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(12) **United States Patent**
**Ellis**

(10) **Patent No.: US 8,141,276 B2**
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(54) **DEVICES WITH AN INTERNAL FLEXIBILITY SLIT, INCLUDING FOR FOOTWEAR**

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This patent is subject to a terminal disclaimer.

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(51) **Int. Cl.**

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See application file for complete search history.

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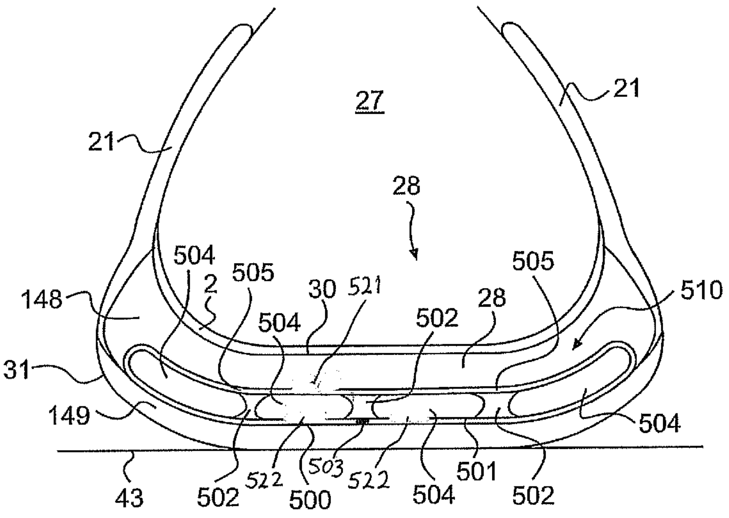
(57) **ABSTRACT**

The invention relates to all forms of footwear and orthotics, as well as any other products benefiting from increased flexibility, better resistance to shock and shear forces, and stable support. More specifically, the invention incorporates a unitary integral component with at least one internal (or mostly internal) sipe, including slits or channels or grooves and any other shape, including geometrically regular or non-regular, such as anthropomorphic shapes, into a large variety of products using materials known in the art or their current or future equivalent. Still more specifically, the internal sipe component provides improved flexibility to products utilizing them, as well as improved cushioning to absorb shock and/or shear forces, while also improving stability of support, and therefore the siped devices can be used in any existing product that provides or utilizes flexibility, cushioning, or stability.

**51 Claims, 101 Drawing Sheets**



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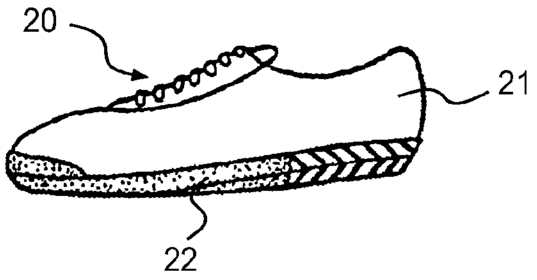

