projected crown silhouette 754 is defined by three projected points 748*b*, 750*b*,752*b* and three segments 756*b*,758*b*,760 shown in an X-Y plane or ground 701 plane. In one embodiment, the projected crown silhouette 754 occupies a projected silhouette area of about 11,977 mm^2 in an X-Y plane while having a width W, height H, and depth D dimension of about 126 mm, 65 mm, and 123 mm, respectively. Furthermore, the face size is about 4,793 mm^2.

In addition, the golf club head 750 has a CG with a CG x-axis 734 coordinate, a CG y-axis 732 coordinate, and a CG z-axis 730 coordinate within the ranges described herein.

Furthermore, the club head 700 has a moment of inertia about the CG z-axis, I_{CGz}, and a moment of inertia about the CG x-axis I_{CGx} within the ranges described herein.

In one exemplary embodiment, the top portion 704 surface area S_t is about 17,869 mm^2 and the bottom portion 706 surface area S_b including the indentation 738 is about 18,818 mm^2 resulting in a total surface area of about 36,687 mm^2 and a surface ratio S_r of about 0.95.

FIG. 7E shows a front view of the club head 700 and striking surface 722 at an address position having a hosel longitudinal axis 770 and angle 764. Again, projection lines 762*a*,762*b* are shown in dashed lines to further illustrate how the crown silhouette is projected on to the ground 701, as previously described.

FIG. 8A shows a wood-type (e.g., driver or fairway wood) golf club head 800 including a hollow body 802 having a top portion 804, a bottom portion 806, a front portion 808, and a back portion 810. A hosel 812 which defines a hosel bore 814 is connected with the hollow body 802. The body 802 further includes a heel portion 816 and a toe portion 818.

FIG. 8A further shows a side view of a club head 800 having a side portion 820, a striking surface 822, a crown 824, a sole 826, an origin point 828, a Z-axis 830, a Y-axis 832, an X-axis 834, a rearward-most point 848*a*, a CG point 840, a CG z-axis 842, a CU x-axis 844, a and a CG y-axis 846 as previously described.

FIG. 8B shows a bottom view of the bottom portion 806 having a first indentation 838*a* and a second indentation 838*b* located on the bottom portion 806 of the club head 800. The first indentation 838*a* is located near the toe portion 818 and the second indentation 838*b* is located near the heel portion 816. In one exemplary embodiment, the first 838*a* and second 838*b* indentation are triangular in shape and arranged so that the sole 826 forms a T-shape. In one embodiment, the first 838*a* and second 838*b* indentation are mirrored across the Y-axis 832 and are about the same shape and size. In one embodiment, the indentations 838*a*,838*b* each have a maximum X-direction 834 dimension of about 55 mm and a maximum Y-direction 832 dimension of about 85 mm and a maximum depth of about 9 mm to about 12 mm.

The first indentation 838*a* has a first edge 839*a*, a second edge 839*b*, and a third edge. 839*c*. The second indentation 838*b* has a first edge 837*a*, a second edge 837*b*, and a third edge 837*c*. The first edges 839*a*,837*a* of both indentations extend in an X-direction and are generally parallel with the X-axis 834. The second edges 839*b*,837*b* of both indentations extend in a Y-direction and are generally parallel with the Y-axis 832. In one embodiment, the first 839*a*,837*a* and second edges 839*b*,837*b* of both indentations create a side wall 836*a*,836*b* that extends below the surface of the sole 826 and into the body 802.

The third edge 839*c* of the first indentation 838*a* is a curved edge in the X-Y plane that generally follows a

silhouette profile near the toe side **818** of the club head **800**. The third edge **837***c* of the second indentation **838***b* is also a curved edge in the X-Y plane that generally follows a silhouette profile near the heel side **819** of the club head **800**. In one embodiment, the third edges **839***c*,**837***c* of both indentations do not create a side wall below the surface of the sole **826**.

The first **838***a* and second **838***b* indentations are separated by a plateau or center sole portion **841** that extends in a direction parallel to the Y-axis **832**. In one embodiment, the plateau or center sole portion **841** is about 25 mm to about 35 mm wide. The center sole portion **841** also contains a movable weight port **835** located on the sole **826** near the back portion **810** where a movable weight may he inserted or removed to change characteristics of the CG location. In certain embodiments, a movable weight system is implemented as described in U.S. patent application No. 10/290,817 (U.S. Pat. No. 6,773,360), Ser. No. 10/785,692 (U.S. Pat. No. 7,166,040), Ser. No. 11/025,469, 11/067,475 (U.S. Pat. No. 7,186,190), Ser. No. 11/066,720 (U.S. Pat. No. 7,407,447), and Ser. No. 11/065,772 (U.S. Pat. No. 7,419,441), which are hereby incorporated by reference in their entirety.

