Office de la Propriété Intellectuelle du Canada
Un organisme d'Industrie Canada

Canadian Intellectual Property Office
An agency of Industry Canada

CA 2736646 A1 2007/09/22

(21) 2 736 646

(12) DEMANDE DE BREVET CANADIEN
CANADIAN PATENT APPLICATION

(13) A1

(22) Date de dépôt/Filing Date: 2007/03/21

(41) Mise à la disp. pub./Open to Public Insp.: 2007/09/22

(62) Demande originale/Original Application: 2 582 746

(30) Priorité/Priority: 2006/03/22 (US11/387,461)

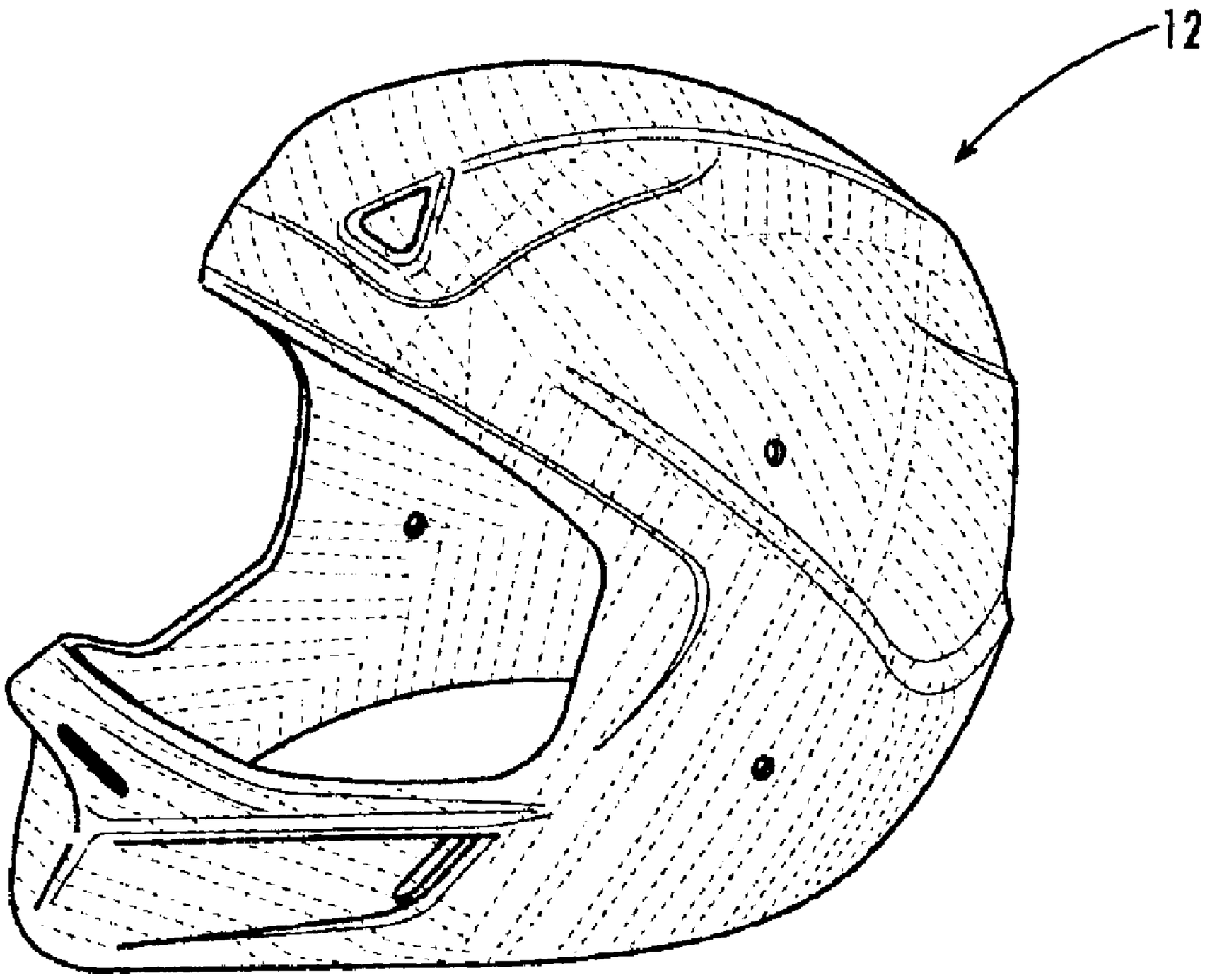
(51) Cl.Int./Int.Cl. *B29C 70/00* (2006.01),
A42B 3/06 (2006.01), *A42B 3/10* (2006.01),
B29D 99/00 (2010.01)

(71) Demandeur/Applicant:
FOX RACING, INC., US

(72) Inventeur/Inventor:
PIERCE, BRENDAN, US

(74) Agent: SMART & BIGGAR

(54) Titre : CASQUE AVEC DOUBLURE ANTI-CHOC DIRECTEMENT MOULEE ET METHODE DE FABRICATION
(54) Title: HELMET APPARATUS AND METHOD WITH DIRECTLY IN-MOLDED IMPACT LINER



(57) Abrégé/Abstract:
A motorcycle helmet including a shell and an impact liner directly in-molded to the shell and method for making same.

ABSTRACT

A motorcycle helmet including a shell and an impact liner directly in-molded to the shell and method for making same.

HELMET APPARATUS AND METHOD WITH DIRECTLY IN-MOLDED IMPACT LINER

BACKGROUND

The inventive subject matter disclosed herein generally relates to molded articles and methods relating to protective equipment. The molding and manufacturing techniques are particularly suitable for use in the manufacturing of a protective helmet structure for motor sports, including street and off-road motorcycling (including motocross), and human powered or gravity sports, such as bicycling and skiing. In the following description, a motorcycle helmet is used as a representative example of a product of the molding methods according to the inventive subject matter disclosed herein.

Modern motorcycle helmets have two principal protective components: (**1**) an outer shell made of a thin, hard materials and (**2**) an inner liner of an impact absorbing material. The shell is typically formed of one or more layers of composite or moldable polymer materials based on carbon fiber, fiber glass, aramid fibers (e.g., Kevlar®), polycarbonate, and/or acrylonitrile butadiene styrene (ABS) plastic, as well as combinations of the foregoing. The outer shell serves to help prevent penetration of the helmet by a pointed object that might otherwise puncture the skull, to spread the force of impact, and to provide structure to the inner impact liner so it does not disintegrate upon abrasive contact with pavement or objects. The impact liner attenuates impact forces by crushing or compressing. Not only must helmets be safe, but consumers also are looking for lighter weight and better ventilated helmets, among other things.

Conventional helmet shells may be manufactured using a molding process that may be referred to as the "Pressure Bladder" molding technique. The Pressure Bladder molding technique involves layering sheets of a composite onto an inflatable bladder that is the male portion of a male-female mold. The composite sheets may be "prepreg" sheets having an impregnated resin or they may be composite sheets that become treated with a resin in a wet lay-up on the inflatable bladder. The inflatable bladder with the composite sheets is placed into a female mold, and the mold is closed forming a seal. Heat is introduced into the mold to activate the resin, and the bladder is inflated with sufficient pressure to force the

composite sheet material into the shape of the mold, which corresponds to the shape of the outer shell.

In the prior art, impact liners have been formed in an injection molding process separate from shells and then pressed into the shells for motorcycle helmets. The pressing process is usually performed by hand and it necessitates that the shell be designed somewhat larger than is ideal so that the liner, which has a larger topside than bottom side, can more easily fit into the cavity of the shell, which also has a small bottom side opening relative to the topside. This relationship in a helmet between the topside and bottom side corresponds to the anatomy of wearer's head and is known as "undercutting". The larger size increases the weight of the shell. Glue or tape may be used to secure the liner in place. Additionally, it would be more advantageous to structurally fuse the liner with the shell, which should result in a stronger helmet.

Another problem with conventional helmets is that the impact liners, such as EPS foam and similar material are highly thermally insulating, like a Styrofoam cup, which may cause the wearer to suffer discomfort during use. An overheated wearer is not only uncomfortable but may also be impeded from performing optimally during motor sport and athletic competitions. There may even be a risk of dehydration or dangerous lapses of attention resulting from the overheating, especially in certain sports, such as motocross, which may be held in hot climates. Accordingly, a substantial need exists for helmets that do not promote overheating. Unfortunately, dictating against the use of alternative materials to current foams are the substantial advantages that foam has on impact absorption. Foams are also lightweight, which is another factor that is important to wearers and which relates to comfort and performance.

There have been various attempts to improve helmets so that they are less prone to over-heating. Vents have been provided in helmet shells. The vents have an opening in the shell that leads to vent channels formed in the impact liner material, which is typically EPS, or between sections of the liner material. The channels deliver air to the interior area of the helmet, thereby exposing the wearer's head to the air. One of the problems with conventional vents is that the channels must be carefully engineered so that the helmet's ability to absorb impacts is not compromised by the changes in structure. Consequently,

there are limitations to how large the channels can be and how they can be routed to deliver air. Another problem is that conventional vent structures formed in a combination of outer shell and impact materials, such as EPS, may result in a gap or rough interface between the opening of the shell and the pressed-in impact liner that is not conducive to good air flow into the helmet, or at least requires extra finishing steps.

In view of the foregoing, there is a substantial need for improved helmets that are stronger and safer, lighter, cooler and more comfortable to use. Some progress has been made at addressing some of the aforementioned problems. See, for example, U.S. Publication Numbers **20050278833** and **20060031978**, and U.S. Design Patent Number **D526092**, which disclose generally a motorcycle helmet and various components. More particularly a ventilation system is disclosed in co-owned USSN **11/434,304**, filed on May **15, 2006** and published as US **2008-0134415** A**1**, entitled Low Profile Helmet Vents and Venting Systems. However, notwithstanding such progress, there is an ever present need for improvements.

SUMMARY

In certain respects, the inventive subject matter disclosed herein provides novel and advantageous methods for direct molding of an impact liner (or portion thereof) to an outer shell (or portion thereof) for a protective helmet, such as a motorcycle helmet , mountain biking helmet, and downhill skiing helmet. The helmet may be of any style, including full-face and skull cap helmets. The direct molding eliminates the need for extra production steps such as the separate formation of the liner and the manual pressing of the liner into the shell, which also entails a risk of possible damage to the liner and its ability to perform. Consequently, production time speeds-up. Advantageously, an in-molding of the liner also means that the shell need not be formed larger to accommodate the pressing operation, saving shell weight plus the weight of incidental materials used in the pressing, such as tapes. Air gaps between the shell and impact liner can also be eliminated or reduced for better safety testing and use.

In certain other respects, the inventive subject matter disclosed herein addresses the problems in the prior art by providing a method for forming larger and more efficient

ventilation tunnels and channels in a helmet. The tunnels may also enhance the protective nature of the shell by forming a unitary structure with the outer shell that is double walled along tunnel regions. The double walling of the tunnel provides additional reinforcement zones that may help better withstand spiking in safety testing and use. In contrast, the vents in conventional helmets are simply openings that lead into venting channels formed in the relative soft impact liner. Aesthetically, the tunnels disclosed herein can produce cleaner vent openings in the shell of a helmet. Still further, the inventive methods should reduce venting formation steps and can save costs associated with the removed steps.

In certain other respects, the inventive subject matter uses a novel combination of processes to produce advantageous new helmets and components thereof wherein one or more internal venting air tunnels are formed in or integral to the outer shell. An impact liner, such as EPS, may be directly in-molded to the shell. The impact liner may include one or more venting channels that are coupled to a tunnel integral to the shell structure.

In accordance with one aspect of the invention, there is provided a motorcycle helmet including a shell and an impact liner, the impact liner being directly in-molded to the shell.

The shell may include a molded-composite lay-up.

At least some of the composite lay-up materials may include prepreg materials.

The impact liner may include a moldable, compressible, impact attenuating polymer material.

The impact liner may include a moldable, compressible, impact attenuating polymer material.

The impact liner may include EPS or EPP.

The impact liner may include multiple layers or zones of different moldable, compressible impact attenuating polymer material.

The impact liner may include multiple layers or zones of different densities of moldable, compressible impact attenuating polymer material.

In accordance with another aspect of the invention, there is provided a method of making a motorcycle helmet including providing a shell and in-molding impact liner material directly to the shell to form an impact liner.

The shell may include a molded-composite lay-up.

The impact liner material may include a moldable, compressible, impact attenuating polymer material.

The impact liner material may include EPS or EPP.

The in-molding may include forming multiple layers or zones of different moldable, compressible impact attenuating polymer material.

The in-molding may include forming multiple layers or zones of different densities of moldable, compressible impact attenuating polymer material.

The shell may include at least one of carbon fiber, aramid fiber, fiberglass, polycarbonate, and ABS.

The method may further include forming an integral tunnel to the shell wherein the tunnel material may include at least one of one of carbon fiber, aramid fiber, fiberglass, polycarbonate, and ABS.

The tunnel may have a volume of at least approximately **1.0** cubic inch.

The foregoing is not intended to be an exhaustive list of embodiments and features of the present invention. Persons skilled in the art are capable of appreciating other embodiments and features from the following detailed description in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. **1** shows a flow chart of steps that may be used in certain embodiments according to the inventive subject matter.

Fig. **2** shows an inflatable bladder that may serve as a male mold for a composite lay-up according to the inventive subject matter.

Fig. **3** represents a surface section of the inflatable bladder of Fig. **2**.

Fig. **4** represents the surface section of Fig. **3** with material to be molded in-laid within a relief in the surface.

Fig. **5** represents an inflatable tubular bladder laid over the material and relief of Fig. **4**.

Fig. **6** shows further material for molding laid over the inflatable bladder and surface of Fig. **5**.

Fig. **7**A shows a two-halved female mold component for use in a molding procedure according to the inventive subject matter.

Fig. **7**B shows the top of the mold of Fig. **7**A with the inflatable bladder and composite lay-up fitted therein.

Fig. **8**A shows the inflatable bladder of Fig. **2** with a composite lay-up.

Fig. **8**B is a section of the male-female mold assembly with the composite lay-up fitted there between.

Fig. **9** shows a cross-section of the assembly of Fig. **8**B taken along line **9-9**.

Fig. **10** is an exploded view of the assembly of Fig. **9**.

Fig. **11**A is a top perspective view of a section of a molded shell component with integral tunnel according to the inventive subject matter.

Fig. **11**B is a bottom perspective view of the molded component of Fig. **11**A.

Fig. **12** shows an exploded view of a section of a mold component and shell component for molding impact liner material to a surface of the shell, according to the inventive subject matter.

Fig. **13** shows a cross-sectional, assembled view of the components of Fig. **12** taken along line **13-13**.

Fig. **14** shows the assembly of Fig. **13** with mold material.

Fig. **15**A shows a side perspective view of a molded component according to a molding process using the assembly of Fig. **14**.

Fig. **15**B shows a bottom view of the molded component of Fig. **15**A.

Fig. **16**A shows a rough helmet shell molded according to the inventive subject matter.

Fig. **16**B shows the helmet structure of Fig. **16**A after certain finishing steps.

DETAILED DESCRIPTION

Representative embodiments of the present invention are shown in Figs. **1-16**B, wherein similar features share common reference numerals.

Fig. **1** shows a flowchart listing steps relating to the formation of a venting tunnel that is integral to an outer shell for a protective helmet, according to the inventive subject matter. In step **10** a shell for a helmet **12** is formed using a shell molding technique, such as pressure bladder or injection molding. In step **20**, a tunnel **22** is formed in or on the shell at the same time as the shell is formed. Alternatively, the tunnel **22** may be formed in a separate step that occurs before or after the molding of the shell. For example, it may be a tubular element or open-sided element that forms a tunnel when mated to the surface of a shell. If the element is formed separately from the shell, it may be bonded to the shell by any number of known bonding means. For example, the bonding means may be a co-molding process where the tunnel is preformed placed in the composite lay-up. A pre-formed tunnel structure, formed as a composite or injection molded structure, for example, may also be bonded to the shell by chemical adhesives, fusion, such as welding, or taping (e.g., high strength, double-sided tape). In step **30**, an impact-absorbing liner **32** is formed in the shell. Hereafter a tunnel that is co-molded to the shell or chemically bonded or otherwise fused to the shell may be referred to as being integral to the shell or forming a unitary structure with the shell. As used herein "tunnel" means a pipe, pipe-like, tubular, or tube-like element of any uniform or varying cross-sectional configuration or configurations capable of conveying a stream of fluid, such as air, from one opening in a tunnel structure to another spaced apart opening, even if there is some loss of fluid along the path. For example, a tube having some perforations, slits, or other openness in its wall would still be within the definition of "tunnel" if a substantial stream of fluid could still be transported from one end to another. The following describes in more detail the production of a helmet according to the foregoing steps.

Fig. **2** shows an inflatable bladder **112** that is the male component of a male-female mold. The bladder usually represents the shape of a finished helmet shell and composite material is laid over it in forming the shell. While a full helmet shell is represented in Fig. **2**, the inventive subject matter contemplates bladders that represent only portions of a helmet, which may then be used to form a multi-piece helmet. For example, an upper shell and chin piece components may be formed in separate processes and combined together to form a finished helmet. Similarly, while a full-face helmet is shown, helmet shells that provide less

than full face coverage are within the scope of the inventive subject matter. The bladder **112** may be formed of rubber or other inflatable materials known as suitable for pressure bladder molding. As already noted, the pressure bladder is a male component of male-female pressure bladder molding tooling. The female component is a cavity that has a complementary shape to that of the finished helmet shell and is sized to receive the inflatable bladder plus the laid-up composite material that ultimately forms the helmet shell.

The inventive subject matter also contemplates that the pressure bladder molding may invert the roles of the female and male molds. In other words, the inflatable bladder shown in Fig. **2** could instead be a male core mold onto which a composite lay-up is placed, and the female mold could include an inflatable material that inflates to press the lay-up against the core mold, and in combination with heat, cures and sets the lay-up in to the final shape of the shell. The core mold could be made collapsible so that it can be removed from the cavity of the shell. The making of collapsible molds is well-known in the art. They can, for example, be based on two or more metal pieces that form a unit during molding but which can be separated into individual pieces (or collapsed one within another) for insertion into or for removal from spaces or openings that are smaller than the assembled unit. The assembly of pieces comprising the core may be manipulated by hand or pneumatics, for instance.

Shells made in whole or part of injection molded polymer materials are also contemplated by the inventive subject matter. Tunnels may be formed in injection molded shells by providing a tubular form in the mold so that the injected shell material forms a tunnel around the form that is integral to the shell. The tunnel may also be formed using a composite lay-up molding in a relief, as described above, or pre-formed injection molded tubular structure, for example. Shell material is then injected over the tubular composite lay-up or structure to form an integral shell-tunnel structure. Another, alternative is to form the injection molded shell and tunnel in separate steps and then bond the two together, as described above.

A significant amount of detail can be molded into a product using a tubular bladder pressure technique. US Patent Publication No. **20040188882** is representative of the technology of molding tubular members from composite materials. Typically, the tubular bladder is a thin, tube-shaped pressure-resistant nylon air bladder. Composite material is

loosely laid over the tube-shaped bladder. A support structure may also be provided in the tube to help support the piece that is removed from the bladder prior to molding. The piece is placed into a mold, and the mold is then closed leaving both ends of the tube bladder outside the mold. One end is clamped tight, while the other end is attached to a pressurized air source. The mold is heated, the bladder inflated, and the composite material is heated and pushed into the mold by the inflated bladder. The resin is activated and begins to cure, and the piece is finished. The whole process typically takes approximately **20** minutes. A novel and advantageous application of the technique not previously recognized or suggested is as follows.