**FIG. 1**
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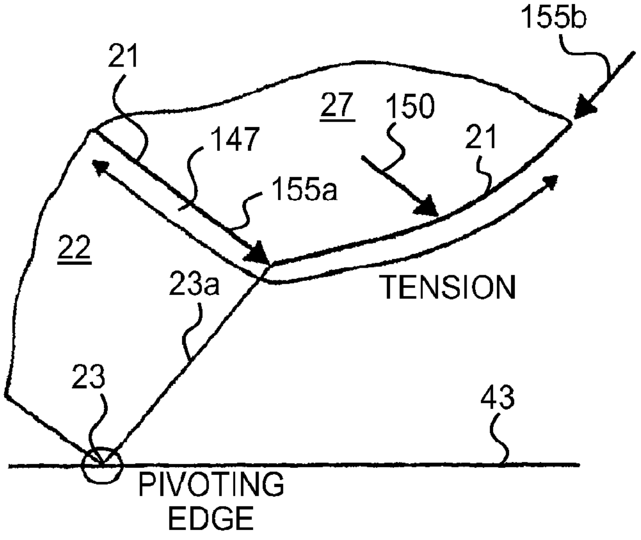

**FIG. 2**
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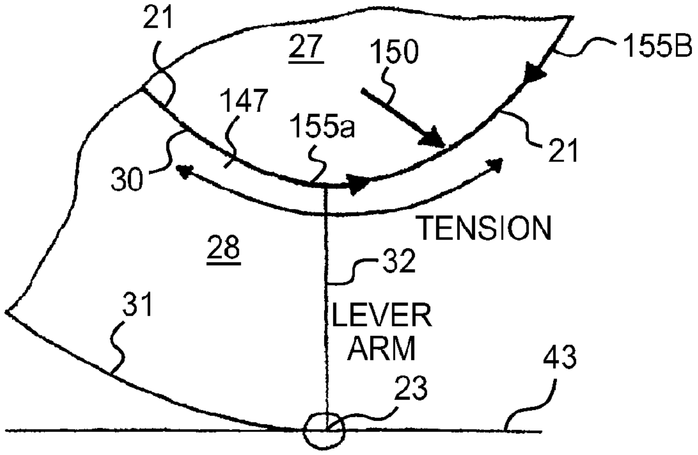

**FIG. 3**
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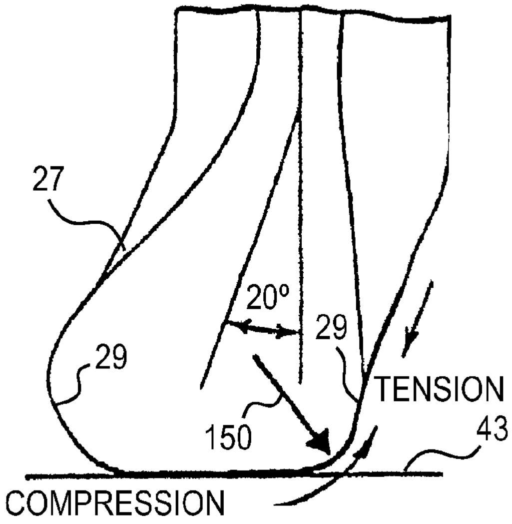

**FIG. 4**
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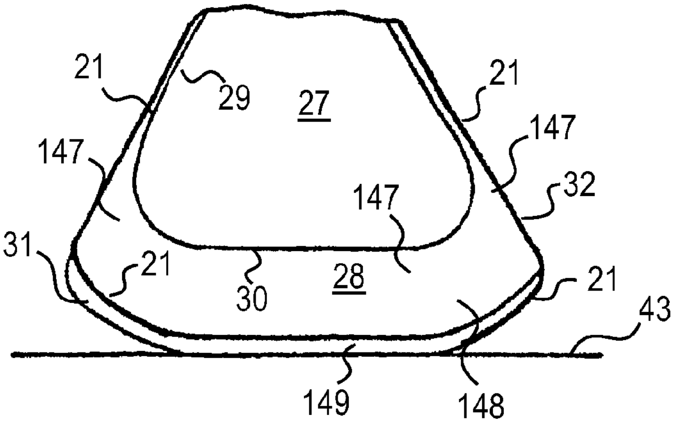

**FIG. 5A**
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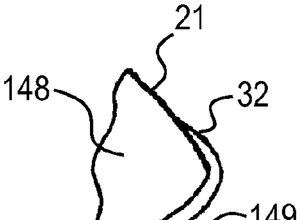
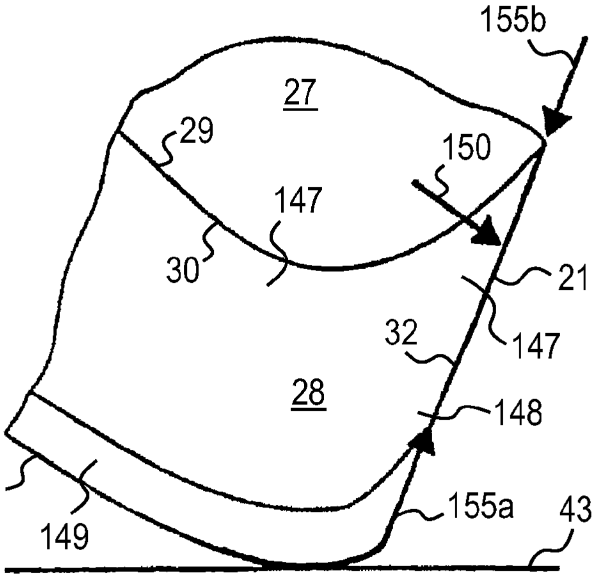