In certain embodiments, the indentations **838***a*,**838***b* remove a total of about 12 cm^3 to about 16 cm^3 from a total volume of the club head **800** thereby allowing the saved volume to be reallocated in other regions of the club head **800**. In one embodiment, the indentations **838***a*,**838***b* remove about of 15 cm^3 from the total volume of the club head **800**. For example, the first body volume can be about 458 cm^3 before indentation removal and about 473 cm^3 after indentation removal. In other words, the removal of the indentations **838***a*,**838***b* would increase the volume of the head **800** by about 15 cm^3 to create a second body volume. In one embodiment, the second body volume (without indentations) is about 4-5% larger than the first body volume (with indentations). In another embodiment, the bottom portion volume is about 60% of the total volume of the club head. For example, the top portion volume can be about 185 cm^3 while the bottom portion has a volume is about 277 cm^3 for a total volume of about 462 cm^3.

FIG. **8**C shows a top view of the club head **800** including the top portion **804**, striking surface **822**, and the hosel **812**. The X-axis **834** and the Y-axis **832** extend from the origin point **828** as previously mentioned. The club head **800** also has a first point **848***a*, a second point **850***a*, and a third point **852***a* located about the perimeter of the top portion **804** as previously described.

Again, a top portion silhouette profile is shown including a first contour **856***a*, a second contour **858***a*, and a third segment **859** is located along a perimeter of the top portion **804** defining the outer bounds of the top portion **804** in substantially an X-direction **834** and Y-direction **832** as previously described. Again, the first contour **856***a*, second contour **858***a*, and third segment **859** are substantially coplanar in one embodiment.

FIG. **8**D shows a projected crown silhouette **854** being the top portion silhouette profile shape that is externally projected on to the ground when looking vertically down at the crown **824** when the head **800** is in the address position, as previously described. As noted above, the projected crown silhouette **854** is defined by three projected points **848***b*, **850***b*,**852***b* and three segments **856***b*,**858***b*,**860** shown in an X-Y plane or ground **801** plane. In one embodiment, the projected crown silhouette **854** occupies a silhouette area of 11,919 mm^2 in an X-Y plane while having a width W, height H, and depth D dimension of about 126 mm, 70 mm, and 125 mm, respectively. In addition, a face size or striking surface area, in one embodiment, is about 5,632 mm^2, according to the striking surface area measurement procedure, as previously described.

Furthermore, the golf club head **850** has a CG with a CG x-axis **834** coordinate, a CG y-axis **832** coordinate, and a CG z-axis **830** coordinate within the ranges described herein.

In certain embodiments, the club head **800** has a moment of inertia about the CG z-axis, I_{CGz}, and a moment of inertia about the CG x-axis I_{CGx} within the range described herein.

In one exemplary embodiment, the top portion **804** surface area S_t is about 17,798 mm^2 and the bottom portion **806** surface area S_b including the indentation **838** is about 20,421 mm^2 resulting in a total surface area of about 38,219 mm^2 and a surface ratio S_r of about 0.87.

FIG. **8**E shows a front view of the club head **800** and striking surface **822** at an address position having a hosel longitudinal axis **870** and angle **864**. Again, projection lines **862***a*,**862***b* are shown in dashed lines to further illustrate how the crown silhouette **854** is projected on to the ground **801**, as previously described.

FIG. **9**A shows a wood-type (e.g., driver or fairway wood) golf club head **900** including a hollow body **902** having a top portion **904**, a bottom portion **906**, a front portion **908**, and a back portion **910**. A hosel **912** which defines a hosel bore **914** is connected with the hollow body **902**. The body **902** further includes a heel portion **916** and a toe portion **918**.

FIG. **9**A further shows a side view of a club head **900** having a side portion **920**, a striking surface **922**, a crown **924**, a sole **926**, an origin point **928**, a Z-axis **930**, a Y-axis **932**, an X-axis **934**, a rearward-most point **948***a*, a CG point **940**, a CG z-axis **942**, a CG x-axis **944**, a and a CG y-axis **946**, as previously described.

FIG. **9**B shows a single dimple or small indentation **938** being located on the sole **926** in the bottom portion **906** of the club head **900**. The bottom portion **906** extends substantially in an X and Y direction along the X-axis **934** and the Y-axis **932**.