Fig. **3** represents an exterior section **112**A of the pressure bladder of Fig. **2**. It shows details of a relief **122** for creating a tunnel **22** in the shell. In this example, the tunnel will protrude from the surface of the shell in a forehead area of the shell. However, the tunnel may also be formed above or below the general surface of the shell and have an open end at or through the surface. The tunnel may be formed in any forward, side or rear region of the shell. It may also be formed off the main shell in a chin guard. In some applications the tunnel is located so that it intakes air. In a typical application, the air is forced into a tunnel by virtue of the motion of a wearer. Additionally, the tunnel may be located at a rear portion of the shell to exhaust air from the helmet. Such an exhaust tunnel may be directly or indirectly coupled to a tunnel on a forward portion of a shell. It is also contemplated that the tunnel may house an electric fan unit that directs air into or out of the helmet. A power source for the fan could be a battery or even a solar power cell molded or otherwise integrated into the surface of the outer shell. Tunnels according to the inventive subject matter may also be associated with mechanical features that allow for control of air flow, such as adjustable shutters or other flow restriction means. There may also be connectors to the tunnel that extend the tunnel to inner or outer parts of the shell or provide an aesthetic look at vent openings in the outer or inner surface of a helmet.

For ease of production, the tunnel for a composite outer shell preferably is formed using the same or similar composite materials used to form the shell, and, like the shell, is rigid. The tunnel structures may have varying lengths. In certain embodiments the opening of the tunnel is disposed on a frontal portion of a helmet where there is most wind exposure

and leads to an interior portion of the helmet towards the middle of the head at the top or sides, where ventilation may be most needed. Accordingly, a tunnel structure that is suitable for delivering air from a location of high windage to a location of high cooling demand typically may be from about **1**" to about **12**" inches long, depending on the location in the helmet where air is to be delivered. To ensure good flow through the helmet, the average internal diameter of the tunnel should typically be at least about **1/4** inches. (If the tunnel is not circular in cross section, the average cross-sectional area should be about the same as that of a circle with the foregoing diameter.) Fig. **4** represents one or more layers of a moldable material **24** for forming an inner layer of the tunnel **22** laid into relief **122**. The relief defines the shape of the tunnel to be formed in the shell **12**. A suitable moldable tunnel material **24** is a composite material. The composite may be formed using a "prepreg" composite material. Prepreg composite materials are typically mats, continuous fibers, fabrics, nonwoven materials or roving materials that are pre-impregnated with a thermoset or thermoplastic organic resin matrices that is partially cured and ready for molding. Alternatively, the tunnel, as well as the outer shell, may be formed using composites that are not pre-impregnated by a standard wet lay-up technique, which is well known to persons skilled in the art. Part of the outer shell material may also be laid out as well at this time so that it overlaps the tunnel material in the relief **122** and ties it to the general shell structure. Suitable resins may be based on polyester, polyurethane, epoxy, polybutylene, polyamide, or vinyl ester. The resins may be cured via heating and/or exposure to an activating wavelength of light, which usually is in the UV range.

In Fig. **5**, a tubular inflatable bladder **124** is placed into the tunnel relief **122** over the composite materials. The tubular bladder is generally intended to match the shape of a desired tunnel. Although the tunnel that will form in relief **122** will have a generally elongate hollow structure with opposing open ends, the inventive subject matter contemplates that the tunnel may have branches, for example a "Y" shape, that takes air in from a central opening in the outer shell and directs it to two or more other openings venting into the helmet. Further, any given shell may have a plurality of tunnels at desired locations. The size and shape of the tunnels, and how many and where they are located around a shell,

are matters of design choice, depending on desired air flow, ventilation zones, and/or aesthetic effects, for example.

Fig. **6** represents the main outer shell prepreg composite material **14** placed around the air bladder **112** and over the tubular bladder **124** in relief **122**. This forms the outer shell structure **12**. It will be appreciated by persons skilled in the art that the composite material **14** is a lay-up that can be based on any number of layers of composite materials and any kind of composite. Motorcycle helmets formed with composite shells typically have two to ten layers of composite materials, the layering being greater where more protection is needed. For example, a chin piece may have only **2** layers, while a side of the helmet may have **10** layers. One or more of carbon fiber, aramid fiber (e.g., Kevlar®), fiberglass, polycarbonate, and ABS composite or injection molded polymer layers may be used in forming a shell. A typical composite or polymer shell is from about **0.08** inches to **0.20** inches thick and the thickness may vary according to where protection is most needed. The composites may have unidirectional or bidirectional fibers. The fibers in a given layer may be angled relative to those in an adjacent layer to impart strength. It is well within the person skilled in the art to determine the appropriate selection and arrangement of composite materials and layering for helmet applications, so further detail is not provided herein. Optionally, strips of honeycomb material and/or other types of structural material (not shown) may be incorporated in the composite lay-up that is disposed on air bladder **112**. Honeycomb and other geometrical structures can provide force attenuation based on their ability to compress or crush under force. These materials can therefore supplement the impact liner to absorb impact forces and are incorporated directly in the shell.

A scrim composite material layer may also be placed on the lay-up (Fig. **8**A) as the outermost layer of the shell. The scrim layer is typically fiberglass that can be sanded for cosmetic finishing. The scrim layer protects underlying layers whose functional integrity could be jeopardized by finishing treatments such as sanding or painting.

Looking further at Fig. **6**, tubular bladder **124** has a first end **124**A that is closed and a second end **124**B that is open. Open end **124**B can be coupled to a pressure source for pressurizing the tubular bladder. For this purpose, second end **124**B extends out and away

from the surface **122** of the shell composite **122**. Any metal or plastic anchors (such as visor screw bosses or chin-strap hangers) may be inserted into the composite lay up at this time.

Looking at Figs. **7-13**, a mold assembly and section of a molded component are shown. The female mold **114** is typically a tooled metal apparatus of one or more pieces. In this case the mold is formed in two halves **114**A and **114**B that together form a cavity that receives the inflatable bladder and laid-up composite materials. In addition to defining the outer shell's shape, the female mold is adapted to provide heat to the composite materials **14**, **24** laid over the pressure bladder to activate resins and cause curing or setting of the shell materials into a finished shape. To this effect, composite lay-up and bladders are placed into the female halves **114**A and **114**B (Figs. **7**B, **8**B, and **9**). One end **112**A of the tunnel bladder may be sealed off at this point, and the other end **112**B may be attached to a pressurized air or other fluid source. The tool halves **114**A and **114**B close, and the top **115** is sealed (Fig. **7**B). The tunnel bladder **124** is not compressed by the mold halves and has room to inflate. The composite material is heated up, becomes pliable, and the composite's resin is activated. Bladders **112**, **124** are simultaneously inflated. The pressure from the bladder **112** pushes the composite material **14** into the tool and shape of the helmet. The pressure from the tunnel bladder **124** forms the tunnel in the composite **24** and keeps the pressure from the main bladder from collapsing the tunnel. Pressure is relieved, and the shell **12** is allowed to sit in the tool while the resin in the composite material sets and starts to cure. Once the shell is stable enough to remove (typically about **20** minutes), it is removed from the mold (Fig. **16**A). The inflatable bladder **112** is removed. The air tunnel bladder **124** is pulled out and removed (or it might be trimmed to the vent opening). The shell **12** is trimmed of the excess material and cleaned up (Fig **16**B). The eye port and head opening areas are trimmed to size. Any screw holes may be drilled in. Internal vent holes in the air tunnels are not yet formed, but may be according to the process described below. Figs. **11**A and **11**B, respectively show top and bottom views of a section of shell **12** with a tunnel **22** formed therein. As can be seen in Figs. **11-12**, the tunnel is a hollow tubular structure with opposing, open ends.

As used herein, "shell" is intended to encompass an untrimmed shell, a completed shell, or a partial shell that is assembled with other shell components. The term "impact liner" is intended to encompass analogous products.

After the shell is formed, and any trimming is done, it is ready for the addition of the impact liner **32**. As previously noted, the impact liner is a crushable or otherwise compressible material for absorbing the force of impacts. The impact liner material may generally be any compressible, impact attenuating polymer material that is moldable and can attenuate forces sufficiently to meet common safety testing standards, such as those promulgated by the DOT and Snell Foundation. Preferably, such materials are light weight and serve other objectives noted in the Background section above. Expanded polystyrene (EPS) or polypropylene (EPP) are typically used for motorcycle helmets. Other expandable polymers that may be suitable include expanded polyurethane (EPU), polyethylene, polybutylene, polyvinyl chloride or polymethacrylamide. Co-polymers of any of the foregoing polymers, and similar polymers and co-polymers, may also be suitable as moldable, compressible, impact attenuating polymer materials. The foam may be expanded to a density typically in the range of from about **25-120**kg/m^3. Ultimately, the density is determined by the desired amounts of shock attenuation and helmet purpose.

EPS, as a material of choice, is used hereinafter as a representative liner material, but persons skilled in the art will appreciate how other impact liner materials may be directly formed and bonded to a motorcycle helmet shell from the teachings herein.

The direct molding of expandable polystyrene (EPS) energy-absorbing bead or other impact liner material into a shell is known in the manufacture of high-end bicycle helmets, but is believed never to have been used or suggested for manufacturing motorcycle helmets given significant differences between motorcycle helmet shells and bicycle helmet shells. US Patent No. **5,298,208** is a representative patent which discloses in-molding for a protective helmet that may be used in bicycling and some other sports.

The in-molding technique entails placing and fixing a pre-formed outer shell (a thin layer of thermoformed ABS or PC sheet for bicycle helmets) into an EPS mold. The tool is closed and the EPS is injected into the mold where it chemically bonds to the outer shell, creating a one-piece shell assembly. In-molding creates a very strong and lightweight shell.

The inventive subject matter herein unexpectedly recognizes that despite significant differences between the nature of a motorcycle helmet outer shell (e.g., high impact resistance and fuller head and face coverage) and a bicycle helmet outer shell, in-molding for motorcycle helmets yields important advantages not previously achieved.

Referring to Figs. **12-15**B, the newly formed and trimmed shell **12** is placed into the female cavity (analogous to the female mold of Fig. **7**A) of an impact liner male-female mold. In actuality, the shell's interior may be considered the female portion of the mold, and the cavity means to secure and seal the shell for molding. After the shell **12** is placed in the female mold the other side closes around. The head opening or bottom of the helmet is left open. Alternatively, the shell may be fitted into one female bowl-like mold, or might be fixtured to a vacuum shell, or otherwise setup using techniques known to persons skilled in the art.

To help impact liner material to better bond to a shell, it may be advantageous to roughen or chemically prep the inner shell, using techniques known to persons skilled in the art.

A collapsible male component or inner core **214** of the mold is inserted into the head opening of the shell **12**. (The collapsible core is as earlier described in connection with the molding of the shell.). A preferred collapsible core has a central piece and adjacent side pieces so that removal of the central piece first facilitates removal of the adjacent pieces. In the Figures, mold core **214**, is shown as an isolated rectangular section of the full core that would be rounded to complement the interior of shell **12** and defines the shape and features of the impact liner. The edges (not shown) of core **214** come into direct contact with the inner surface of the outer composite shell, forming a seal between the shell and the tool. This will create a neat junction between the EPS and the shell, and prevents any EPS from bleeding over and blowing out of the shell. After the core portion **214** of the impact liner mold is placed into the interior of the shell, a gap is generally left between it and the shell for infill of the impact liner material during the molding process. The core **214** may be configured and spaced from the shell so that the resulting liner has a uniformly thick surface, a surface of varying thickness corresponding to shell regions providing different levels of protection, structural features, such as venting channels, and/or collapsible force attenuation

structures. Typically, an impact liner has a thickness of from about **25** millimeters to about **40** millimeters. The impact absorbing properties of the impact layer also depend on the density of the foam. International Publication No. WO **2005/000059** also discloses details on molding shells and impact liners.

Impact liners according the inventive subject matter may also have zones or layers, or both, of (**1**) homogenous materials of different densities, and/or (**2**) different materials that are co-molded or assembled together. The zones or layers may be formed simultaneously in an injection molding process using molding tools with multiple injection channels or injection heads or vacuum controls for direction of materials to separate layers or zones. Alternatively, individual zones or layers could be formed in sequential molding processes. For example, a first mold core could include a male portion representing the crown portion of a helmet. A first density of EPS, for example, is injected into the mold assembly that fills the shell with foam everywhere but the crown. The mold is collapsed and a second core is assembled where the mold core has a female portion corresponding to the crown. A second injection of different density EPS customizes the impact resistance of the crown region to desired specifications.

Still further a layer or zone could be preformed and bonded (e.g., taped or glued) into a place in a shell and other layers or zones formed around to create an integral impact liner structure. Where materials are injected molded into contact with a first layer or zone that is co-molded or bonded to a shell, chemical bonds may form at the contacting surfaces, creating a monolithic molded impact liner (or portion thereof).

The thickness and structural features also depend on current safety standards, such as are issued by the Snell Memorial Foundation (www.smf.org), and the US Department of Transportation (DOT). Motorcycle and other motor sport helmets can be distinguished from other kinds of protective helmets, such as bicycle helmets, based on their ability to meet such safety standards. As used herein, a motorcycle helmet (including motorcycle helmets for moto-cross) are those hard shell-impact liner helmet constructions that are capable of passing DOT Standards promulgated under the Code of Federal Regulations **49** CFR § **571.218** (as existing February, **2006**), which is reproduced in Appendix A attached hereto below, and also available, for example through websites such as http://www.gpoaccess.gov/.

Although the term "motorcycle helmet" is used in relation to the DOT standard, it is not intended to limit the purpose of a helmet. Protective helmets for other activities and sports may be designed to comply with the foregoing testing standard and any such helmets may also be considered a motorcycle helmet that is within the scope of the inventive subject matter disclosed herein.

One or more venting channels **34** and **36** that are coupled to one or more tunnels **24** are particularly within the scope of the inventive subject matter disclosed herein and are described in more detail below. In the context of the subject matter herein, "coupled" and its variants means that there can be fluid communication from one item to the other. For example, air from the tunnel is vented to the channel. Male parts **234** on mold core **214** correspond to vent channels **34**. These parts seal against the shell's inner composite air tunnel **22**. When the mold core is removed, channels are left where the male parts **134** created voids. The mold may also be configured to couple the vent channels **34**, which are directly coupled to a tunnel **22**, to one or more other channels **36**. Channels **36** are intended to run across a wearer's head and increase the surface area of ventilation. Accordingly, a tunnel **22** directs air through at least one channel **34**. The channel **34** may in turn direct air to one or more other channels **36**.

Any EPS plastic inserts may be added to the tool at this time (for example, comfort liner snaps, visor pivots, etc.). EPS beads are injected into the shell and tool at the proper pressure and heat. The beads chemically adhere to the inner surface of the outer composite shell (Fig.**14**). Proper time is allowed for the EPS to inflate and cure.

The inner collapsible core is removed, the middle part pulls out slightly, the two sides slide closer together, and then the whole core lifts out of the head opening. The finished shell (Figs. **15**A-B), now co-molded with the impact liner, is removed from the tool.

The completed helmet shell may be carefully weighed to discover any air voids in the EPS that might not be visible under the outer shell. Any excess EPS flash is trimmed.

The helmet may be fixtured to a trimming mandril and all final trimming is performed. The vent holes for the air tunnels on the inside of the helmet may be trimmed out to provide coupling to channels **34**. Any final cleaning and trimming is done on the shell.

EPS shell may be masked to prevent paint and clear-coat from contaminating it. The mask can be re-usable.

The shell may then go through normal assembly procedures, such as application of primer, sanding, and painting. Graphic decals may be applied over a base coat and clear coat applied over that. EPS interior fabric may be glued on. The chin bar may be attached if not already co-molded. Base/eyeport trims may be glued on. Extraneous items are attached, such as mouthpiece, vents, comfort liners, cheekpads, visors, straps, etc.

The helmet tunnel venting system can also be tuned to achieve Venturi effects by selectively locating constrictions in tunnels that will provide low pressure zones that will pull air from across a wearer's head. To accomplish this, the low pressure zone of a tunnel may be coupled via a tube or similar structure to the cavity of a helmet so that air is pulled through the cavity and across a user's head and into the low pressure zone of the constriction. The low pressure portion of the tunnel may then vent air out of the helmet.

While the inventive subject matter disclosed may be used to construct all types of protective helmets for all types of activities, particularly those that satisfy the DOT standard identified above, it may also be used to construct other molded structures. For example, elbow, knee, thigh, shin, hand, or foot guards. Aside from wearable protective equipment, it may also be used to create ventilated panel-like structures that are impact resistant for use in motor- or human-powered vehicles.

As used herein, the term "comprise" and its variants, in keeping with longstanding patent parlance, is an open-ended term akin to "include".

Persons skilled in the art will recognize that many modifications and variations are possible in the details, materials, and arrangements of the parts and actions which have been described and illustrated in order to explain the nature of this invention and that such modifications and variations do not depart from the spirit and scope of the teachings and claims contained therein.

APPENDIX A

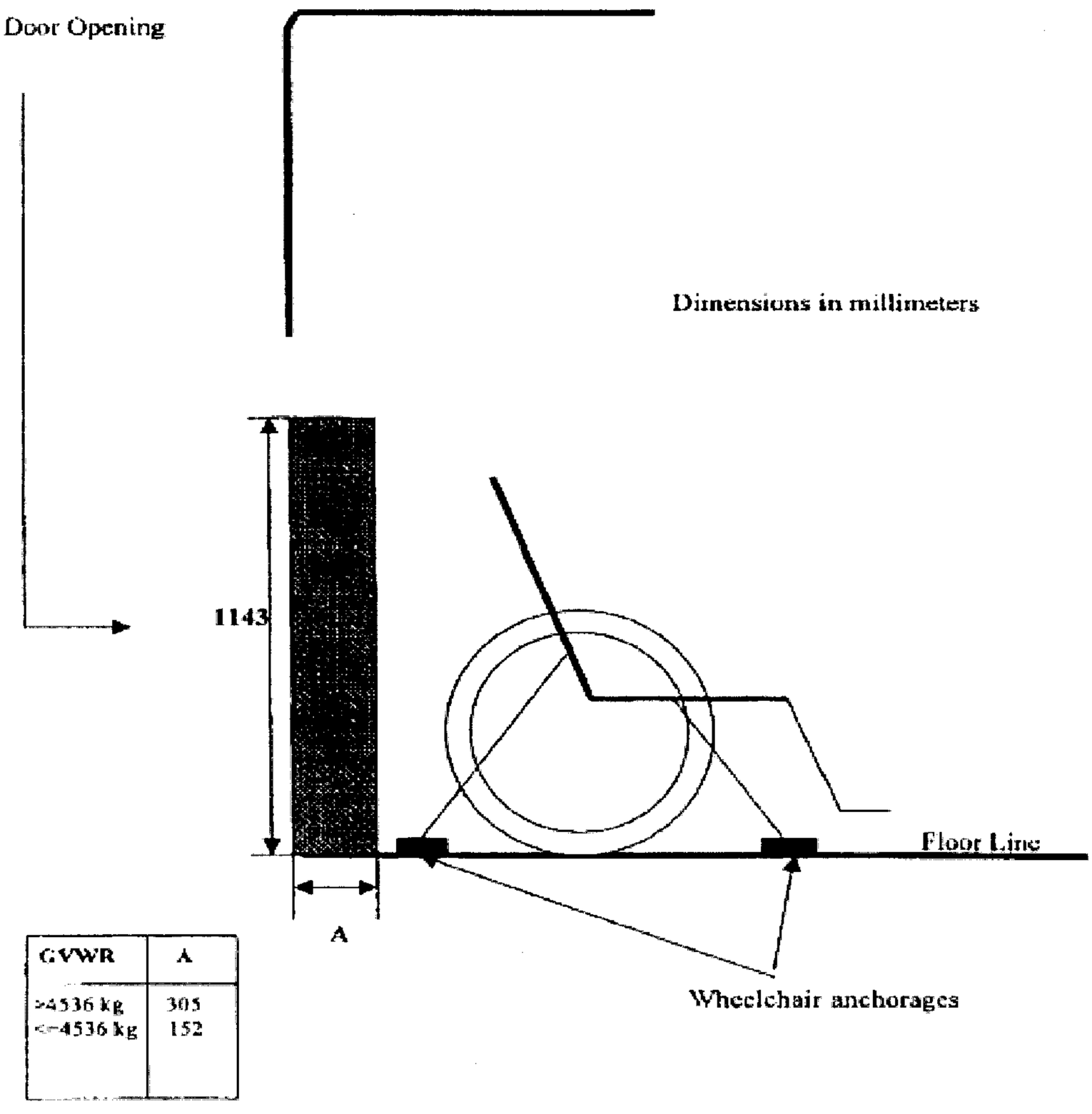


Figure 6 D. Rear Door Emergency Exit - No Wheelchair Anchorages within the shaded region

§ 571.218 Standard No. 218; Motorcycle helmets.