**FIG. 5B**
**PRIOR ART**



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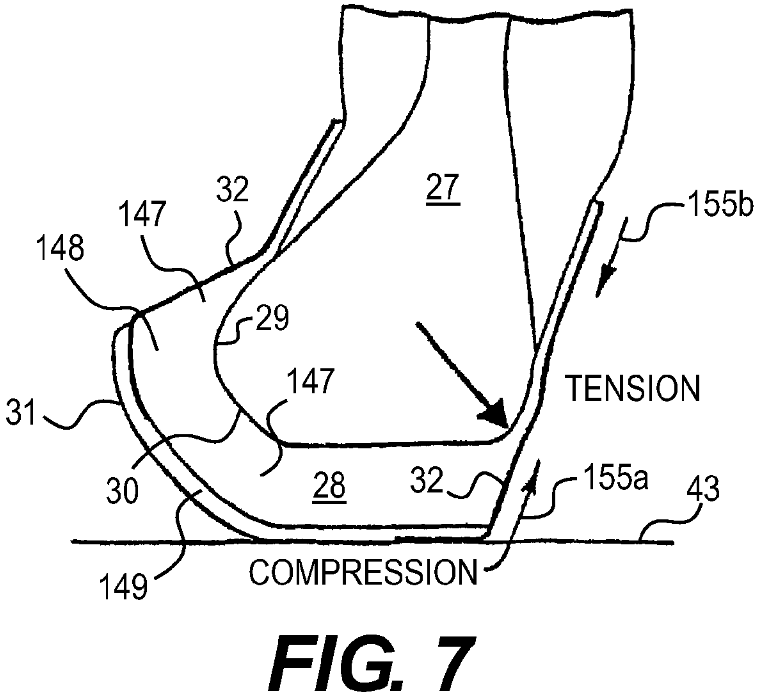

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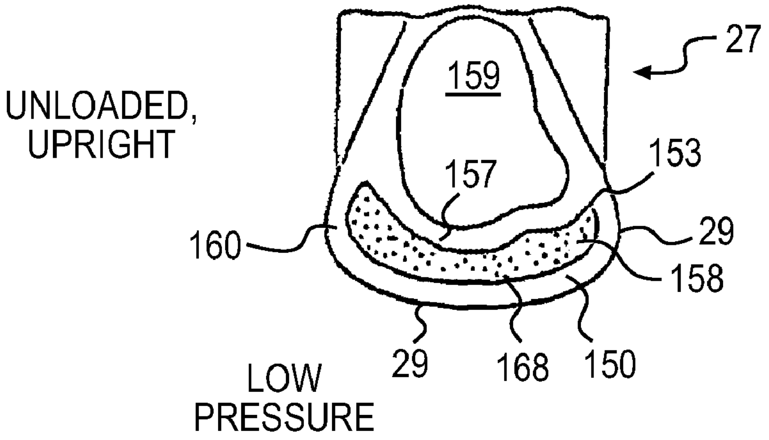

FIG. 8A
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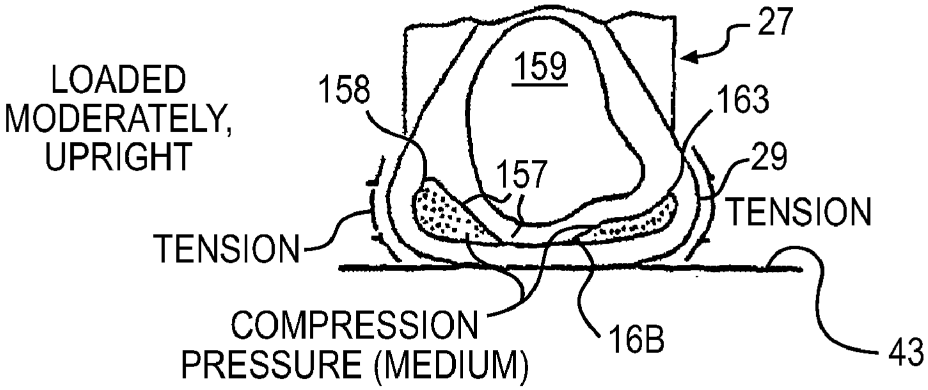