It is understood that the single indentation **938** can be located anywhere on the bottom portion **906**. In one embodiment, the single indentation **938** is positioned on the bottom portion **906** between the heel **916** and toe **918** along the X-axis **934**. The single indentation **938** is also positioned between the striking surface **922** and a rearward-most point **948***a* located along the Y-axis **932**. In one embodiment, the single indentation **938** is a circular or an elliptical shaped indentation that is centrally located on the bottom portion **906** of the club head **900**. The single indentation **938** includes a concave surface **936** extending below the top surface of the bottom portion **906** into the body **902**. A center point **939** of the single indentation **938** is located about 48 mm from the origin point **928** and has a diameter of about 50 mm.

In certain embodiments, removal of the indentation **938** would increase the volume of the head **900** by about 12 cm^3 to about 22 cm^3. In one embodiment, the presence of the indentation **938** removes about 15 cm^3 from the bottom portion **906** allowing the saved volume to be reallocated in other regions of the club head, such as the top portion **904** or crown area **924**. In one exemplary embodiment, a second body volume (without indentations) is about 4-5% larger than the first body volume (with indentations). In another embodiment, the bottom portion volume is about 55% of the total volume. For example, an embodiment having a 22 cm^3 indentation has a top portion volume of about 201 cm^3 and a bottom portion volume of about 248 cm^3 resulting in a total volume of about 449 cm^3.

FIG. **9**C shows a top view of the club head **900** including the top portion **904**, striking surface **922**, and the hosel **912**. The X-axis **934** and the Y-axis **932** extend from the origin point **928** as previously mentioned. The club head **900** also has a first point **948***a*, a second point **950***a*, and a third point **952***a* located about the perimeter of the top portion **904** as previously described.

Again, a top portion silhouette profile is shown including a first contour **956***a*, a second contour **958***a*, and a third segment **959** is located along a perimeter of the top portion **904** defining the outer bounds of the top portion **904** in substantially an X-direction **934** and Y-direction **932** as previously described. Again, the first contour **956***a*, second contour **958***a*, and third segment **959** are substantially coplanar in one embodiment.

FIG. **9**D shows a projected crown silhouette **954** being the crown top view profile shape as the external projected profile of the crown on to the ground **901** when looking vertically down at the crown **924** when the head **900** is in the address position, as previously described. As noted above, the projected crown silhouette **954** is defined by three projected points **948***b*,**950***b*,**952***b* and three segments **956***b*, **958***b*,**960** shown in an X-Y plane or ground **901** plane. In one embodiment, the projected crown silhouette **954** occupies a silhouette area of 11,913 mm^2 in an X-Y plane while having a width W, height H, and depth D dimension of 125 mm, 65 mm, and 123 mm, respectively. In addition the face size achieved is about 4,793 mm^2.

Furthermore, the golf club head **950** has a CG with a CG x-axis **934** coordinate, a CG y-axis **932** coordinate, and a CG z-axis **930** coordinate within the ranges described herein.

In one exemplary embodiment, the club head **900** has a moment of inertia about the CG z-axis, I_{CGz}, and a moment of inertia about the CG x-axis I_{CGx} according to the ranges described herein.

In one exemplary embodiment, the top portion **904** surface area S_t is about 17,530 mm^2 and the bottom portion **906** surface area S_b including the indentation **938** is about 19,660 mm^2 resulting in a total surface area of about 37,191 mm^2 and a surface ratio S_r of about 0.89.

FIG. **9**E shows a front view of the club head **900** and striking surface **922** at an address position having a hosel longitudinal axis **970** and angle **964**. Again, projection lines **962***a*,**962***b* are shown in dashed lines to further illustrate how the crown silhouette **954** is projected on to the ground **901**, as previously described.

In all of the embodiments described herein, the ball striking surface can have a maximum height H value of about 67 mm to about 71 mm, a maximum width W value of about 118 mm to about 12.7 mm and a corresponding ball striking surface area of about 4,000 mm^2 to about 8,875 mm^2. In certain embodiment, a striking surface are of about 4,000 mm^2 to about 6,500 mm^2 is preferred. A maximum club head depth value D of about 118 mm to about 127 mm is also possible with a preferred depth D of about 122 mm to about 126 mm. Furthermore, the embodiments described herein show a range of indentation volumes between from about 9 cm^3 to about 22 cm^3 with a preferred range of about 12 cm^3 to about 15 cm^3.

Moreover, club head sizes described herein can be within a range of about 400 cm^3 to about 470 cm^3 with a preferred range of about 460 cm^3 to about 470 cm^3. The first body volume described herein is within a range of about 440 cm^3 to about 465 cm^3 and the second body volume is within a range of about 460 cm^3 to about 480 cm^3. The moments of inertia of the embodiments described herein have a club head with a center of gravity with an x-axis coordinate between about −2 mm and about 7 mm, a y-axis coordinate between about 30 mm and about 40 mm, and a z-axis coordinate between about −7 mm and about 2 mm.