S1. *Scope.* This standard establishes minimum performance requirements for helmets designed for use by motorcyclists and other motor vehicle users.

S2. *Purpose.* The purpose of this standard is to reduce deaths and injuries to motorcyclists and other motor vehicle users resulting from head impacts.

S3. *Application.* This standard applies to all helmets designed for use by motorcyclists and other motor vehicle users.

S4. *Definitions.*

Basic plane means a plane through the centers of the right and left external ear openings and the lower edge of

APPENDIX A

the eye sockets (Figure 1) of a reference headform (Figure 2) or test headform.

Helmet positioning index means the distance in inches, as specified by the manufacturer, from the lowest point of the brow opening at the lateral midpoint of the helmet to the basic plane of a reference headform, when the helmet is firmly and properly positioned on the reference headform.

Midsagittal plane means a longitudinal plane through the apex of a reference headform or test headform that is perpendicular to the basic plane (Figure 3).

Reference headform means a measuring device contoured to the dimensions of one of the three headforms described in Table 2 and Figures 5 through 8 with surface markings indicating the locations of the basic, midsagittal, and reference planes, and the centers of the external ear openings.

Reference plane means a plane above and parallel to the basic plane on a reference headform or test headform (Figure 2) at the distance indicated in Table 2.

Retention system means the complete assembly by which the helmet is retained in position on the head during use.

Test headform means a test device contoured to the dimensions of one of the three headforms described in Table 2 and Figures 5 through 8 with surface markings indicating the locations of the basic, mid-sagittal, and reference planes.

S5. *Requirements.* Each helmet shall meet the requirements of S5.1, S5.2, and S5.3 when subjected to any conditioning procedure specified in S6.4, and tested in accordance with S7.1, S7.2, and S7.3.

S5.1 *Impact attenuation.* When an impact attenuation test is conducted in accordance with S7.1, all of the following requirements shall be met:

(a) Peak accelerations shall not exceed 400g;

(b) Accelerations in excess of 200g shall not exceed a cumulative duration of 2.0 milliseconds; and

(c) Accelerations in excess of 150g shall not exceed a cumulative duration of 4.0 milliseconds.

S5.2 *Penetration.* When a penetration test is conducted in accordance with S7.2, the striker shall not contact the surface of the test headform.

S5.3 *Retention system.*

S5.3.1 When tested in accordance with S7.3:

(a) The retention system or its components shall attain the loads specified without separation; and

(b) The adjustable portion of the retention system test device shall not move more than 1 inch (2.5 cm) measured between preliminary and test load positions.

S5.3.2 Where the retention system consists of components which can be independently fastened without securing the complete assembly, each such component shall independently meet the requirements of S5.3.1.

S5.4 *Configuration.* Each helmet shall have a protective surface of continuous contour at all points on or above the test line described in S6.2.3. The helmet shall provide peripheral vision clearance of at least 105° to each side of the mid-sagittal plane, when the helmet is adjusted as specified in S6.3. The vertex of these angles, shown in Figure 3, shall be at the point on the anterior surface of the reference headform at the intersection of the mid-sagittal and basic planes. The brow opening of the helmet shall be at least 1 inch (2.5 cm) above all points in the basic plane that are within the angles of peripheral vision (see Figure 3).

S5.5 *Projections.* A helmet shall not have any rigid projections inside its shell. Rigid projections outside any helmet's shell shall be limited to those required for operation of essential accessories, and shall not protrude more than 0.20 inch (5 mm).

S5.6 *Labeling.*

S5.6.1 Each helmet shall be labeled permanently and legibly, in a manner such that the label(s) can be read easily without removing padding or any other permanent part, with the following:

(a) Manufacturer's name or identification.

(b) Precise model designation.

(c) Size.

(d) Month and year of manufacture. This may be spelled out (for example,

APPENDIX A

June 1988), or expressed in numerals (for example, 6/88).

(e) The symbol DOT, constituting the manufacturer's certification that the helmet conforms to the applicable Federal motor vehicle safety standards. This symbol shall appear on the outer surface, in a color that contrasts with the background, in letters at least 3/8 inch (1 cm) high, centered laterally with the horizontal centerline of the symbol located a minimum of 1 1/8 inches (2.9 cm) and a maximum of 1 3/8 inches (3.5 cm) from the bottom edge of the posterior portion of the helmet.

(f) Instructions to the purchaser as follows:

(1) "Shell and liner constructed of (identify type(s) of materials).

(2) "Helmet can be seriously damaged by some common substances without damage being visible to the user. Apply only the following: (Recommended cleaning agents, paints, adhesives, etc., as appropriate).

(3) "Make no modifications. Fasten helmet securely. If helmet experiences a severe blow, return it to the manufacturer for inspection, or destroy it and replace it."

(4) Any additional relevant safety information should be applied at the time of purchase by means of an attached tag, brochure, or other suitable means.

S5.7 *Helmet positioning index.* Each manufacturer of helmets shall establish a positioning index for each helmet he manufactures. This index shall be furnished immediately to any person who requests the information, with respect to a helmet identified by manufacturer, model designation, and size.

S6. *Preliminary test procedures.* Before subjecting a helmet to the testing sequence specified in S7., prepare it according to the procedures in S6.1, S6.2, and S6.3.

S6.1 *Selection of appropriate headform.*

S6.1.1 A helmet with a manufacturer's designated discrete size or size range which does not exceed 6¾ (European size: 54) is tested on the small headform. A helmet with a manufacturer's designated discrete size or size range which exceeds 6¾, but does not exceed 7½ (European size: 60) is tested on the medium headform. A helmet with a manufacturer's designated discrete size or size range which exceeds 7½ is tested on the large headform.

S6.1.2 A helmet with a manufacturer's designated size range which includes sizes falling into two or all three size ranges described in S6.1.1 is tested on each headform specified for each size range.

S6.2 *Reference marking.*

S6.2.1 Use a reference headform that is firmly seated with the basic and reference planes horizontal. Place the complete helmet to be tested on the appropriate reference headform, as specified in S6.1.1 and S6.1.2.

S6.2.2 Apply a 10-pound (4.5 kg) static vertical load through the helmet's apex. Center the helmet laterally and seat it firmly on the reference headform according to its helmet positioning index.

S6.2.3 Maintaining the load and position described in S6.2.2, draw a line (hereinafter referred to as "test line") on the outer surface of the helmet coinciding with portions of the intersection of that service with the following planes, as shown in Figure 2:

(a) A plane 1 inch (2.5 cm) above and parallel to the reference plane in the anterior portion of the reference headform:

(b) A vertical transverse plane 2.5 inches (6.4 cm) behind the point on the anterior surface of the reference headform at the intersection of the mid-sagittal and reference planes;

(c) The reference plane of the reference headform:

(d) A vertical transverse plane 2.5 inches (6.4. cm) behind the center of the external ear opening in a side view; and

(e) A plane 1 inch (2.5 cm) below and parallel to the reference plane in the posterior portion of the reference headform.

S6.3 *Helmet positioning.*

S6.3.1 Before each test, fix the helmet on a test headform in the position that conforms to its helmet positioning index. Secure the helmet so that it does not shift position before impact or before application of force during testing.

S6.3.2 In testing as specified in S7.1 and S7.2, place the retention system in

APPENDIX A

a position such that it does not interfere with free fall, impact or penetration.

S6.4 *Conditioning.*

S6.4.1 Immediately before conducting the testing sequence specified in S7, condition each test helmet in accordance with any one of the following procedures:

(a) *Ambient conditions.* Expose to a temperature of 70 °F(21 °C) and a relative humidity of 50 percent for 12 hours.

(b) *Low temperature.* Expose to a temperature of 14 °F(−10 °C) for 12 hours.

(c) *High temperature.* Expose to a temperature of 122 °F(50 °C) for 12 hours.

(d) *Water immersion.* Immerse in water at a temperature of 77 °F(25 °C) for 12 hours.

S6.4.2 If during testing, as specified in S7.1.3 and S7.2.3, a helmet is returned to the conditioning environment before the time out of that environment exceeds 4 minutes, the helmet is kept in the environment for a minimum of 3 minutes before resumption of testing with that helmet. If the time out of the environment exceeds 4 minutes, the helmet is returned to the environment for a minimum of 3 minutes for each minute or portion of a minute that the helmet remained out of the environment in excess of 4 minutes or for a maximum of 12 hours, whichever is less, before the resumption of testing with that helmet.

S7. *Test conditions.*

S7.1 *Impact attenuation test.*

S7.1.1 Impact attenuation is measured by determining acceleration imparted to an instrumented test headform on which a complete helmet is mounted as specified in S6.3, when it is dropped in guided free fall upon a fixed hemispherical anvil and a fixed flat steel anvil.

S7.1.2 Each helmet is impacted at four sites with two successive identical impacts at each site. Two of these sites are impacted upon a flat steel anvil and two upon a hemispherical steel anvil as specified in S7.1.10 and S7.1.11. The impact sites are at any point on the area above the test line described in paragraph S6.2.3, and separated by a distance not less than one-sixth of the maximum circumference of the helmet in the test area.

S7.1.3 Impact testing at each of the four sites, as specified in S7.1.2, shall start at two minutes, and be completed by four minutes, after removal of the helmet from the conditioning environment.

S7.1.4 (a) The guided free fall drop height for the helmet and test headform combination onto the hemispherical anvil shall be such that the minimum impact speed is 17.1 feet/second (5.2 m/sec). The minimum drop height is 54.5 inches (138.4 cm). The drop height is adjusted upward from the minimum to the extent necessary to compensate for friction losses.

(b) The guided free fall drop height for the helmet and test headform combination onto the flat anvil shall be such that the minimum impact speed is 19.7 ft./sec (6.0 m/sec). The minimum drop height is 72 inches (182.9 cm). The drop height is adjusted upward from the minimum to the extent necessary to compensate for friction losses.

S7.1.5 Test headforms for impact attenuation testing are constructed of magnesium alloy (K–1A), and exhibit no resonant frequencies below 2,000 Hz.

S7.1.6 The monorail drop test system is used for impact attenuation testing.

S7.1.7 The weight of the drop assembly, as specified in Table 1, is the combined weight of the test headform and the supporting assembly for the drop test. The weight of the supporting assembly is not less than 2.0 lbs. and not more than 2.4 lbs. (0.9 to 1.1 kg). The supporting assembly weight for the monorail system is the drop assembly weight minus the combined weight of the test headform, the headform's clamp down ring, and its tie down screws.

S7.1.8 The center of gravity of the test headform is located at the center of the mounting ball on the supporting assembly and lies within a cone with its axis vertical and forming a 10° included angle with the vertex at the point of impact. The center of gravity of the drop assembly lies within the rectangular volume bounded by $x = -0.25$ inch (-0.64 cm), $x = 0.85$ inch (2.16 cm), $y = 0.25$ inch (0.64 cm), and $y = -0.25$ inch (-0.64 cm) with the origin located at the center of gravity of the test headform. The rectangular volume has no boundary along the z-axis. The

APPENDIX A

x-y-z axes are mutually perpendicular and have positive or negative designations in accordance with the right-hand rule (See Figure 5). The origin of the coordinate axes also is located at the center of the mounting ball on the supporting assembly (See Figures 6, 7, and 8). The x-y-z axes of the test headform assembly on a monorail drop test equipment are oriented as follows: From the origin, the x-axis is horizontal with its positive direction going toward and passing through the vertical centerline of the monorail. The positive z-axis is downward. The y-axis also is horizontal and its direction can be decided by the z- and x-axes, using the right-hand rule.

S7.1.9 The acceleration transducer is mounted at the center of gravity of the test headform with the sensitive axis aligned to within 5° of vertical when the test headform assembly is in the impact position. The acceleration data channel complies with SAE Recommended Practice J211 JUN 80, Instrumentation for Impact Tests, requirements for channel class 1,000.

S7.1.10 The flat anvil is constructed of steel with a 5-inch (12.7 cm) minimum diameter impact face, and the hemispherical anvil is constructed of steel with a 1.9 inch (4.8 cm) radius impact face.

S7.1.11 The rigid mount for both of the anvils consists of a solid mass of at least 300 pounds (136.1 kg), the outer surface of which consists of a steel plate with minimum thickness of 1 inch (2.5 cm) and minimum surface area of 1 ft^2 (929 cm^2).

S7.1.12 The drop system restricts side movement during the impact attenuation test so that the sum of the areas bounded by the acceleration-time response curves for both the x- and y-axes (horizontal axes) is less than five percent of the area bounded by the acceleration-time response curve for the vertical axis.

S7.2 *Penetration test.*

S7.2.1 The penetration test is conducted by dropping the penetration test striker in guided free fall, with its axis aligned vertically, onto the outer surface of the complete helmet, when mounted as specified in S6.3, at any point above the test line, described in S6.2.3, except on a fastener or other rigid projection.

S7.2.2 Two penetration blows are applied at least 3 inches (7.6 cm) apart, and at least 3 inches (7.6 cm) from the centers of any impacts applied during the impact attenuation test.

S7.2.3 The application of the two penetration blows, specified in S7.2.2, starts at two minutes and is completed by four minutes, after removal of the helmet from the conditioning environment.

S7.2.4 The height of the guided free fall is 118.1 inches (3 m), as measured from the striker point to the impact point on the outer surface of the test helmet.

S7.2.5 The contactable surface of the penetration test headform is constructed of a metal or metallic alloy having a Brinell hardness number no greater than 55, which will permit ready detection should contact by the striker occur. The surface is refinished if necessary before each penetration test blow to permit detection of contact by the striker.

S7.2.6 The weight of the penetration striker is 6 pounds, 10 ounces (3 kg).

S7.2.7 The point of the striker has an included angle of 60°, a cone height of 1.5 inches (3.8 cm), a tip radius of 0.02 inch (standard 0.5 millimeter radius) and a minimum hardness of 60 Rockwell, C-scale.

S7.2.8 The rigid mount for the penetration test headform is as described in S7.1.11.

S7.3 *Retention system test.*

S7.3.1 The retention system test is conducted by applying a static tensile load to the retention assembly of a complete helmet, which is mounted, as described in S6.3, on a stationary test headform as shown in Figure 4, and by measuring the movement of the adjustable portion of the retention system test device under tension.

S7.3.2 The retention system test device consists of both an adjustable loading mechanism by which a static tensile load is applied to the helmet retention assembly and a means for holding the test headform and helmet stationary. The retention assembly is fastened around two freely moving rollers, both of which have a 0.5 inch (1.3 cm) diameter and a 3-inch (7.6 cm) center-

APPENDIX A

to-center separation, and which are mounted on the adjustable portion of the tensile loading device (Figure 4). The helmet is fixed on the test headform as necessary to ensure that it does not move during the application of the test loads to the retention assembly.

S7.3.3 A 50-pound (22.7 kg) preliminary test load is applied to the retention assembly, normal to the basic plane of the test headform and symmetrical with respect to the center of the retention assembly for 30 seconds, and the maximum distance from the extremity of the adjustable portion of the retention system test device to the apex of the helmet is measured.

S7.3.4 An additional 250-pound (113.4 kg) test load is applied to the retention assembly, in the same manner and at the same location as described in S7.3.3, for 120 seconds, and the maximum distance from the extremity of the adjustable portion of the retention system test device to the apex of the helmet is measured.

APPENDIX TO §571.218

TABLE 1—WEIGHTS FOR IMPACT ATTENUATION TEST DROP ASSEMBLY

Test headform size	Weight [1]—lb(kg)
Small	7.8 (3.5 kg).
Medium	11.0 (5.0 kg).
Large	13.4 (6.1 kg).

[1] Combined weight of instrumented test headform and supporting assembly for drop test.