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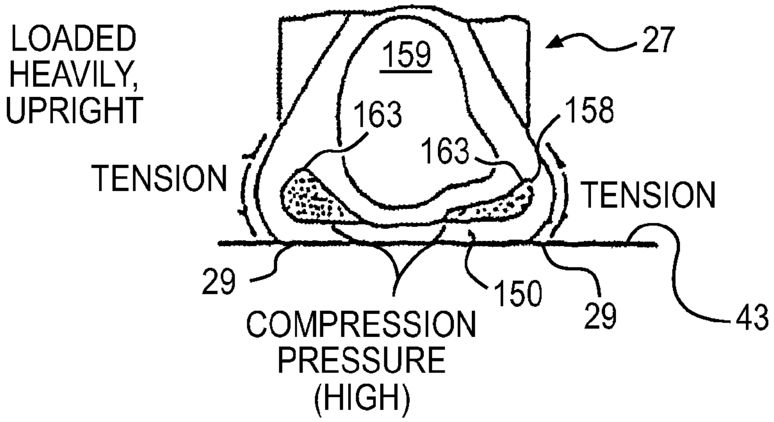

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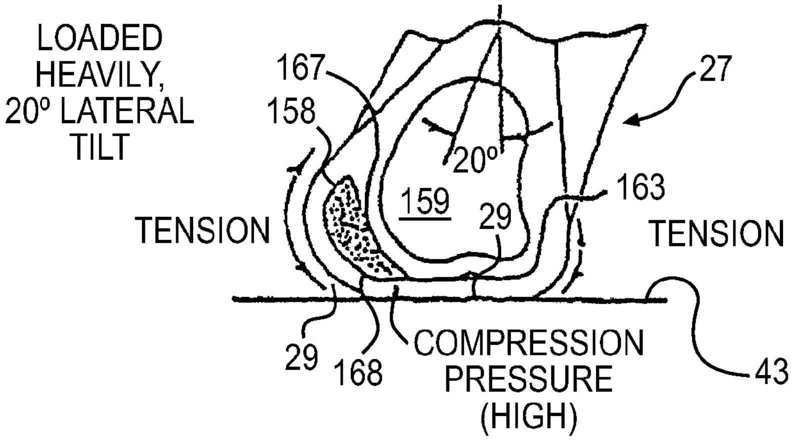

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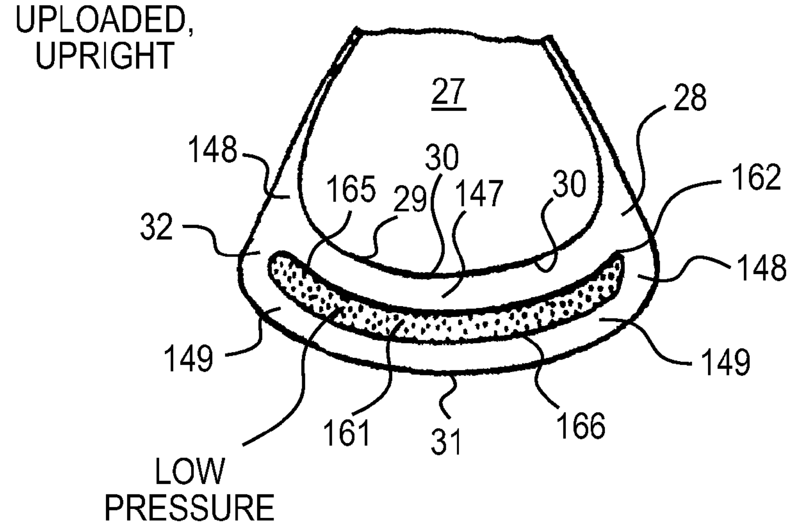