A bottom portion volume percentage of the total club volume of the embodiments described herein are about 50% to about 75% with a preferred range of about 53% to about 72% or greater than 60%.

In use, the embodiments of the present invention create a large crown silhouette profile with a high moment of inertia and a low center of gravity by reducing a bottom portion volume. The embodiments described herein can also have various crown silhouette profile areas of greater than about 11,000 mm^2 and within the range of about 11,700 mm^2 to about 14,000 mm^2. As a result of reducing the bottom portion volume, the surface area of the bottom portion is increased while improving the crown silhouette profile. Thus, the crown silhouette profile is close to the maximum USGA dimension and volume requirements without having a significantly triangular crown silhouette profile shape.

At least one key advantage of the present invention is that a reduction in the sole portion volume of a club head enables a maximum height, width, depth, and face size dimension to be achieved.

In addition, the indentations located on the bottom portion of the club head can be positioned or configured to achieve a certain sound frequency upon direct impact with a golf ball while maintaining club head dimensions.

Furthermore, another advantage of the present invention, is that the reallocation of volume in the club head still achieves a low CG (i.e. at least 2 mm below center-face and at least 15 mm aft of a hosel axis) in order to achieve a high launch angle, low spin trajectory for maximum distance. In one embodiment, the CG is at least 18 mm aft of a hosel axis. Another advantage of the present invention is that the moment of inertia about the vertical axis CG z-axis (I_{CGz}) is greater than about 500 kg·mm^2 and the moment of inertia about the heel-toe axis CG x-axis (I_{CGx}) is greater than about 300 kg·mm^2 plus a test tolerance of 10 kg·mm^2.

At least one advantage of the present invention is that a more non-triangular shaped head can be achieved as the face size approaches a maximum limit (127 mm by 71.12 mm) and the front-to-back dimension approaches the maximum value (127 mm). Because the shape of the club head can be amore non-triangular shape, alignment properties of the golf dub head are improved. In general, as volume is removed from the sole and reallocated, no significant degradation of other properties in the head such as sound, durability, CG, or MOI are observed. The cost of producing the low volume sole design club head is implemented with minimal cost impact.

Another advantage of the present invention is that a relatively high coefficient of restitution (COR) can be maintained. The COR measured in accordance with the U.S.G.A. Rule 4-1a is greater than 0.810 in the embodiments described herein.

In view of the many possible embodiments to which the principles of the disclosed invention may be applied, it should be recognized that the illustrated embodiments are only preferred examples of the invention and should not be taken as limiting the scope of the invention. It will be evident that various modifications may be made thereto without departing from the broader spirit and scope of the invention as set forth. The specification and drawings are, accordingly, to be regarded in an illustrative sense rather than a restrictive sense.

The invention claimed is:

1. A golf club head comprising:

a body having a bottom portion, a top portion, a front portion, and a back portion, defining a volume of at least about 400 cm^3, and a front-rear dimension of at least about 111 mm;

a sole located on the bottom portion and a face positioned at the front portion;

wherein the golf club head has a head origin defined as a position on a face plane at a geometric center of the face, the head origin including an x-axis tangential to the face and generally parallel to the ground when the head is in an address position where a positive x-axis extends towards a heel portion and a negative x-axis extends towards a toe portion, a y-axis extending perpendicular to the x-axis and generally parallel to the ground when the head is in the address position where a positive y-axis extends from the face and through a rearward portion of the body, and a z-axis extending perpendicular to the ground, to the x-axis and to the y-axis when the head is in the address position where a positive z-axis extends from the head origin and generally upward, thereby defining a Y-Z plane including the y-axis and the z-axis wherein the golf club head has a center of gravity with an x-axis coordinate, a y-axis coordinate less than about 50 mm, and a z-axis coordinate less than about 2 mm;

a groove located in the sole and extending from the heel portion to the toe portion, the groove having a toe edge, a heel edge, a leading edge located toward the face and connecting a portion of the toe edge and the heel edge, a trailing edge opposite the leading edge and connecting a portion of the toe edge and the heel edge, an X-direction groove width that is greater than the center of gravity y-axis coordinate, and a Y-direction groove length that is less than the X-direction groove width, wherein a portion of the leading edge is curved and a portion of the trailing edge is curved, and within a vertical plane parallel to the Y-Z plane an exterior surface of the groove transitions from an initial convex contour at the leading edge to a concave contour between the leading edge and the trailing edge;

wherein the golf club head has a moment of inertia about the center of gravity z-axis, I_{CGz}, of at least about 450 kg·mm^2; and

wherein the golf club head has a coefficient of restitution greater than about 0.810.