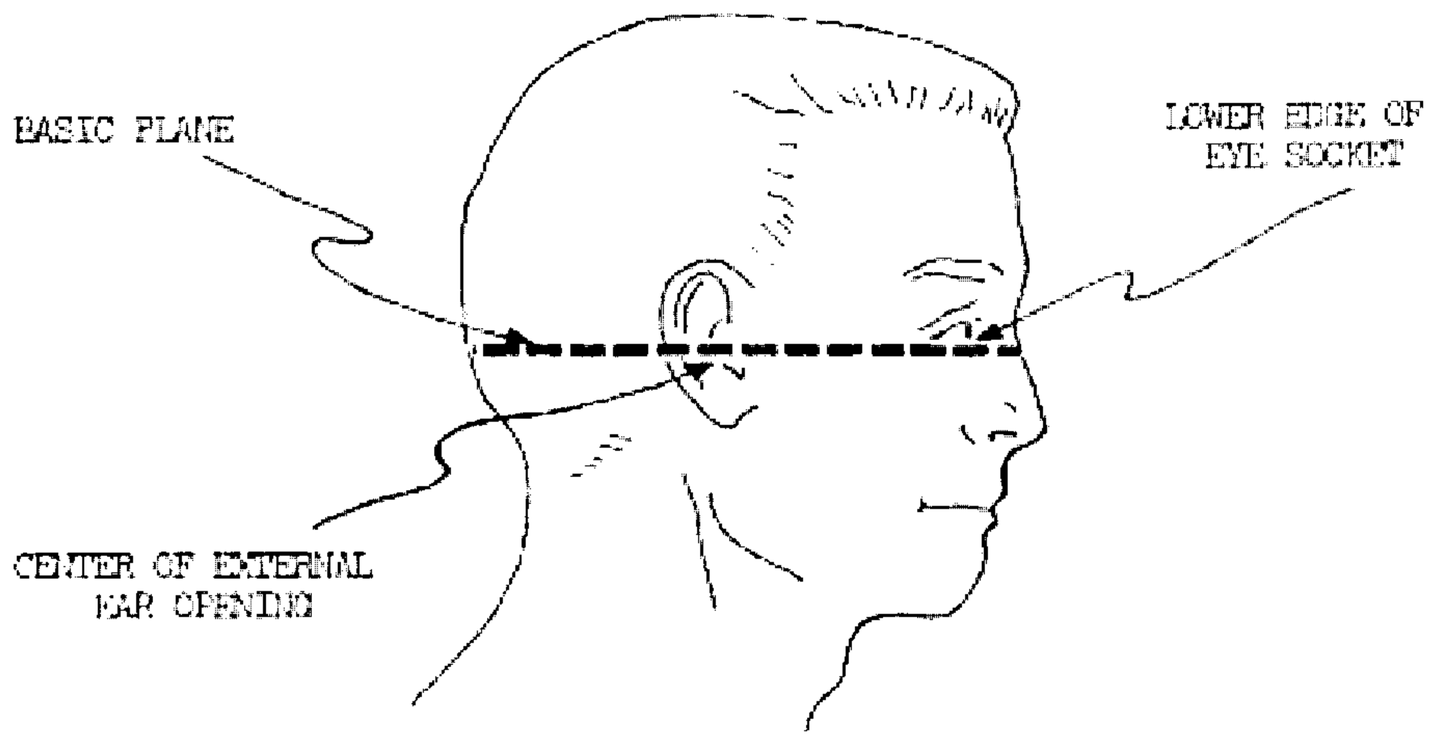


Figure 1

APPENDIX A

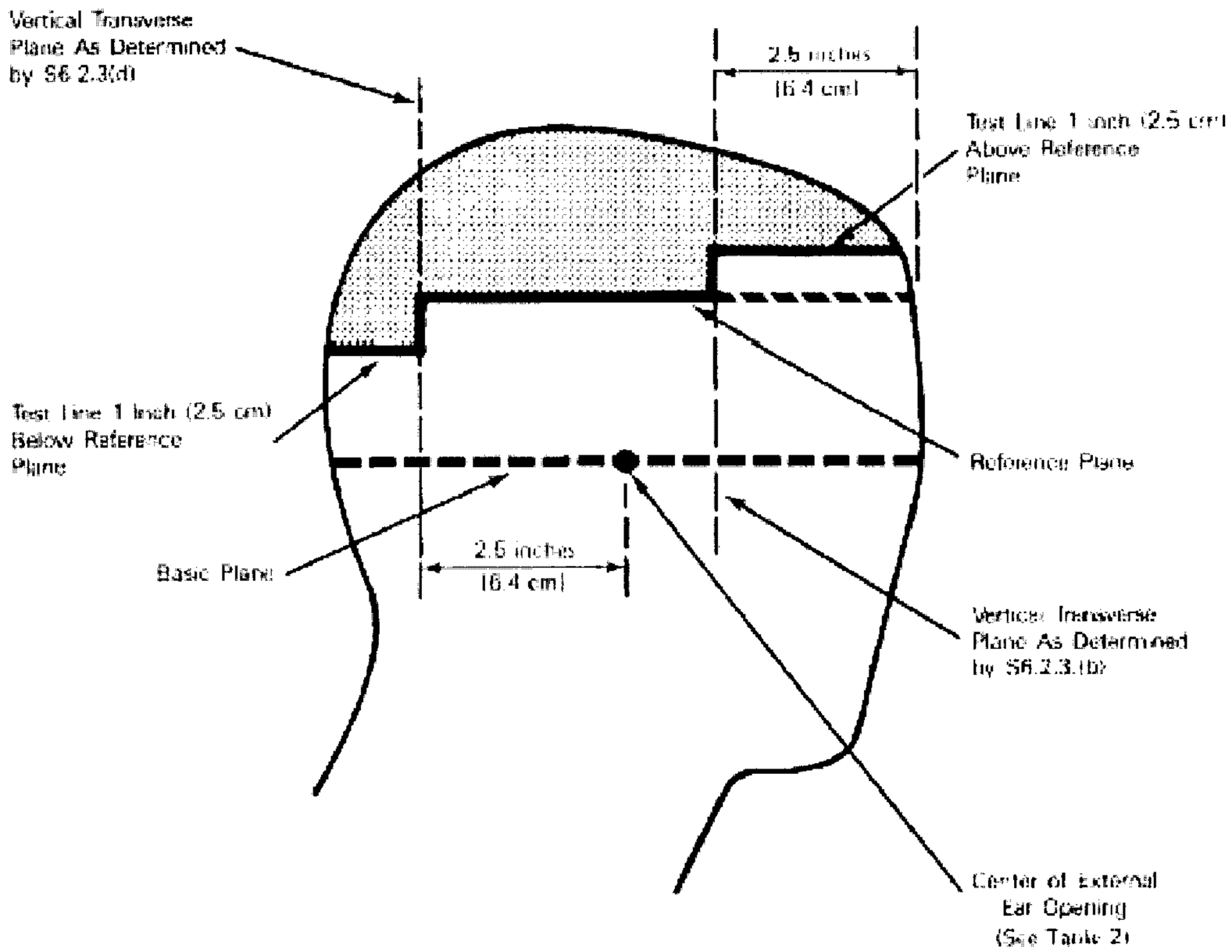


Figure 2

APPENDIX A

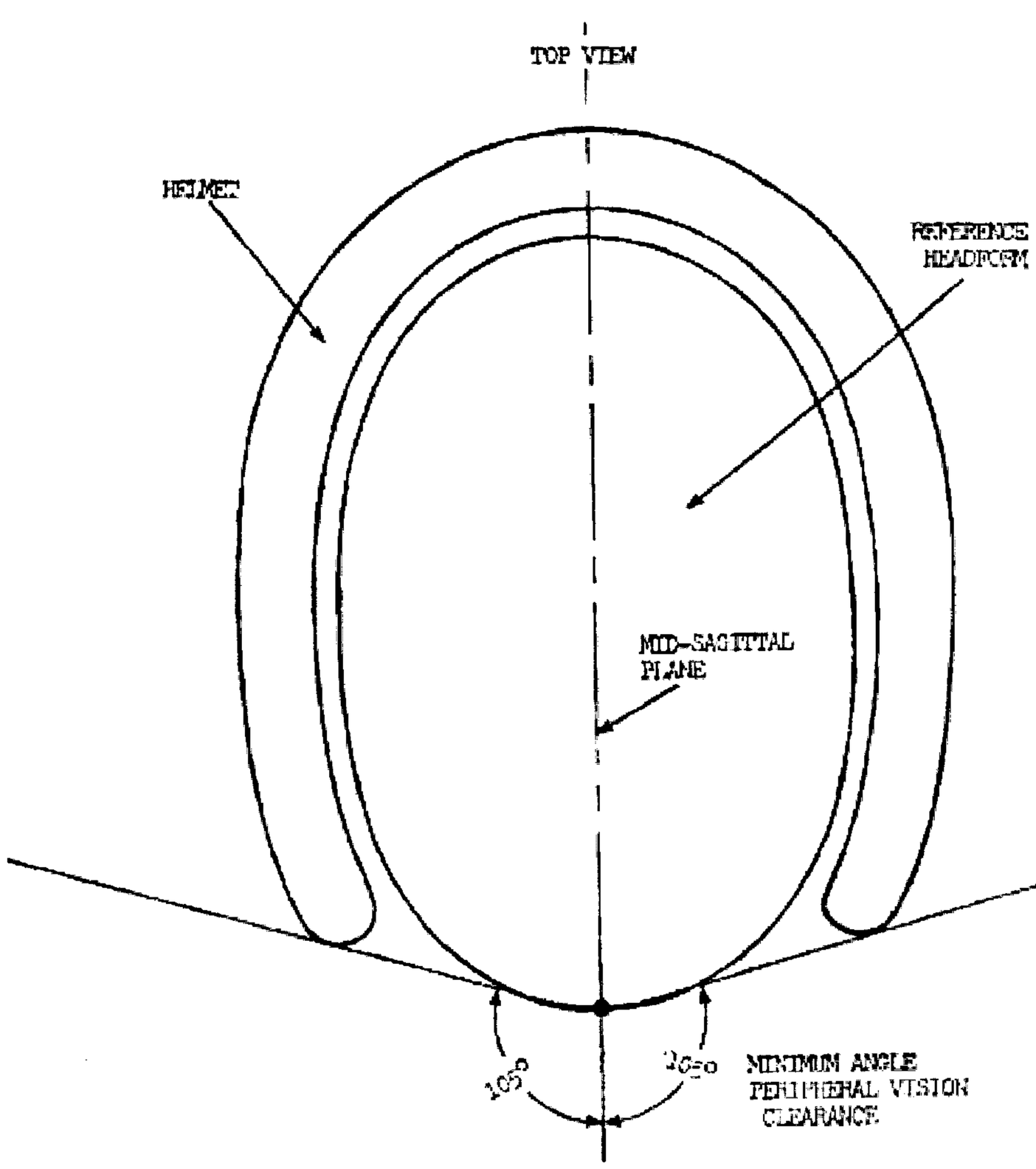
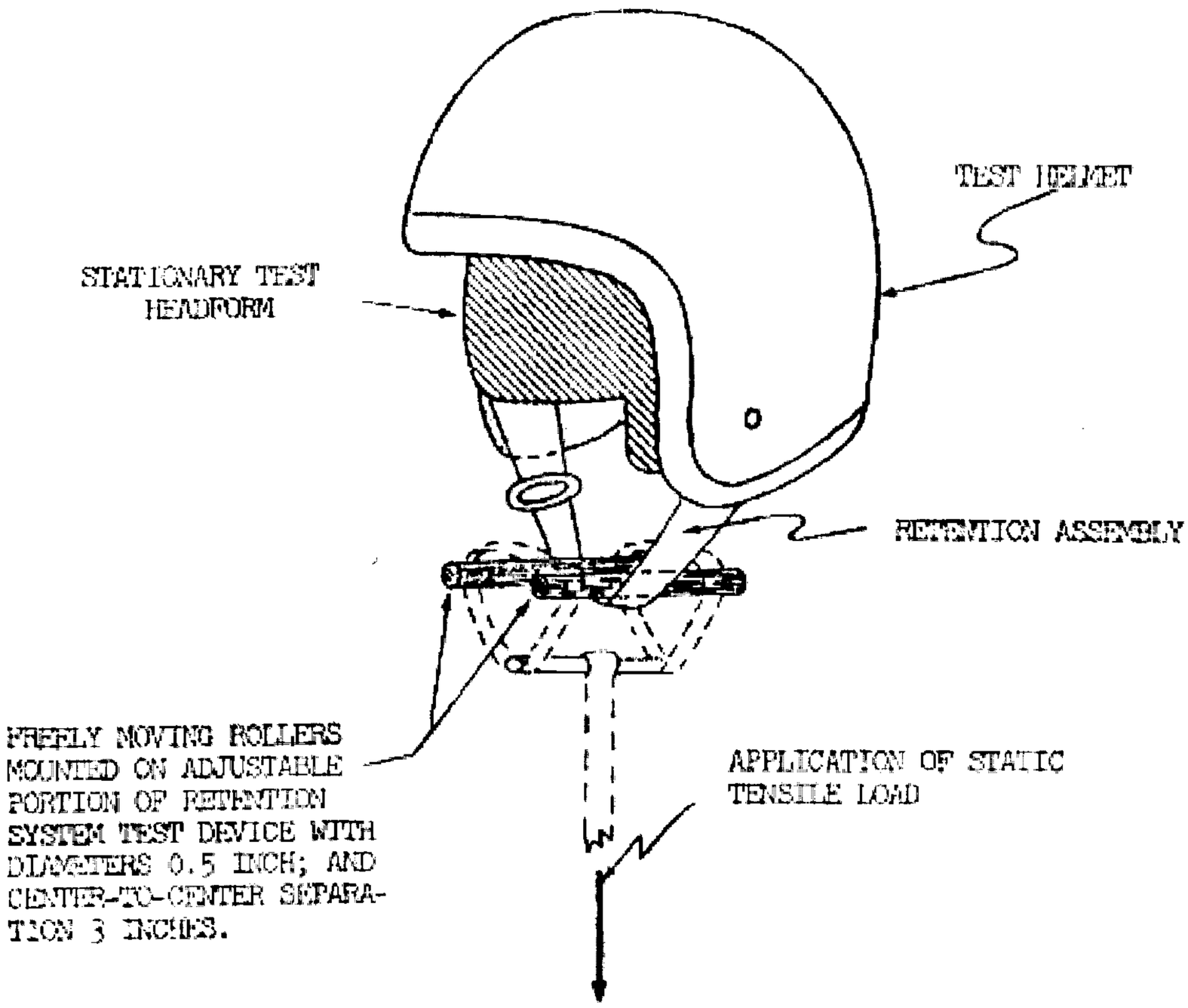


Figure 3

APPENDIX A



RETENTION SYSTEM TEST DEVICE

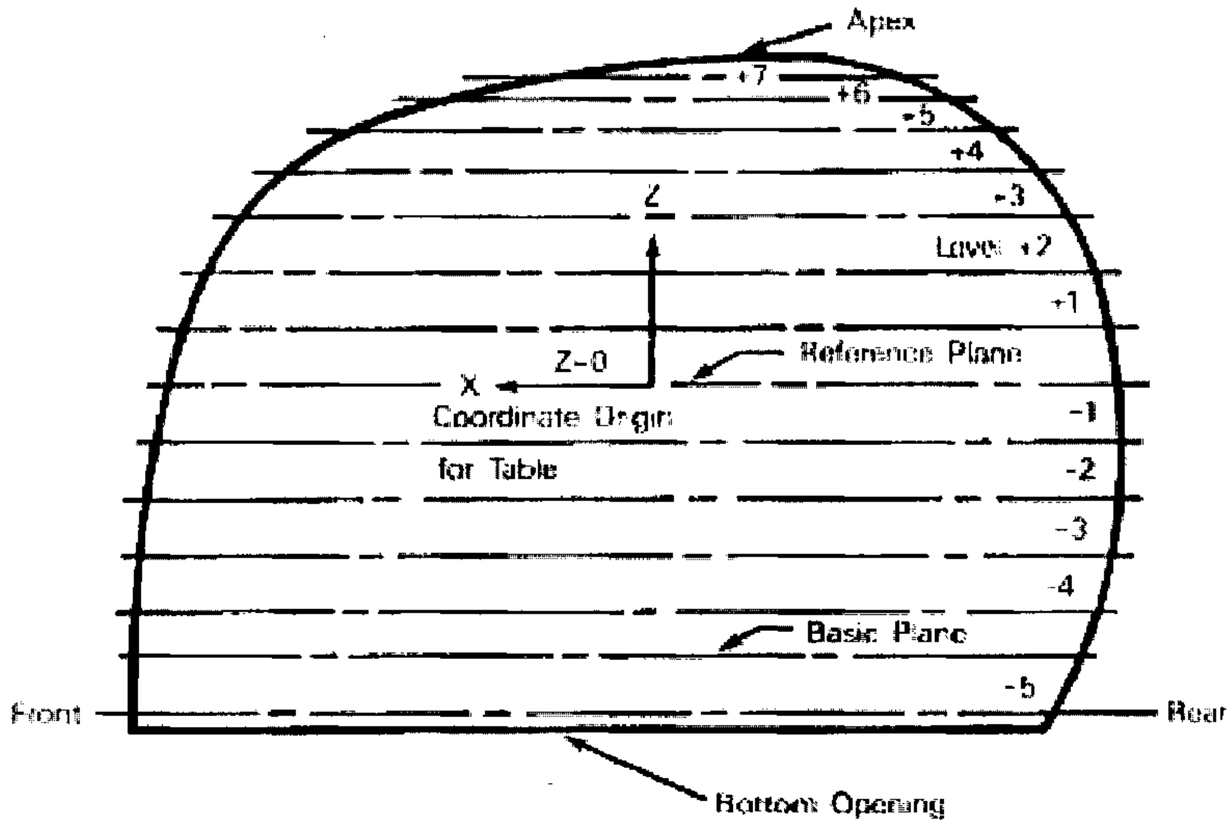
Figure 4

APPENDIX A

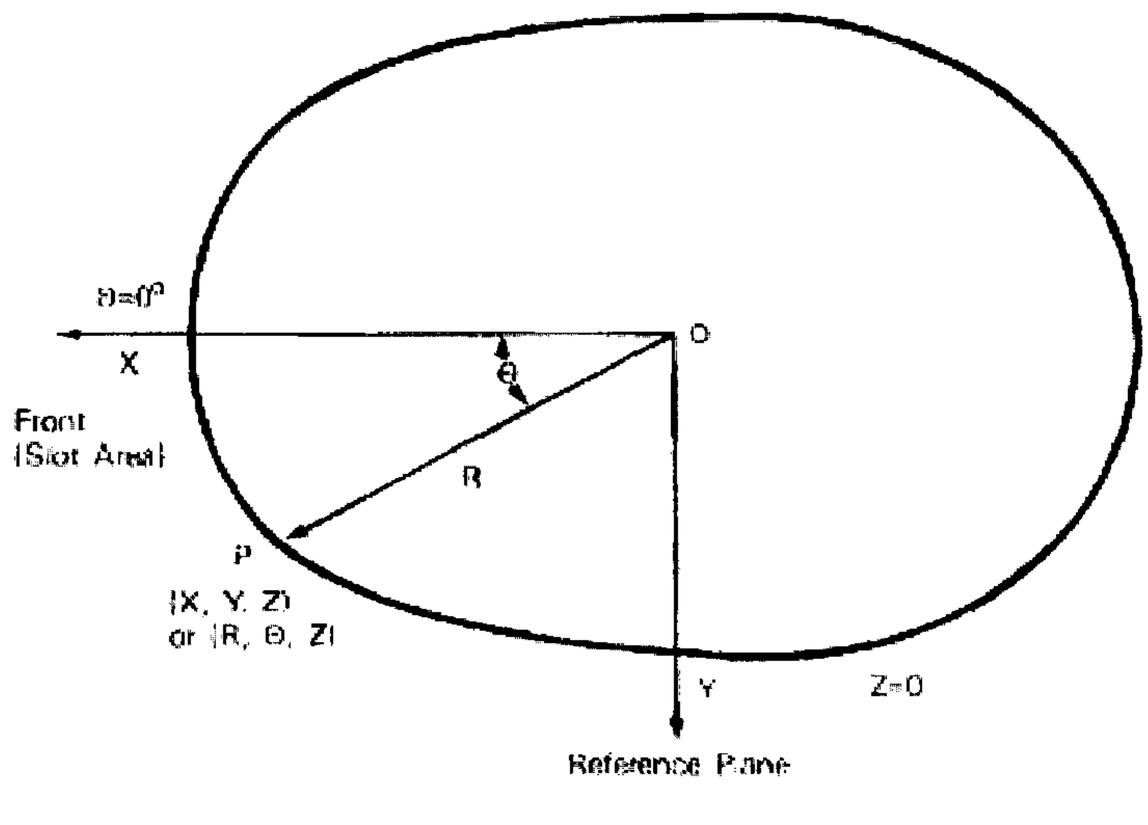
Figure 5

HEADFORM SECTIONS

Mid Sagittal Plane (Symmetrical Plane)



Headform Coordinate Systems
(Right-hand Rule)



APPENDIX A

Table 2

Medium Headform - Exterior Dimensions

Θ	Bottom Opening Z= -3.02			Level-5 Z= 2.900		
	R	X	Y	R	X	Y
0	4.292	4.292	0	4.293	4.293	0
10	4.266	4.201	0.741	4.270	4.205	0.742
20	4.159	3.908	1.423	4.172	3.920	1.427
30	3.967	3.436	1.984	3.961	3.430	1.981
40	3.680	2.804	2.353	3.670	2.811	2.359
50	3.332	2.142	2.553	3.352	2.155	2.568
60	3.039	1.520	2.632	3.067	1.534	2.656
70	2.839	0.971	2.668	2.869	0.981	2.696
80	2.720	0.472	2.679	2.772	0.481	2.730
90	2.675	0	2.675	2.709	0	2.709
100	2.709	-0.469	2.662	2.724	-0.473	2.683
110	2.764	-0.945	2.597	2.794	-0.956	2.626
120	2.868	-1.444	2.501	2.917	-1.469	2.526
130	2.985	-1.919	2.287	3.040	-1.954	2.329
140	3.100	-2.375	1.993	3.175	-2.432	2.041
150	3.175	-2.750	1.588	3.232	-2.799	1.616
160	3.186	-2.994	1.090	3.246	-3.060	1.110
170	3.177	-3.129	0.552	3.237	-3.188	0.562
180	3.187	-3.187	0	3.246	3.246	0