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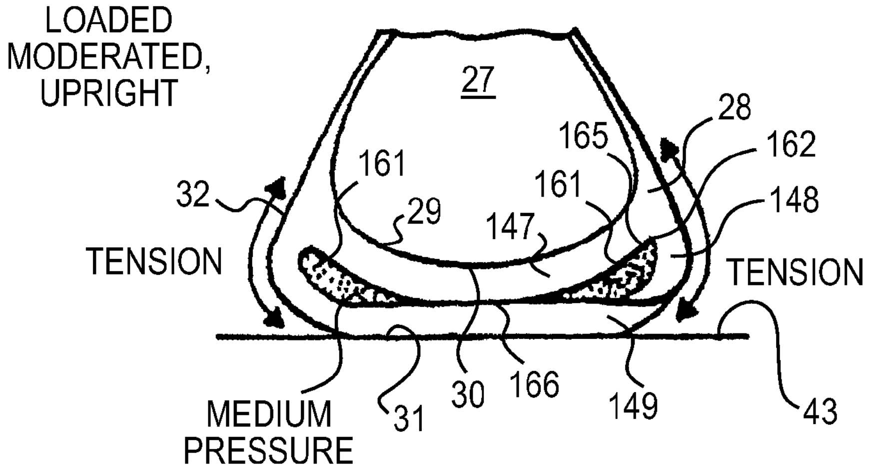

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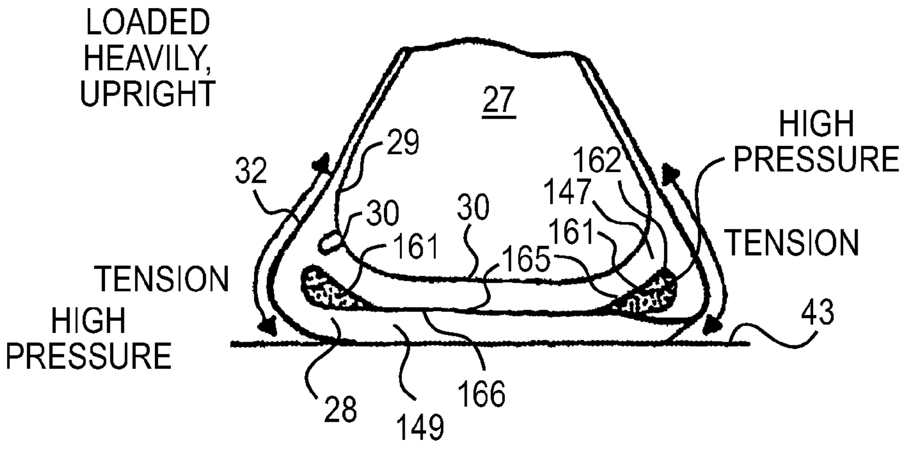

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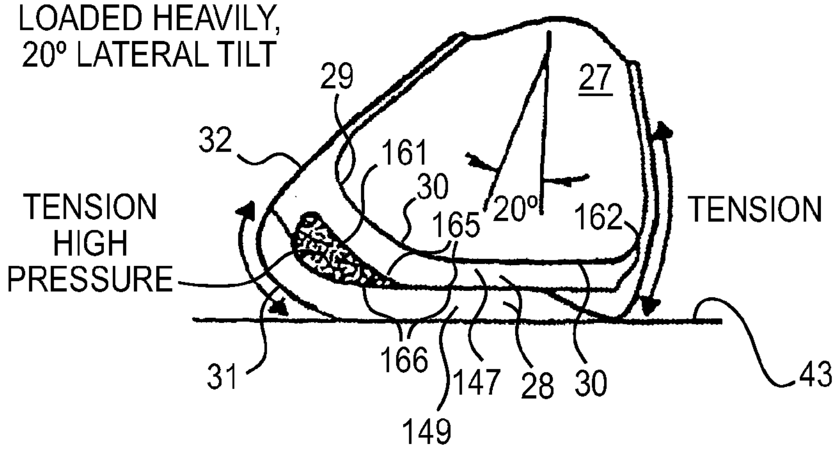
PRIOR ART