2. The golf club head of claim 1, wherein the x-axis coordinate is between about −2 mm and about 7 mm, the y-axis coordinate is at least about 30 mm, and the z-axis coordinate is greater than about −7 mm.

3. The golf club head of claim 2, wherein a portion of the groove has a groove depth of at least 6 mm.

4. The golf club head of claim 3, wherein the moment of inertia about the center of gravity z-axis, I_{CGz}, is at least about 500 kg·mm^2.

5. The golf club head of claim 4, wherein the golf club head has a moment of inertia about the center of gravity x-axis, I_{CGx}, of at least about 300 kg·mm^2.

6. The golf club head of claim 3, wherein the groove has a groove volume of at least about 10 cm^3.

7. The golf club head of claim 2, wherein the center of gravity is at least 15 mm aft of a hosel axis.

8. The golf club head of claim 2, further comprising a weight port located on the sole.

9. The golf club head of claim 8, wherein the weight port is located near the back portion of the golf club head.

10. The golf club head of claim 9, wherein the center of gravity is located toe-ward of a center of the weight port.

11. The golf club head of claim 1, wherein the X-direction groove width is at least 100 mm.

12. The golf club head of claim 1, wherein at least a portion of the top portion is formed of a composite material and the face has a variable face thickness.

13. The golf club head of claim 1, further including (a) two or more indentations located on the sole below the top portion silhouette profile, the two or more indentations being defined in part by a wall that extends inwardly from a surface of the sole and into the body, and (b) a plateau located on the sole, wherein the two or more indentations comprising one or more toe-side indentations located at least partially toe-ward of the plateau and one or more heel-side indentations located at least partially heel-ward of the plateau, the toe-side indentation includes a toe-side curved edge having a portion that follows the top portion silhouette profile, and the heel-side indentation includes a heel-side curved edge having a portion that follows the top portion silhouette profile.

14. The golf club head of claim 13, further comprising a weight port located on the plateau.

15. The golf club head of claim 14, wherein the center of gravity is located toe-ward of a center of the weight port.

16. The golf club head of claim 13, wherein the two or more indentations have a combined volume that is at least 9 cm^3.

17. The golf club head of claim 1, further including a concave depression located on the sole.

18. A golf club head comprising:

a body having a bottom portion, a top portion, a front portion, and a back portion, defining a volume of at least about 400 cm^3, a front-rear dimension of at least about 111 mm, and at least a portion of the top portion is formed of a composite material;

a sole located on the bottom portion and a face positioned at the front portion, wherein a portion of the face is formed of composite material and has a variable face thickness;

wherein the golf club head has a head origin defined as a position on a face plane at a geometric center of the face, the head origin including an x-axis tangential to the face and generally parallel to the ground when the head is in an address position where a positive x-axis extends towards a heel portion and a negative x-axis extends towards a toe portion, a y-axis extending perpendicular to the x-axis and generally parallel to the ground when the head is in the address position where a positive y-axis extends from the face and through a rearward portion of the body, and a z-axis extending perpendicular to the ground, to the x-axis and to the y-axis when the head is in the address position where a positive z-axis extends from the head origin and generally upward, wherein the golf club head has a center of gravity with an x-axis coordinate between about −2 mm and about 7 mm, a y-axis coordinate is at least about 30 mm, and a z-axis coordinate less than about 2 mm and greater than about −7 mm;

a groove located in the sole and extending from the heel portion to the toe portion, the groove having a toe edge, a heel edge, a leading edge located toward the face and connecting a portion of the toe edge and the heel edge, a trailing edge opposite the leading edge and connecting a portion of the toe edge and the heel edge, an X-direction groove width that is greater than the center of gravity y-axis coordinate, and a Y-direction groove

length that is less than the X-direction groove width, wherein a portion of the leading edge is curved and a portion of the trailing edge is curved;

wherein the golf club head has a moment of inertia about the center of gravity z-axis, I_{CGz}, of at least about 450 kg·mm^2, and a moment of inertia about the center of gravity x-axis, I_{CGx}, of at least about 300 kg·mm^2; and

wherein the golf club head has a coefficient of restitution greater than about 0.810.

19. The golf club head of claim **18**, wherein a portion of the groove has a groove depth of at least 6 mm.

20. The golf club head of claim **18**, wherein the moment of inertia about the center of gravity z-axis, I_{CGz}, is at least about 500 kg·mm^2, and the center of gravity is at least 15 mm aft of a hosel axis.

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