Θ	Basic Plane Z= -2.360			Level-4 Z= -2.000		
	R	X	Y	R	X	Y
0	4.272	4.272	0	4.247	4.247	0
10	4.248	4.184	0.738	4.223	4.159	0.733
20	4.147	3.897	1.418	4.120	3.872	1.409
30	3.961	3.430	1.981	3.940	3.412	1.970
40	3.687	2.824	2.370	3.683	2.821	2.367
50	3.384	2.175	2.592	3.392	2.180	2.598
60	3.111	1.556	2.694	3.132	1.566	2.712
70	2.927	1.001	2.751	2.960	1.012	2.782
80	2.815	0.489	2.772	2.860	0.497	2.817
90	2.779	0	2.779	2.838	0	2.838
100	2.802	-0.487	2.759	2.861	-0.497	2.818
110	2.887	-0.987	2.713	2.958	-1.012	2.780
120	3.019	-1.510	2.615	3.098	-1.549	2.683
130	3.180	-2.044	2.436	3.260	-2.096	2.497
140	3.306	-2.533	2.125	3.405	-2.608	2.189
150	3.396	-2.943	1.699	3.516	-3.045	1.758
160	3.458	-3.250	1.183	3.585	-3.369	1.226
170	3.475	-3.422	0.603	3.612	-3.557	0.627
180	3.472	-3.472	0	3.609	3.609	0

APPENDIX A

Table 2

Medium Headform — Exterior Dimensions (Continued)

	Level -3 Z= -1.500			Level -2 Z= -1.000		
θ	R	X	Y	R	X	Y
0	4.208	4.208	0	4.148	4.148	0
10	4.179	4.116	0.726	4.112	4.050	0.714
20	4.075	3.829	1.394	4.013	3.771	1.373
30	3.902	3.379	1.951	3.844	3.329	1.922
40	3.654	2.799	2.349	3.609	2.765	2.320
50	3.377	2.171	2.587	3.352	2.155	2.568
60	3.094	1.547	2.680	3.137	1.569	2.717
70	2.982	1.020	2.802	2.989	1.022	2.809
80	2.891	0.502	2.847	2.902	0.504	2.858
90	2.876	0	2.876	2.884	0	2.884
100	2.918	-0.507	2.874	2.943	-0.511	2.898
110	3.021	-1.033	2.839	3.052	-1.044	2.868
120	3.170	-1.585	2.745	3.225	-1.613	2.793
130	3.337	-2.145	2.556	3.397	-2.184	2.602
140	3.463	-2.668	2.239	3.536	-2.709	2.273
150	3.604	-3.121	1.802	3.657	-3.167	1.829
160	3.692	-3.460	1.269	3.751	-3.525	1.283
170	3.725	-3.668	0.647	3.807	-3.749	0.661
180	3.741	-3.741	0	3.822	-3.822	0

	Level -1 Z= -0.500			Reference Plane Z=0.0		
θ	R	X	Y	R	X	Y
0	4.067	4.067	0	3.971	3.971	0
10	4.033	3.972	0.700	3.935	3.875	0.683
20	3.944	3.706	1.349	3.853	3.621	1.318
30	3.777	3.271	1.889	3.701	3.205	1.851
40	3.552	2.721	2.283	3.491	2.674	2.244
50	3.323	2.136	2.546	3.279	2.106	2.512
60	3.126	1.563	2.707	3.101	1.551	2.686
70	2.987	1.022	2.807	2.979	1.019	2.799
80	2.912	0.506	2.868	2.910	0.506	2.866
90	2.893	0	2.893	2.890	0	2.890
100	2.895	-0.503	2.851	2.945	-0.511	2.900
110	3.064	-1.048	2.879	3.062	-1.047	2.877
120	3.231	-1.618	2.798	3.228	-1.614	2.796
130	3.411	-2.193	2.613	3.413	-2.194	2.615
140	3.560	-2.727	2.288	3.563	-2.729	2.290
150	3.682	-3.189	1.841	3.681	-3.188	1.841
160	3.763	-3.556	1.294	3.773	-3.546	1.290
170	3.885	-3.826	0.675	3.832	-3.774	0.665
180	3.857	-3.857	0	3.844	-3.844	0

APPENDIX A

Table 2

Medium Headform — Exterior Dimensions (Continued)

Θ	Level+1 Z=0.500			Level +2 Z=1.000		
	R	X	Y	R	X	Y
0	3.830	3.830	0	3.665	3.665	0
10	3.801	3.743	0.660	3.613	3.558	0.627
20	3.725	3.500	1.274	3.554	3 340	1.216
30	3.587	3.106	1.794	3.436	2.976	1.718
40	3.399	2.604	2.185	3.271	2.506	2.103
50	3.205	2.060	2.456	3.102	1.994	2.376
60	3.044	1.522	2.636	2.959	1.480	2.563
70	2.927	1.001	2.751	2.854	0.976	2.682
80	2.861	0.497	2.818	2.792	0.485	2.750
90	2.856	0	2.856	2.783	0	2.783
100	2.897	-0.503	2.853	2.832	-0.492	2.789
110	3.007	-1.029	2.826	2.938	-1.005	2.761
120	3.176	-1.588	2.751	3.102	-1.551	2.686
130	3.372	-2.168	2.583	3.294	-2.117	2.523
140	3.520	-2.697	2.263	3.450	2 643	2.218
150	3.643	-3.155	1.822	3.564	-3 087	1.782
160	3.728	-3.503	1.275	3.637	-3.418	1.244
170	3.777	-3.720	0.656	3.675	-3.619	0.638
180	3.782	3.782	0	3.670	-3.670	0

Θ	Level +3 Z=1.450			Level +4 Z=1.860		
	R	X	Y	R	X	Y
0	3.419	3.419	0	3.061	3.061	0
10	3.382	3.331	0.587	3.035	2.989	0.527
20	3.299	3.100	1.128	2.966	2.787	1.014
30	3.197	2.769	1.599	2.872	2 487	1.436
40	3 052	2.338	1.962	2.754	2.110	1.770
50	2.911	1.871	2.230	2.642	1.696	2 024
60	2.786	1.393	2.413	2.522	1.261	2.184
70	2.700	0.924	2.537	2.477	0.847	2.328
80	2.647	0.460	2.607	2.442	0.424	2.405
90	2.636	0	2.636	2.442	0	2.442
100	2.681	-0.467	2.650	2.492	-0 433	2.454
110	2.796	-0.956	2.627	2.599	-0.889	2.442
120	2.961	-1.481	2.564	2.758	-1.379	2.389
130	3.147	-2.023	2.411	2.936	-1.887	2.249
140	3.301	-2.529	2.122	3.081	-2.360	1.980
150	3.408	-2.951	1.704	3.176	-2.751	1.588
160	3.479	-3.269	1.190	3.230	-3.035	1.105
170	3.514	-3.461	0.610	3.270	-3.220	0.568
180	3.502	-3.502	0	3.271	-3.271	0

APPENDIX A

Table 2

Medium Headform — Exterior Dimensions (Continued)

	Level +5 Z=2.250			Level +6 Z=2.560		
θ	R	X	Y	R	X	Y
0	2.526	2.526	0	1.796	1.796	0
10	2.521	2.483	0.483	1.798	1.771	0.312
20	2.464	2.315	0.843	1.757	1.651	0.601
30	2.387	2.067	1.191	1.719	1.489	0.860
40	2.305	1.766	1.482	1.678	1.285	1.079
50	2.232	1.435	1.710	1.652	1.062	1.266
60	2.174	1.087	1.893	1.641	0.821	1.421
70	2.144	0.733	2.015	1.645	0.563	1.546
80	2.132	0.370	2.100	1.673	0.291	1.648
90	2.147	0	2.147	1.712	0	1.712
100	2.213	-0.384	2.179	1.809	-0.314	1.782
110	2.316	-0.792	2.176	1.925	-0.658	1.809
120	2.463	-1.232	2.133	2.068	-1.033	1.789
130	2.624	-1.687	2.010	2.213	-1.423	1.695
140	2.763	-2.117	1.778	2.368	-1.806	1.516
150	2.863	-2.479	1.432	2.469	-2.138	1.235
160	2.919	-2.743	0.998	2.536	-2.383	0.867
170	2.954	-2.909	0.513	2.561	-2.522	0.445
180	2.958	-2.958	0	2.566	-2.566	0

	Level +7 Z=2.750		
θ	R	X	Y
0	1.081	1.081	0
10	1.088	1.072	0.189
20	1.056	0.991	0.361
30	1.039	0.900	0.520
40	1.039	0.796	0.668
50	1.052	0.676	0.806
60	1.068	0.534	0.925
70	1.106	0.378	1.039
80	1.171	0.203	1.153
90	1.242	0	1.242
100	1.422	-0.247	1.400
110	1.489	-0.509	1.399
120	1.643	-0.842	1.468
130	1.801	-1.158	1.380
140	1.954	-1.497	1.266
150	2.083	-1.804	1.042
160	2.136	-2.009	0.731
170	2.175	2.142	0.378
180	2.175	-2.175	0

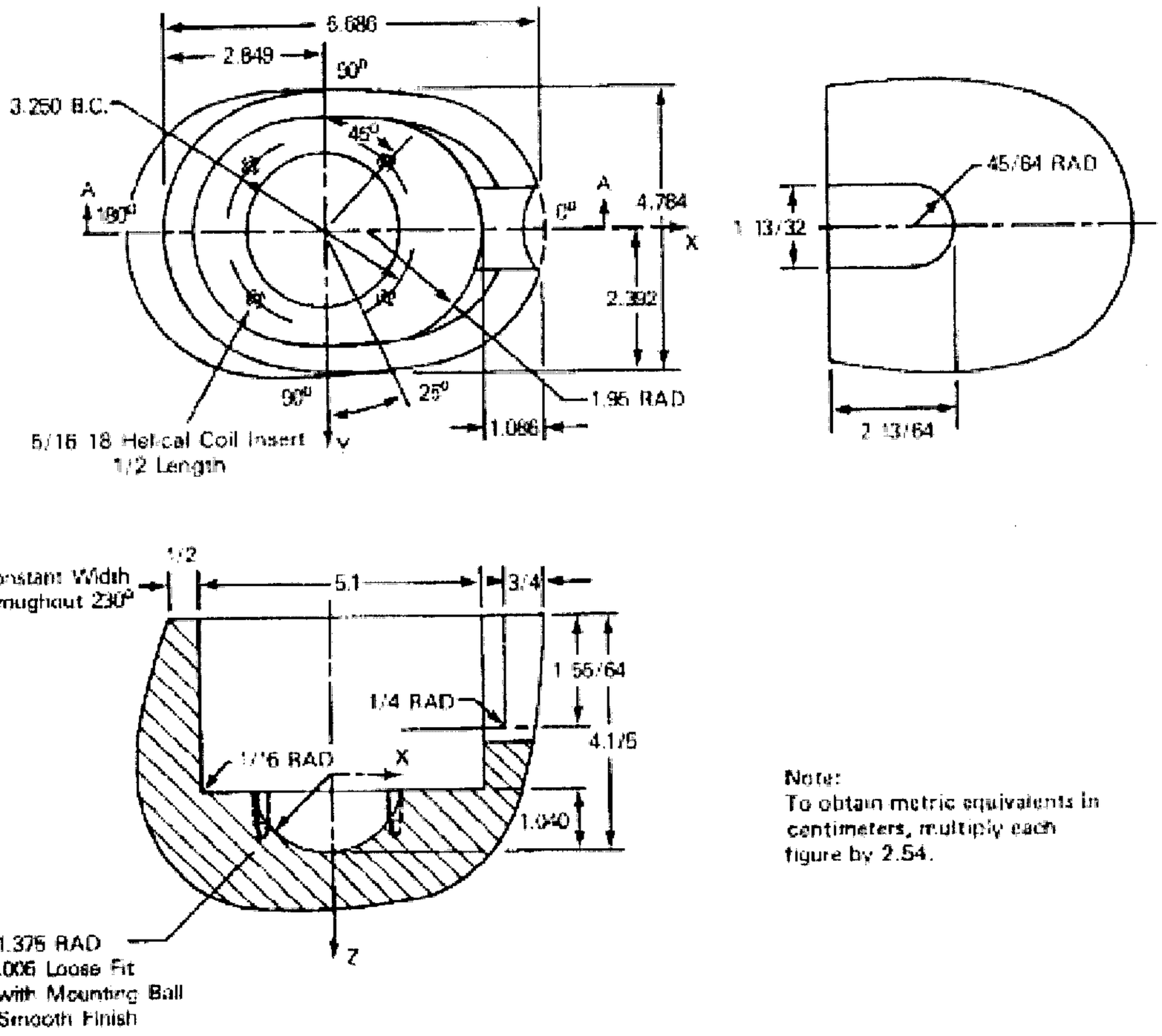
Notes:

1. Apex is located at (-0.75, 0, 3.02) for (X,Y,Z) or (0.75, 180, 3.02) for (R, θ, Z).
2. Center of ear opening is located at (0.40, 2.78, -2.36) for (X,Y,Z) or (2.80, 81.8, -2.36) for (R,θ,Z).
3. Scale all dimensions by 0.8941 for small headform.
4. Scale all dimensions by 1.069 for large headform.
5. Headform is symmetrical about the mid-sagittal plane.
6. Units
   R,X,Y,Z — inches.
   θ — degrees.
7. To obtain metric equivalents in centimeters, multiply each figure by 2.54.

APPENDIX A

Figure 6

Small Headform — Interior Design



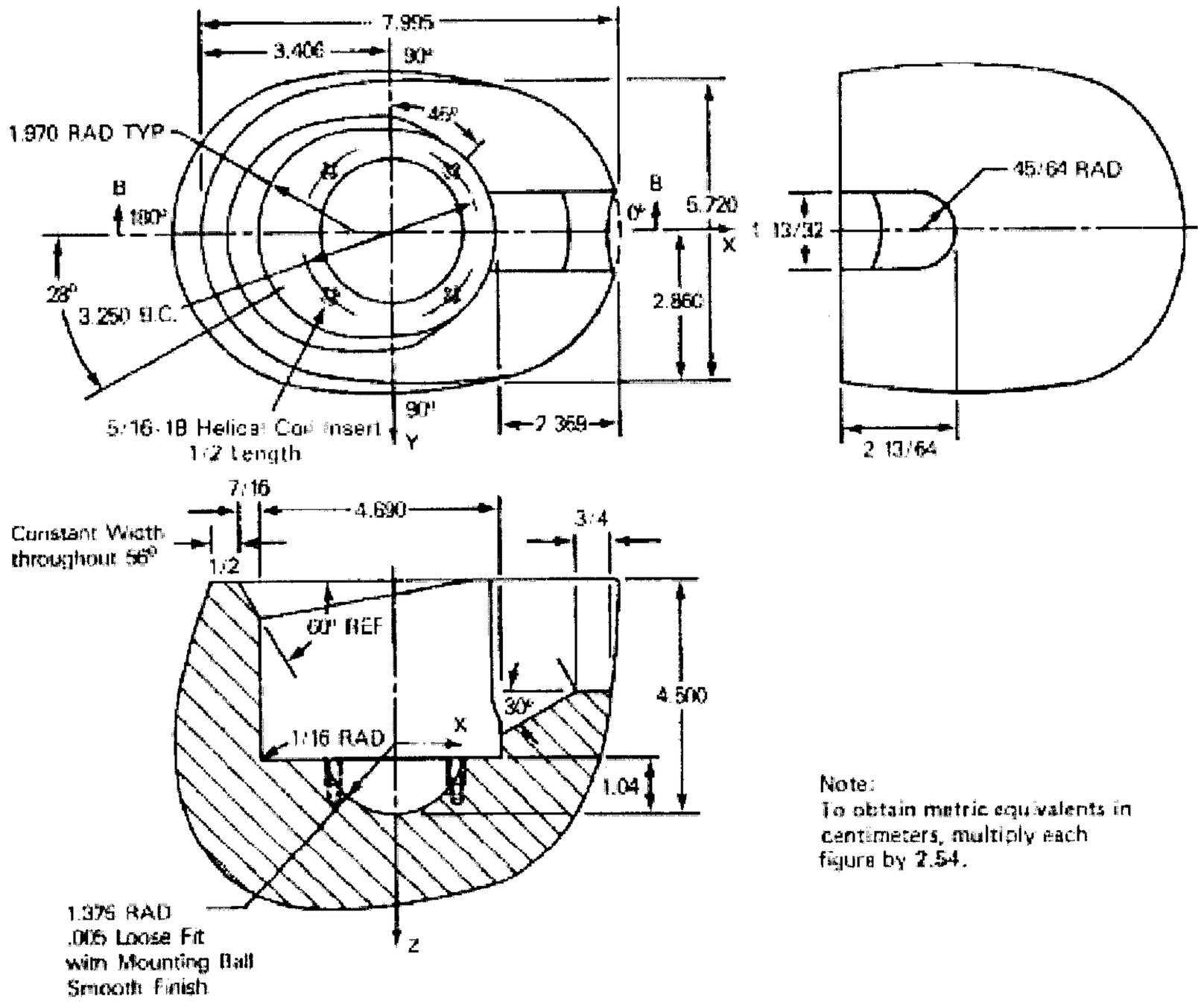
Section A-A

Note:
To obtain metric equivalents in centimeters, multiply each figure by 2.54.

APPENDIX A

Figure 7

Medium Headform — Interior Design

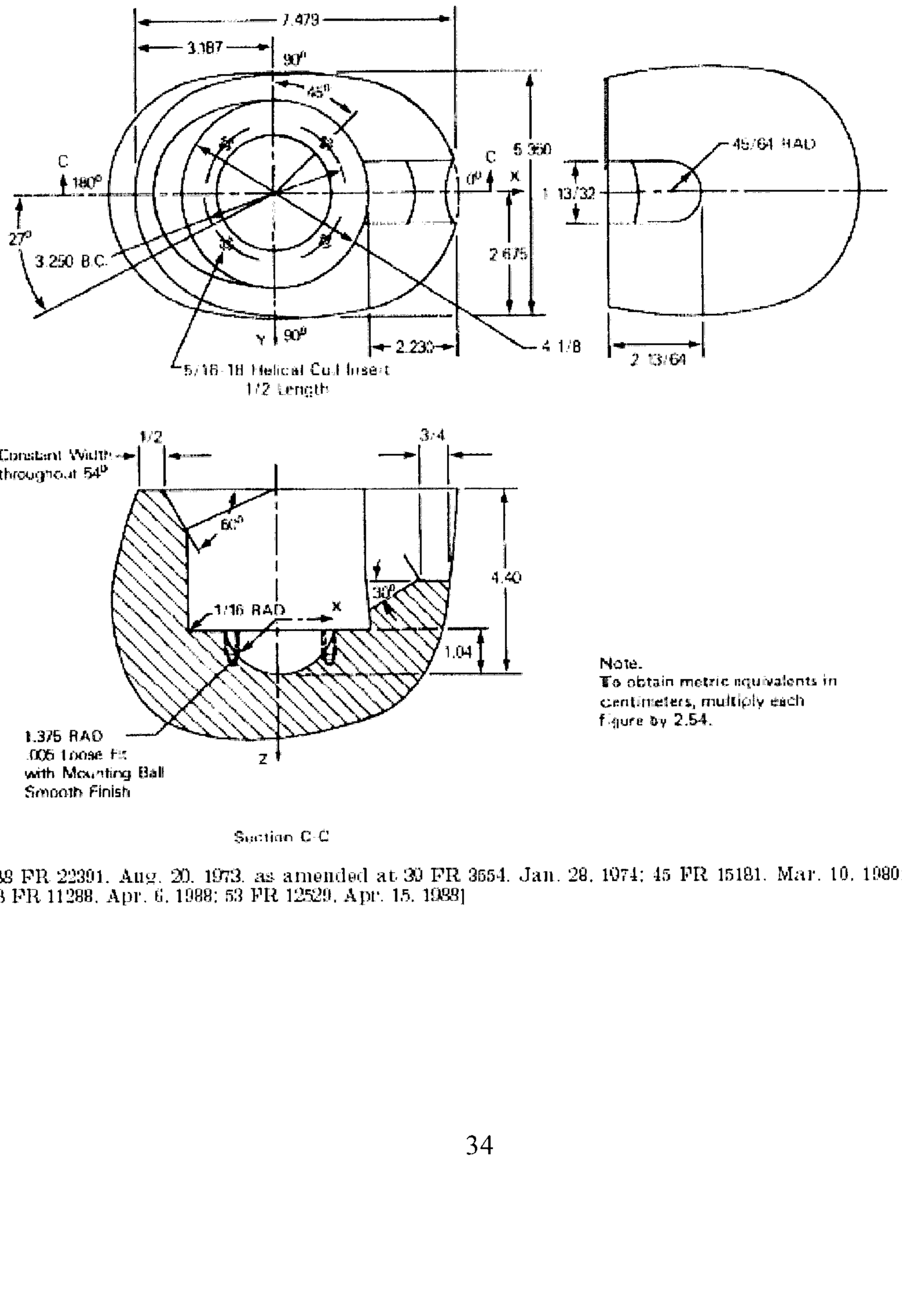


Note:
To obtain metric equivalents in centimeters, multiply each figure by 2.54.