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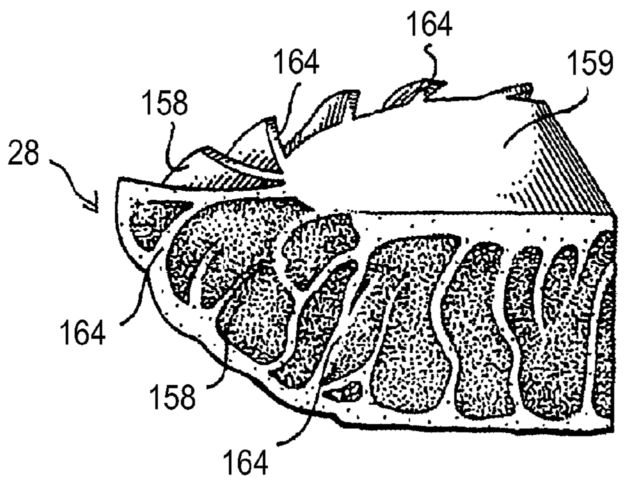

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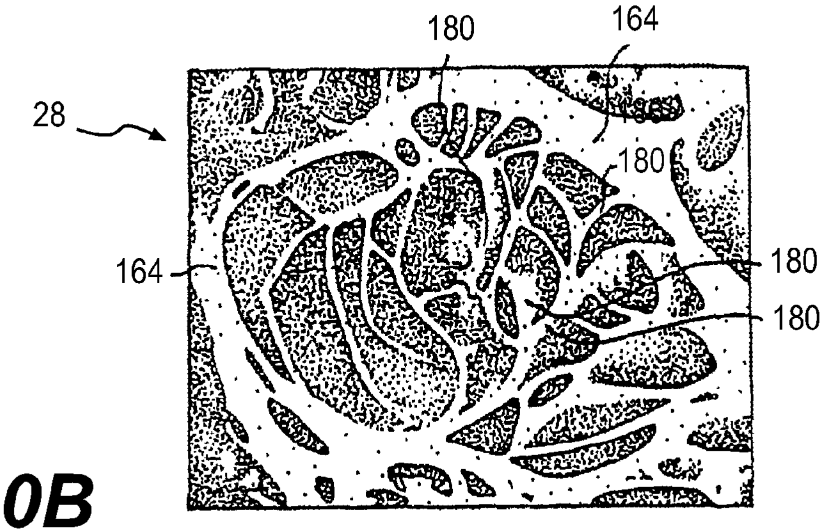

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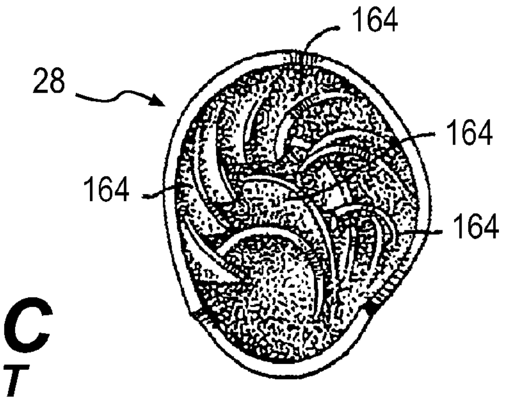

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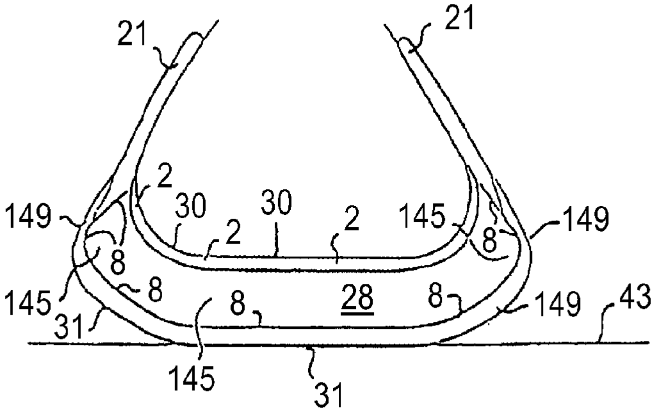

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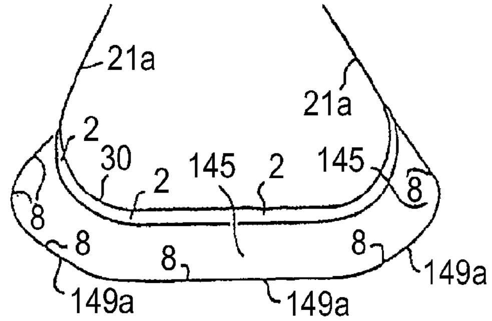