APPENDIX A

Figure 8

Large Headform—Interior Design



Note.
To obtain metric equivalents in centimeters, multiply each figure by 2.54.

[38 FR 22391, Aug. 20, 1973, as amended at 39 FR 3664, Jan. 28, 1974; 45 FR 15181, Mar. 10, 1980; 53 FR 11288, Apr. 6, 1988; 53 FR 12529, Apr. 15, 1988]

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A motorcycle helmet comprising a shell and an impact liner, the impact liner being directly in-molded to the shell.

2. The motorcycle helmet of claim **1** wherein the shell comprises a molded-composite lay-up.

3. The shell of claim **2** wherein at least some of the composite lay-up materials include prepreg materials.

4. The shell of claim **1** wherein the impact liner comprises a moldable, compressible, impact attenuating polymer material.

5. The shell of claim **2** wherein the impact liner comprises a moldable, compressible, impact attenuating polymer material.

6. The shell of claim **5** wherein the impact liner comprises EPS or EPP.

7. The shell of claim **5** wherein the impact liner comprises multiple layers or zones of different moldable, compressible impact attenuating polymer material.

8. The shell of claim **5** wherein the impact liner comprises multiple layers or zones of different densities of moldable, compressible impact attenuating polymer material.

9. A method of making a motorcycle helmet comprising providing a shell and in-molding impact liner material directly to the shell to form an impact liner.

10. The method of claim **9** wherein the shell comprises a molded-composite lay-up.

11. The method of claim **10** wherein the impact liner material comprises a moldable, compressible, impact attenuating polymer material.

12. The method of claim **9** wherein the impact liner material comprises EPS or EPP.

13. The method of claim **9** wherein the in-molding comprises forming multiple layers or zones of different moldable, compressible impact attenuating polymer material.

14. The method of claim **9** wherein the in-molding comprises forming multiple layers or zones of different densities of moldable, compressible impact attenuating polymer material.

15. The method **9** of claim wherein the shell comprises at least one of carbon fiber, aramid fiber, fiberglass, polycarbonate, and ABS.

16. The method of claim **15** further comprising forming an integral tunnel to the shell wherein the tunnel material comprises at least one of one of carbon fiber, aramid fiber, fiberglass, polycarbonate, and ABS.

17. The method of claim **16** wherein the tunnel has a volume of at least approximately **1.0** cubic inch.

MOLDING OF SHELL **10**
FORMING A TUNNEL INTEGRAL WITH THE SHELL **20**
MOLDING OR PRESSING OF IMPACT LINER INTO SHELL **30**

Fig. 1

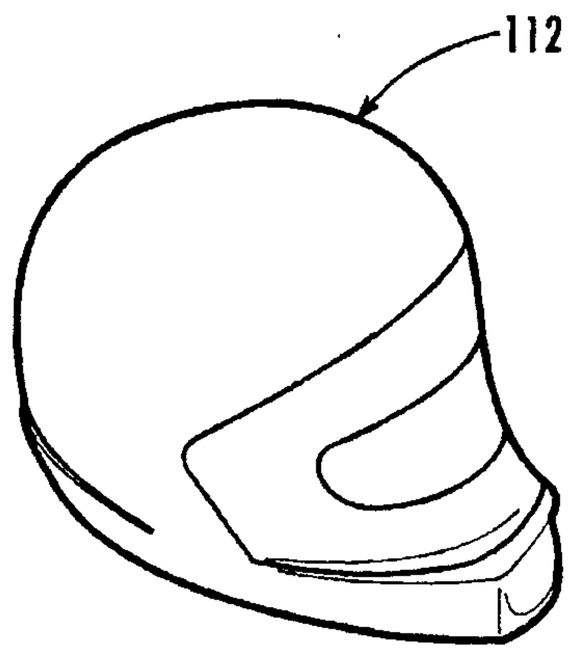


Fig. 2

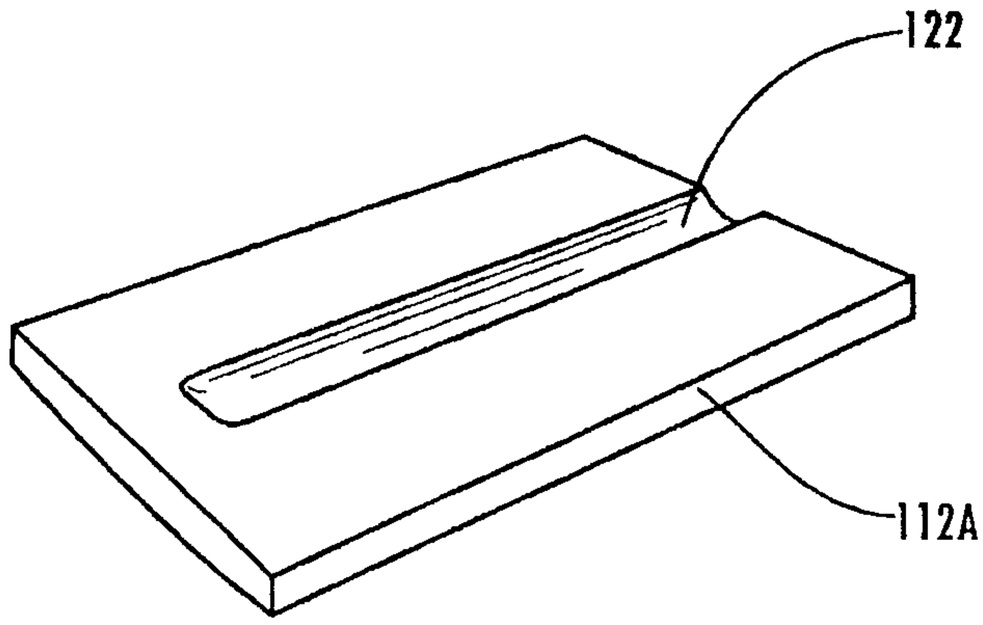


Fig. 3

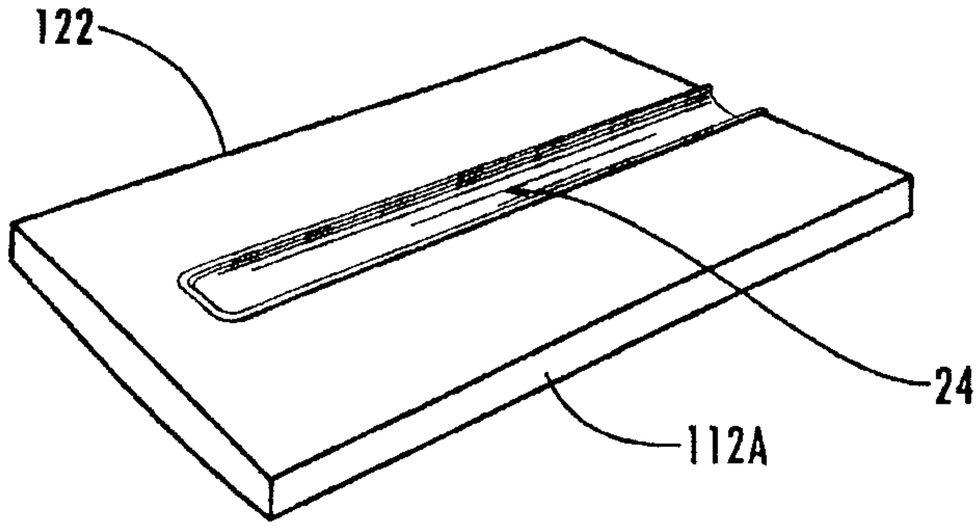


Fig. 4

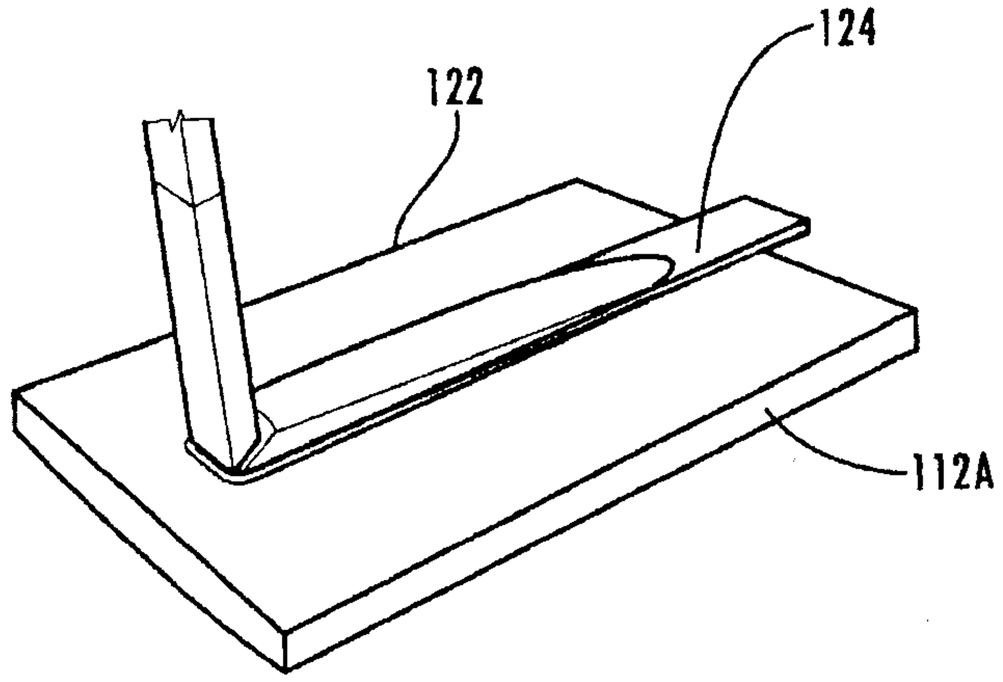


Fig. 5

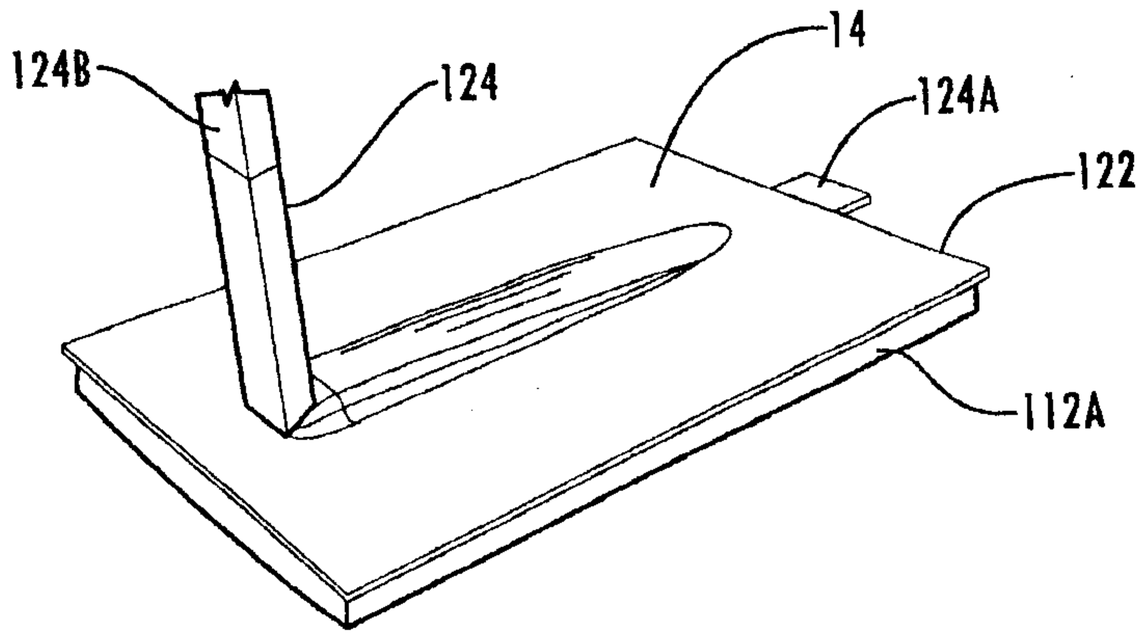


Fig. 6

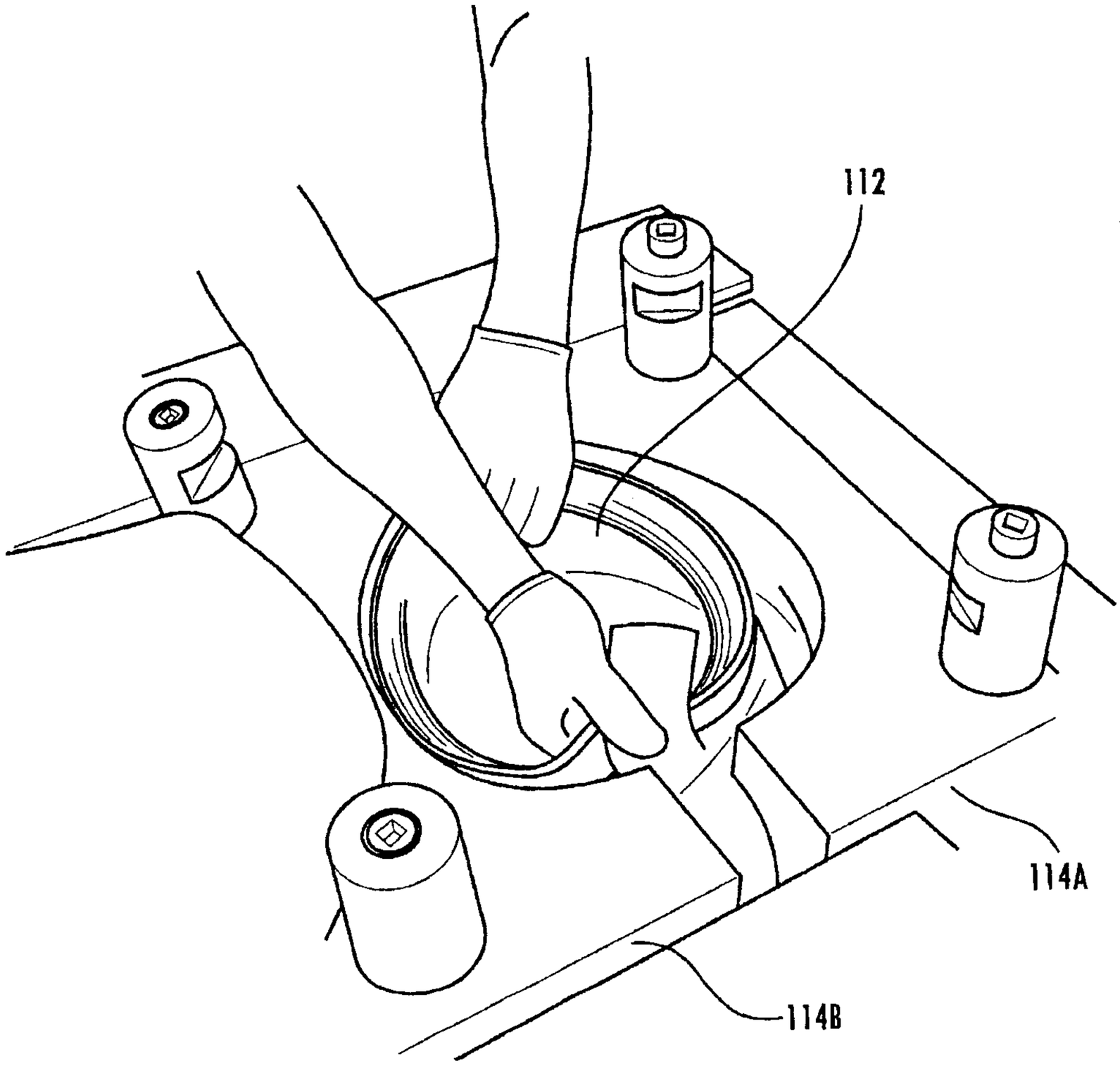


Fig. 7A

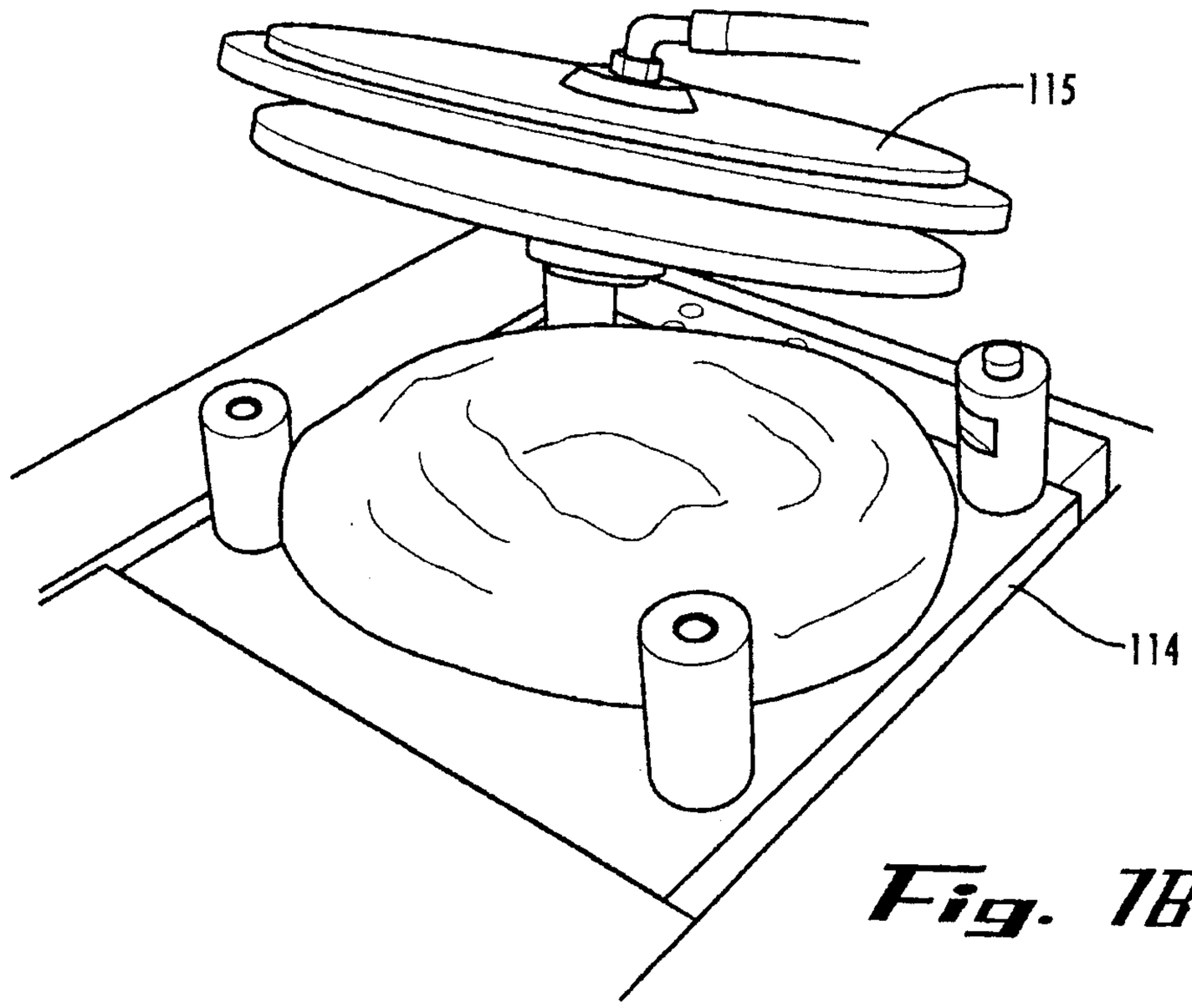


Fig. 7B

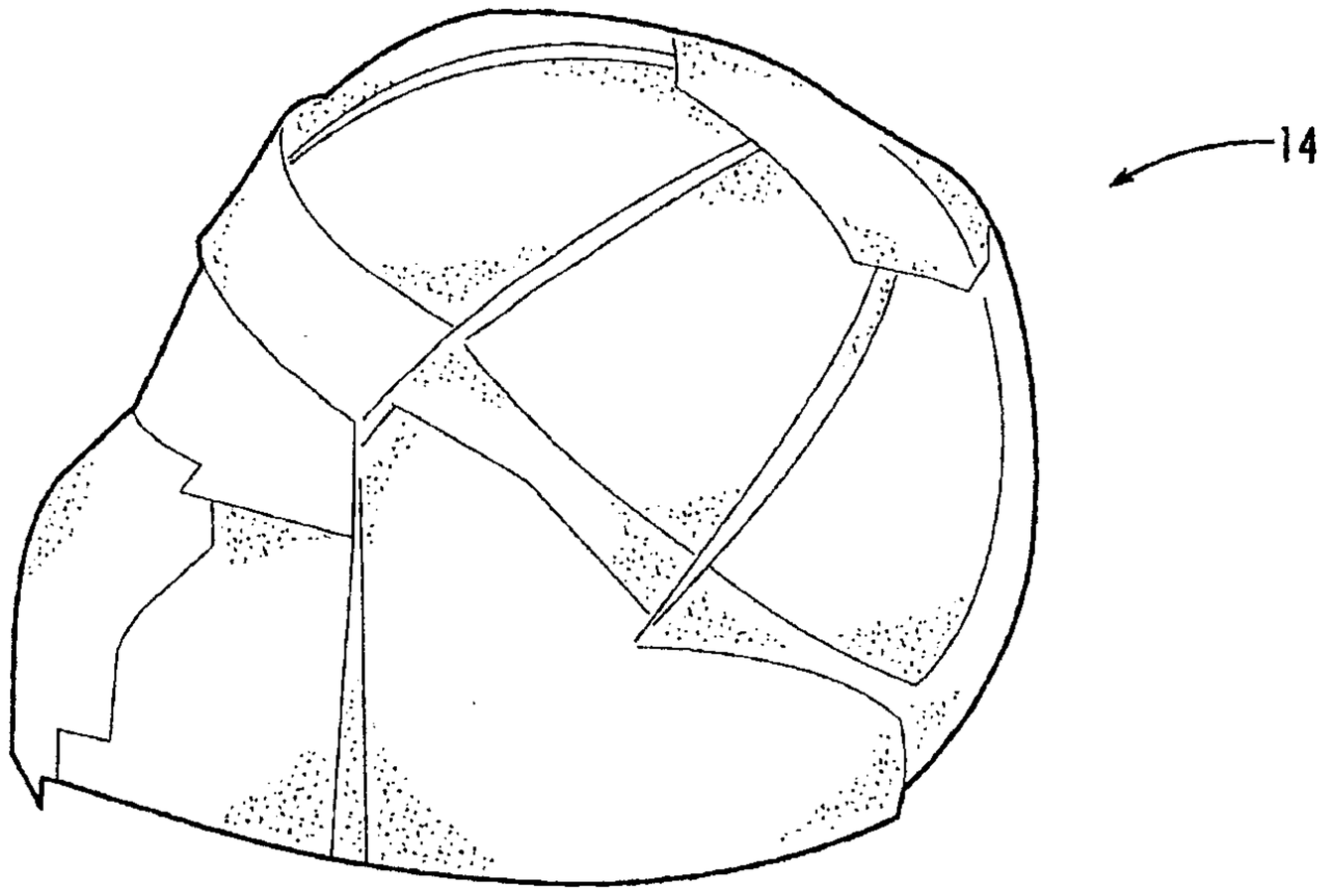


Fig. 8A

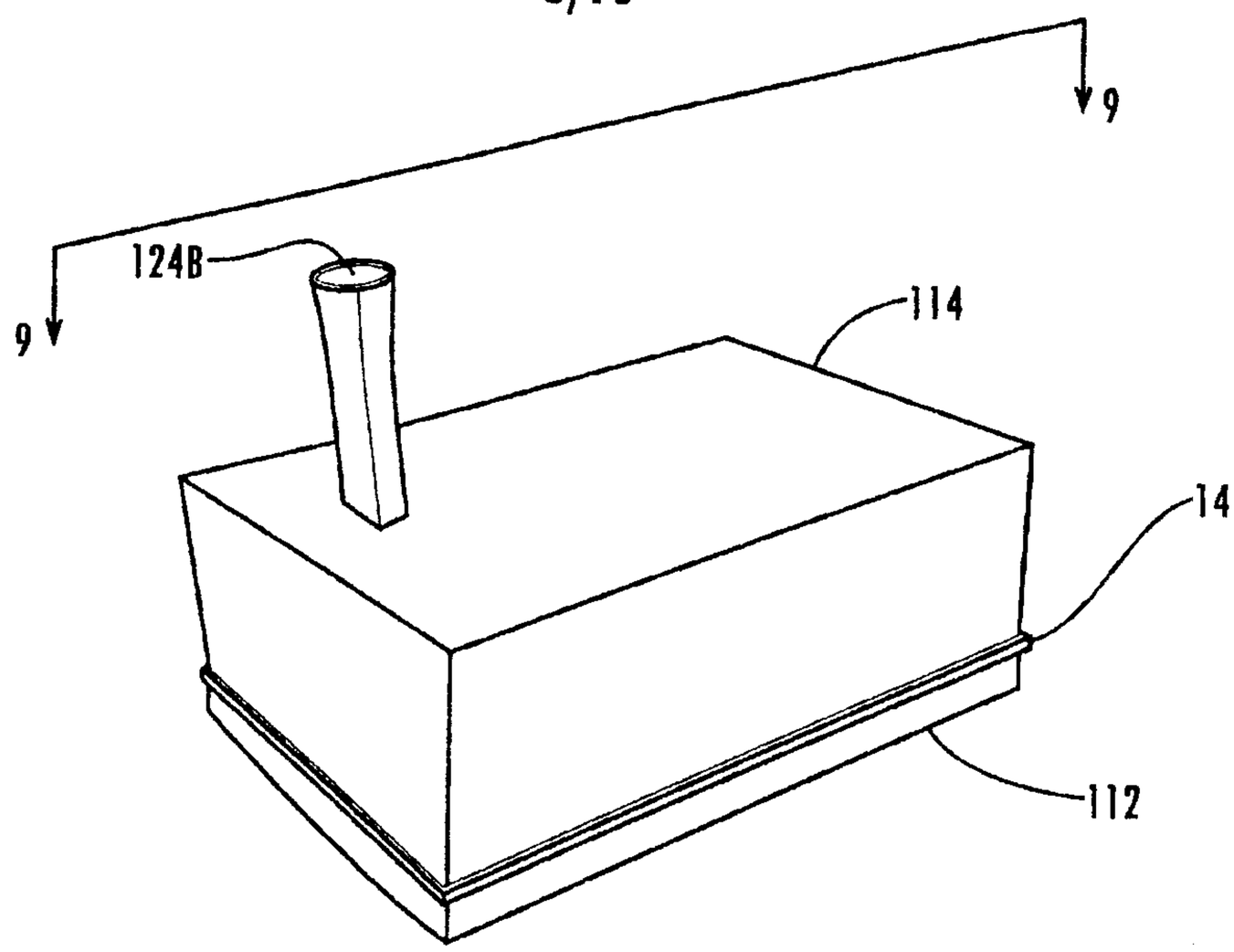


Fig. 8B

Fig. 9

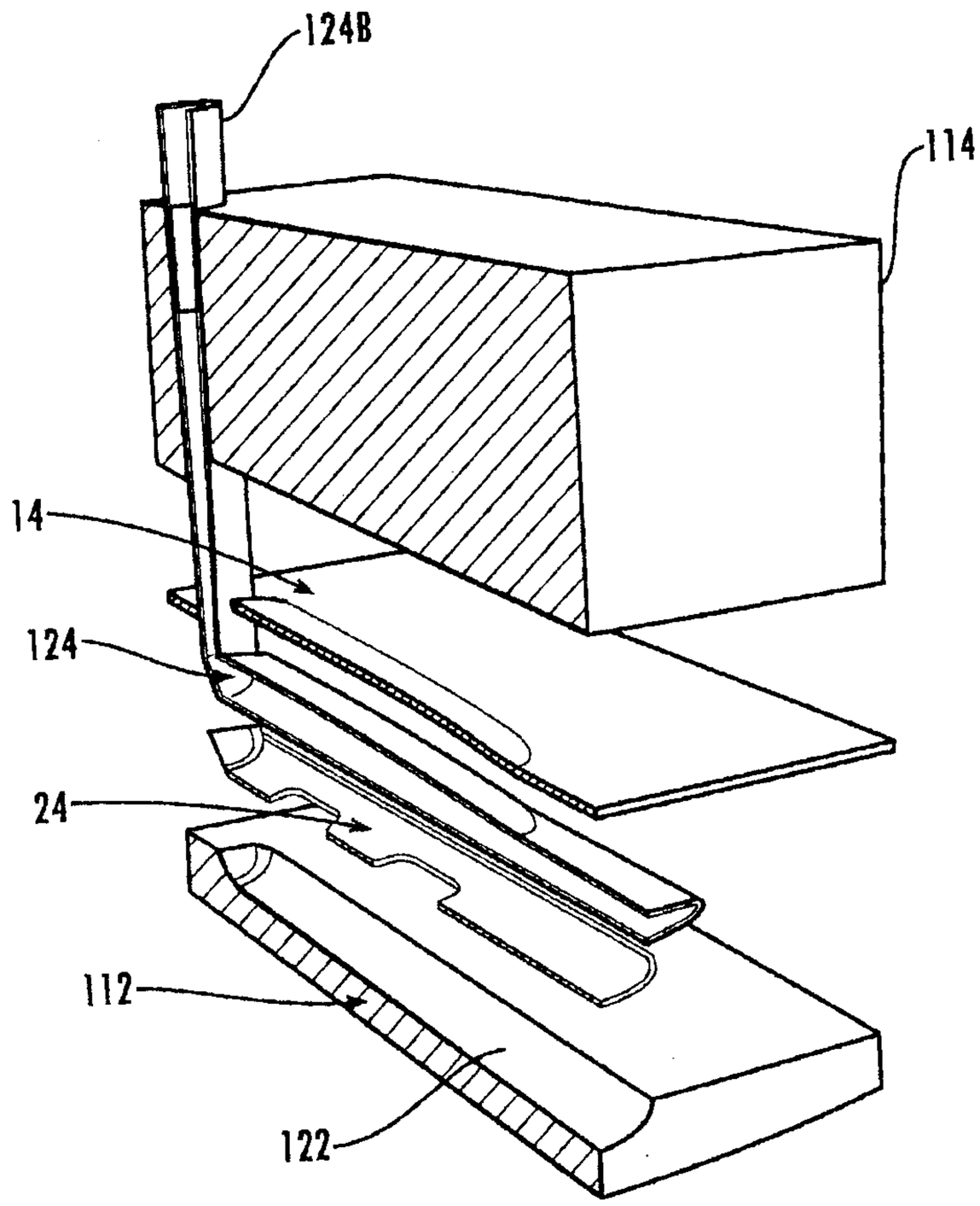