FIG. 11Q
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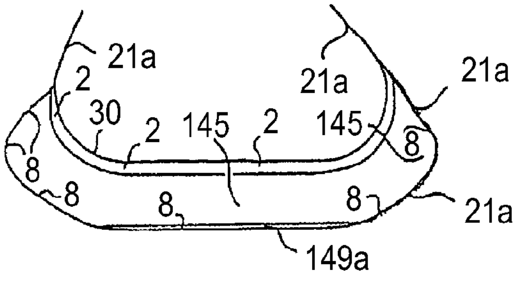

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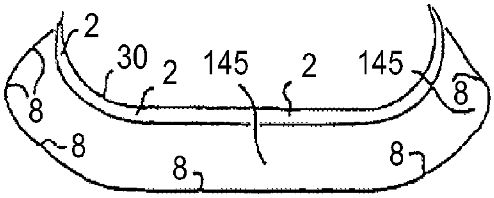

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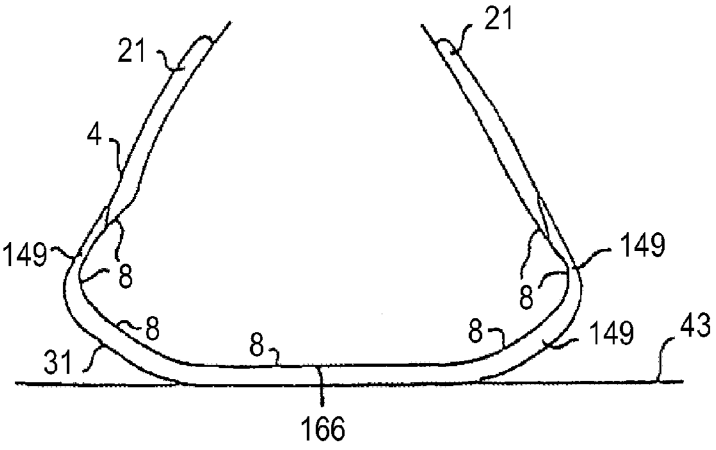

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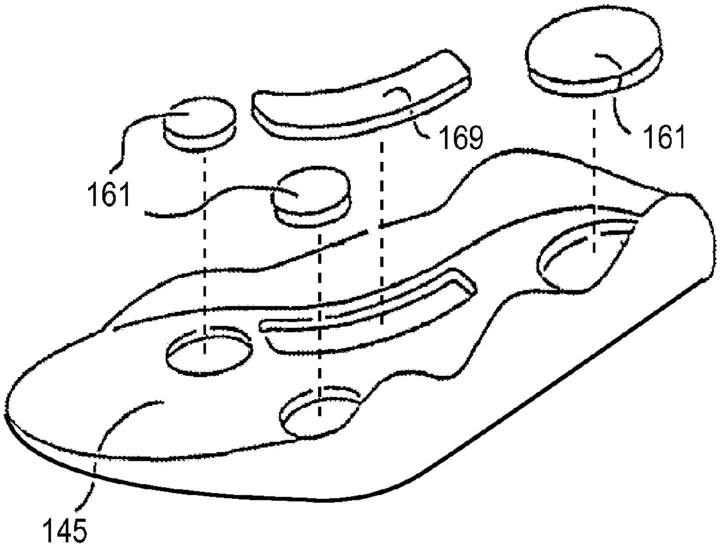

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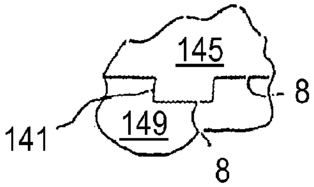

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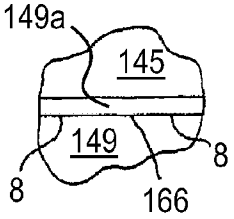

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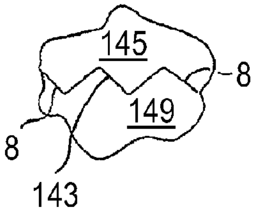

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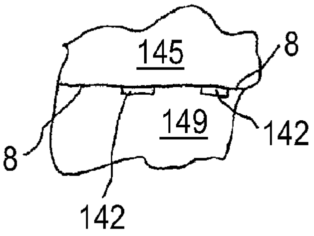
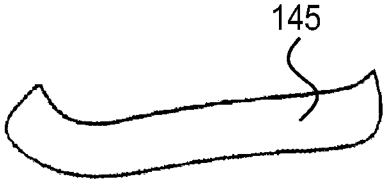