Fig. 10

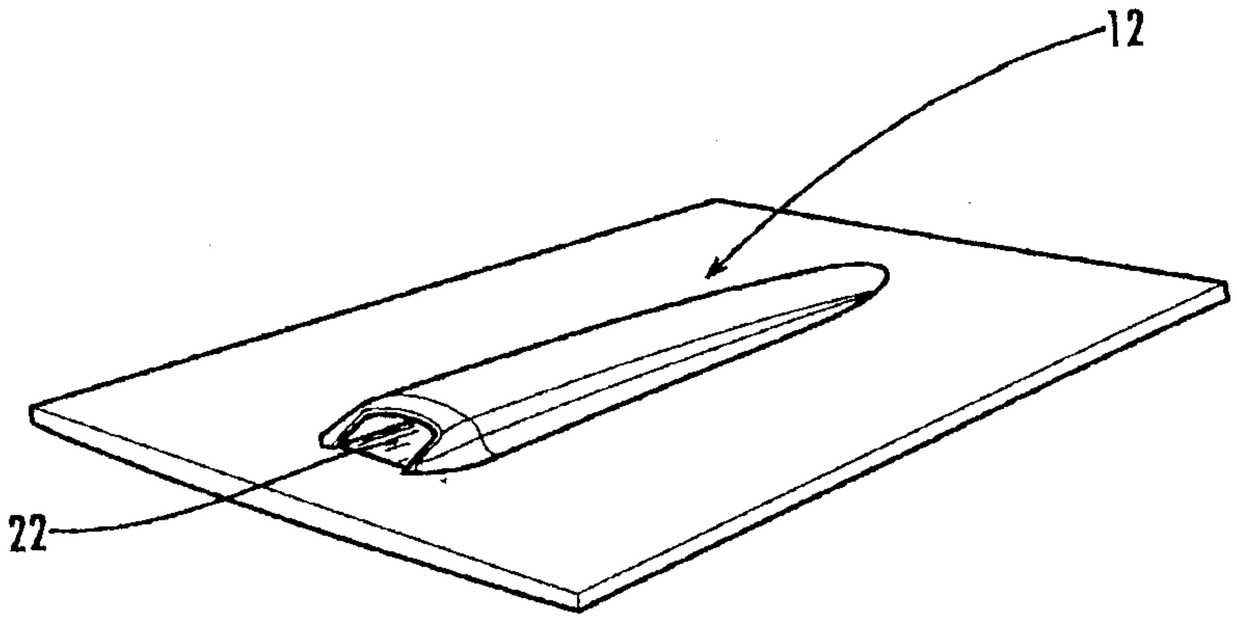


Fig. 11A

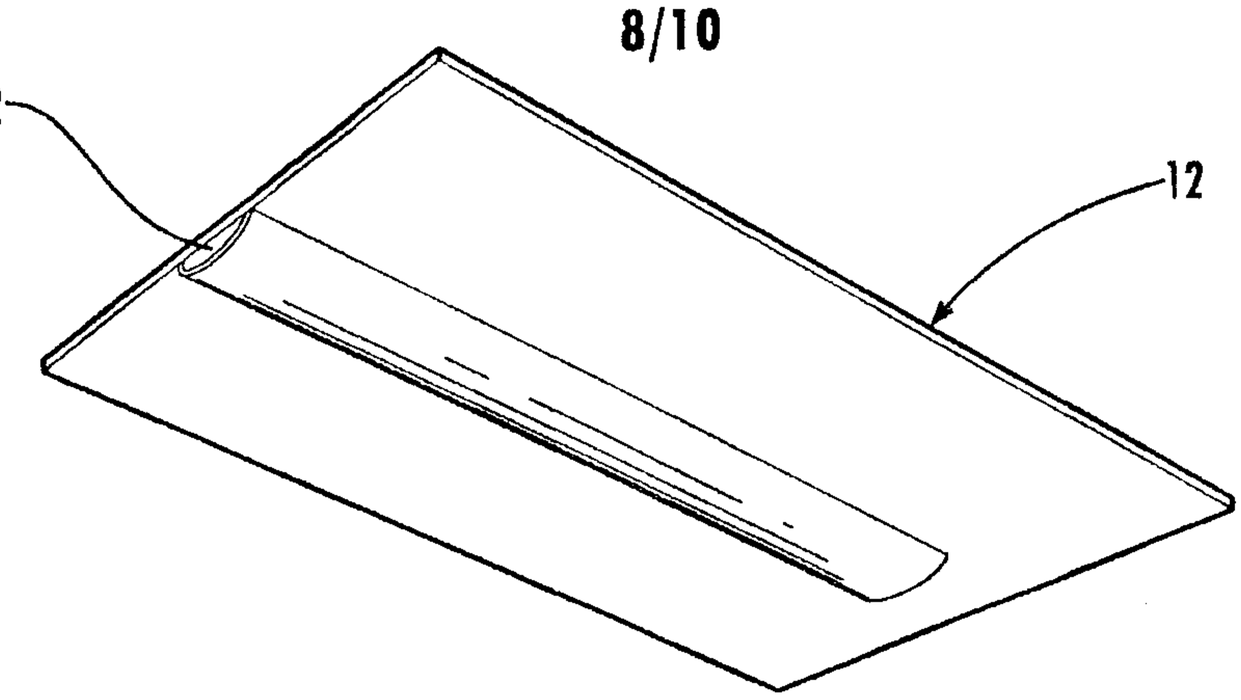


Fig. 11B

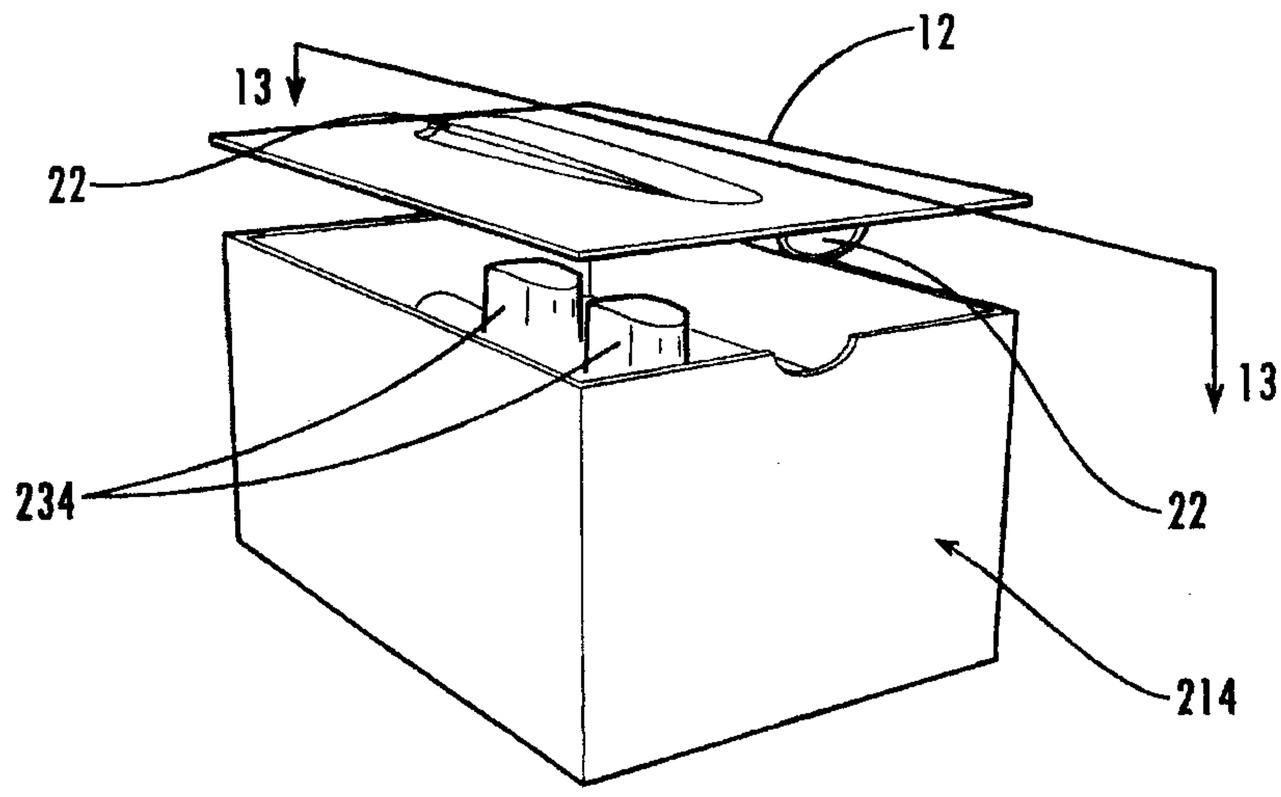


Fig. 12

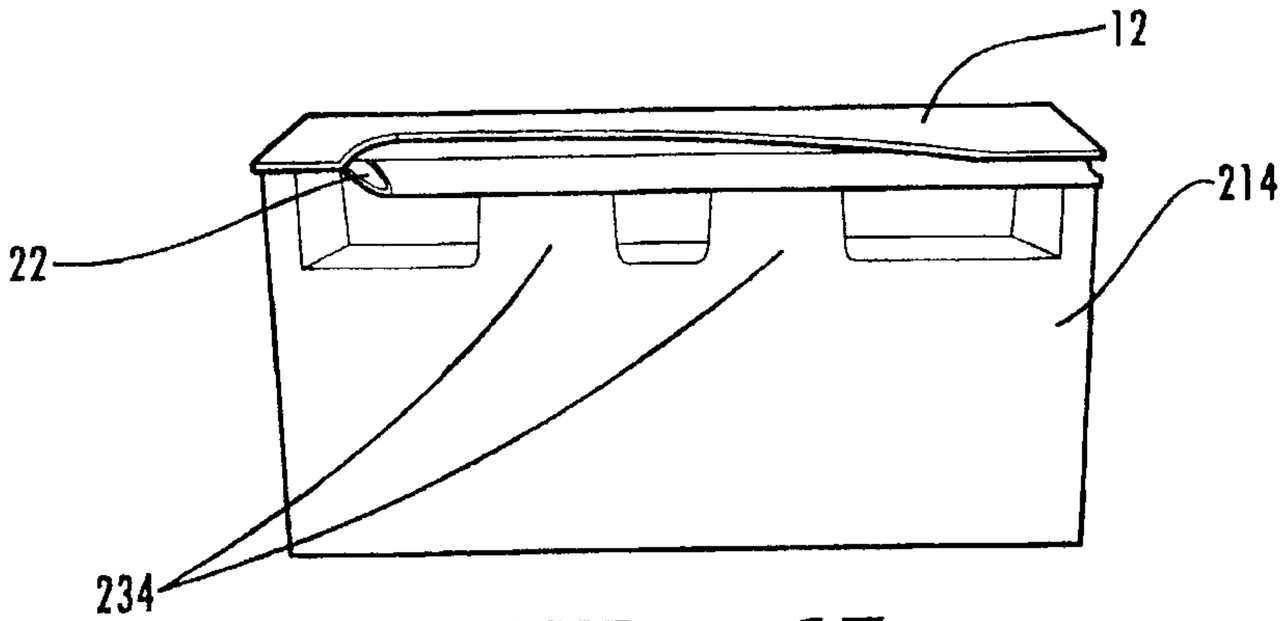


Fig. 13

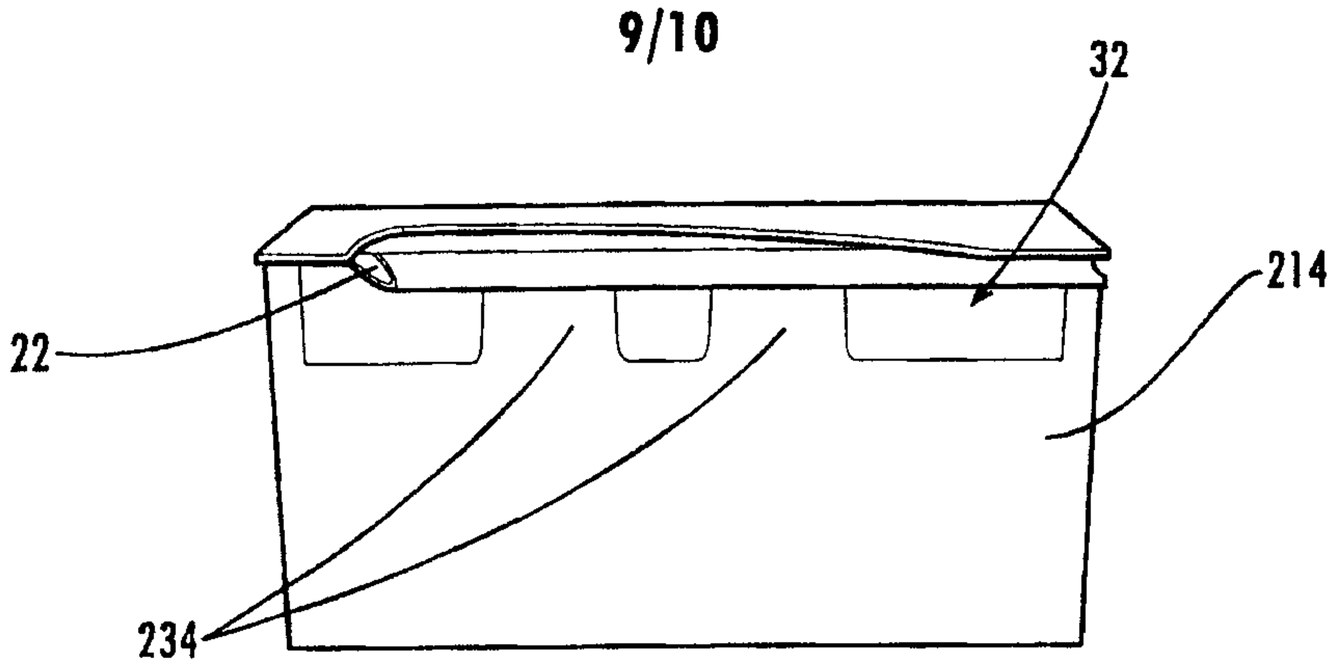


Fig. 14

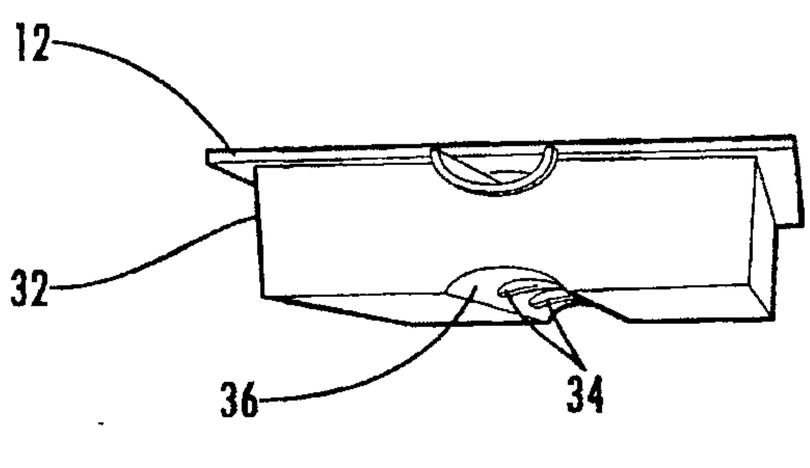


Fig. 15A

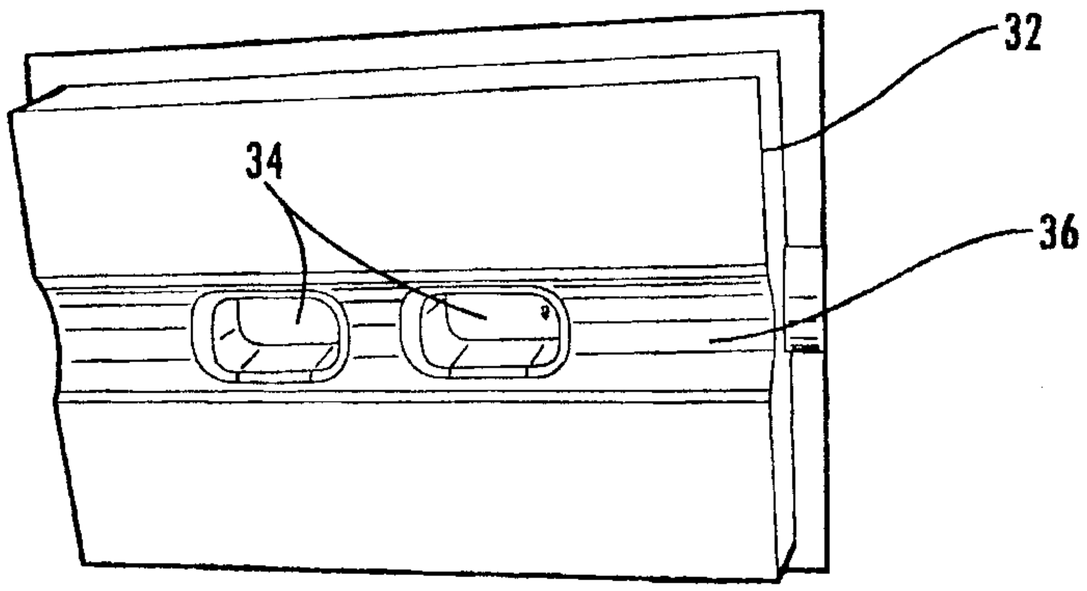


Fig. 15B

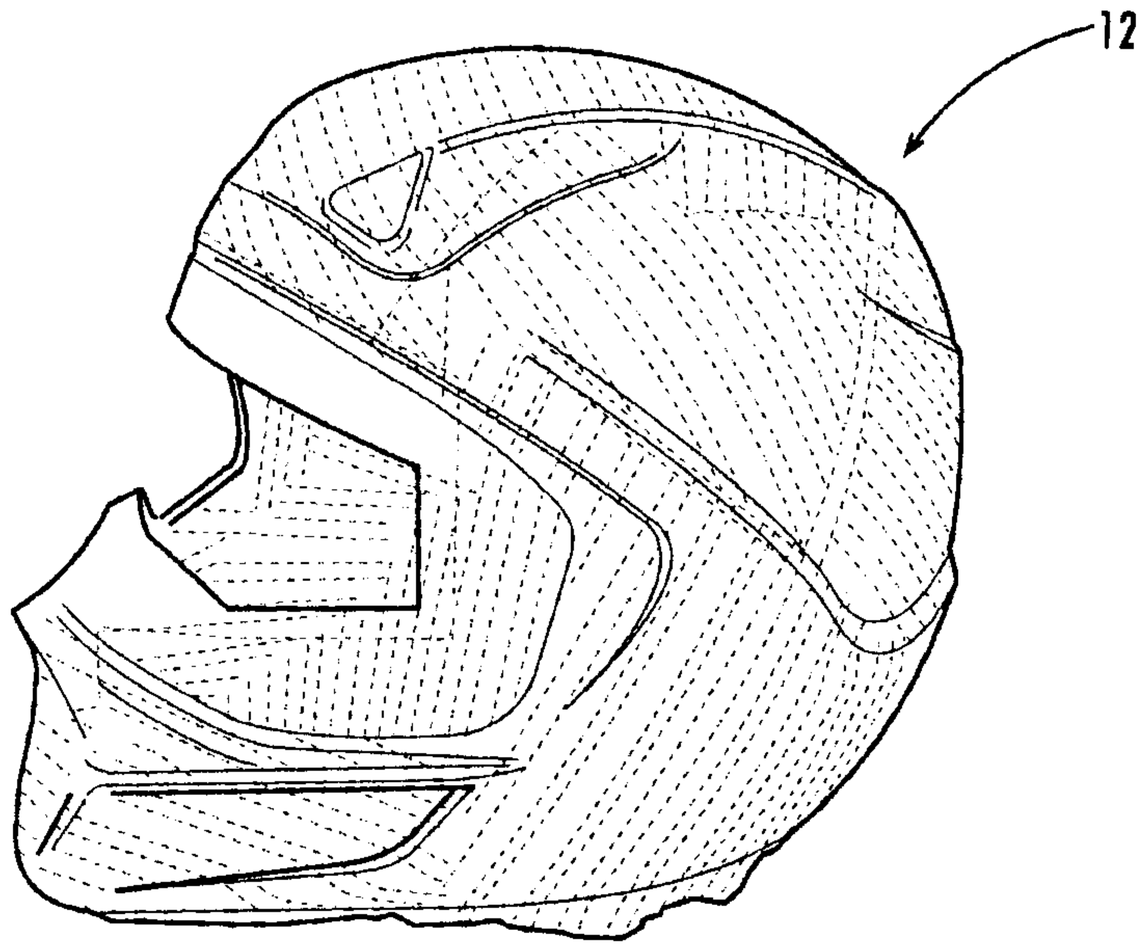


Fig. 16A

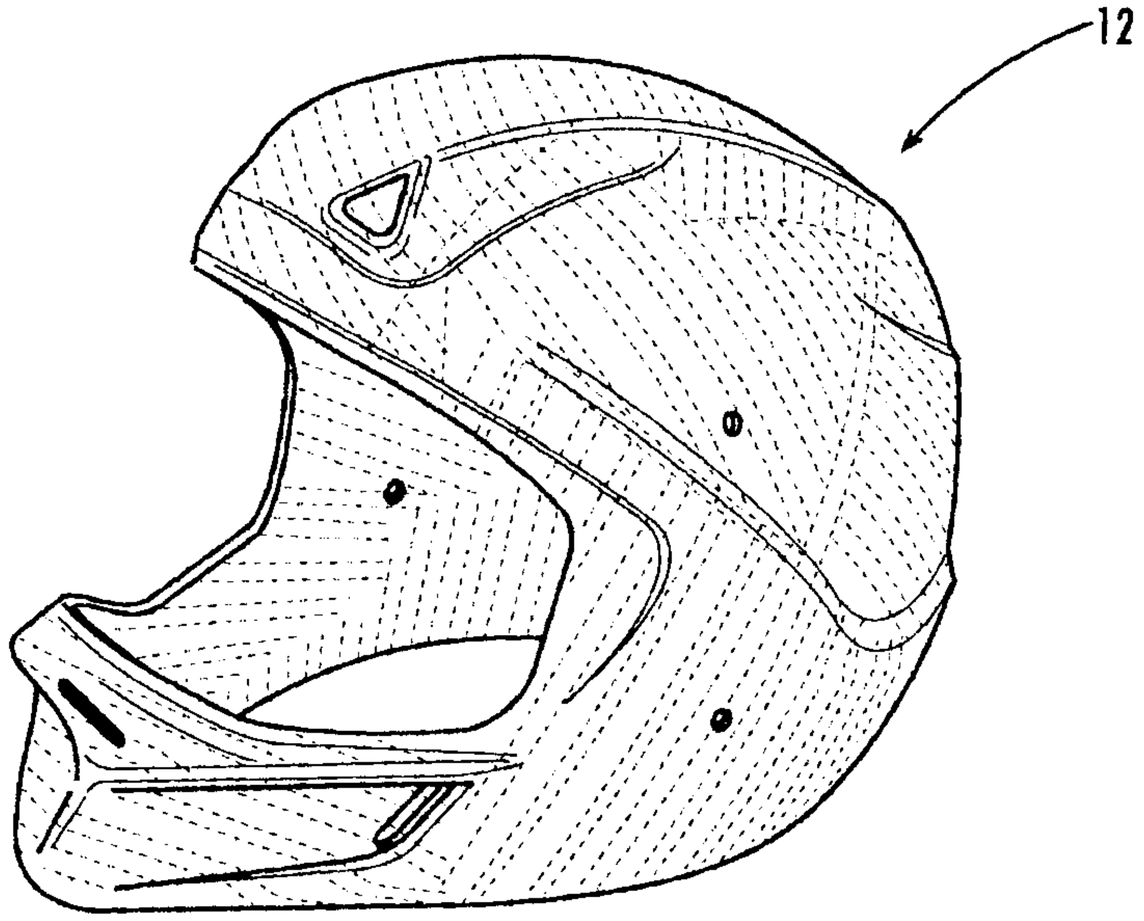
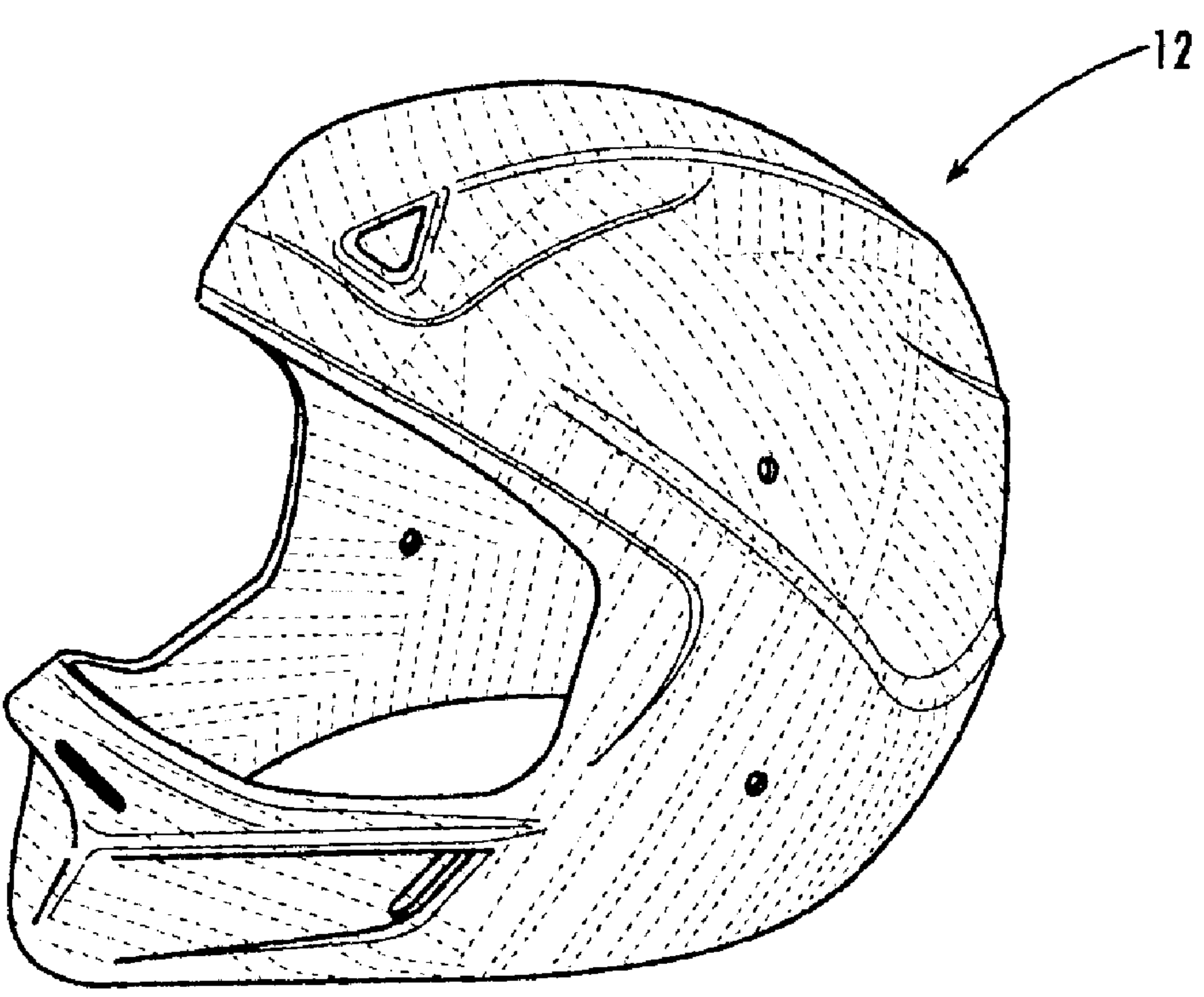


Fig. 16B


12