FIG. 11V
PRIOR ART

FIG. 11J
PRIOR ART

FIG. 11I
PRIOR ART



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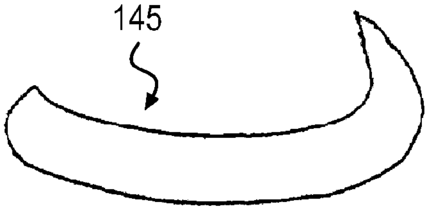

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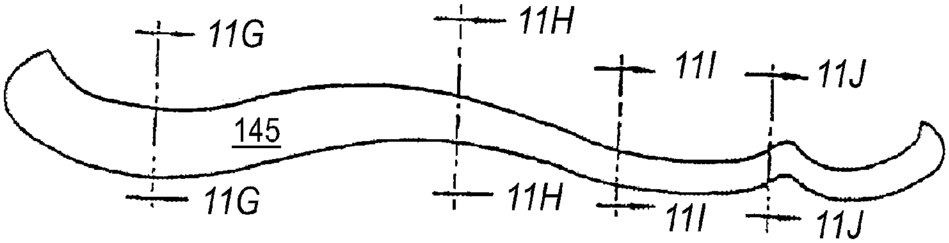


FIG. 11K
PRIOR ART

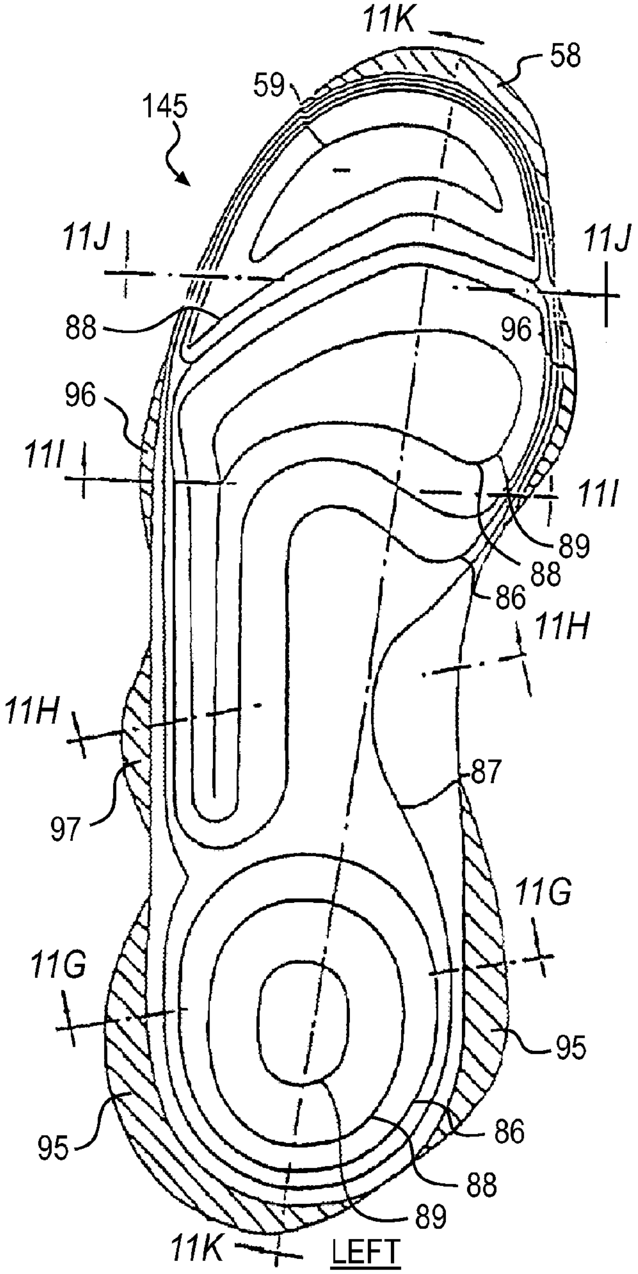


FIG. 11L
PRIOR ART

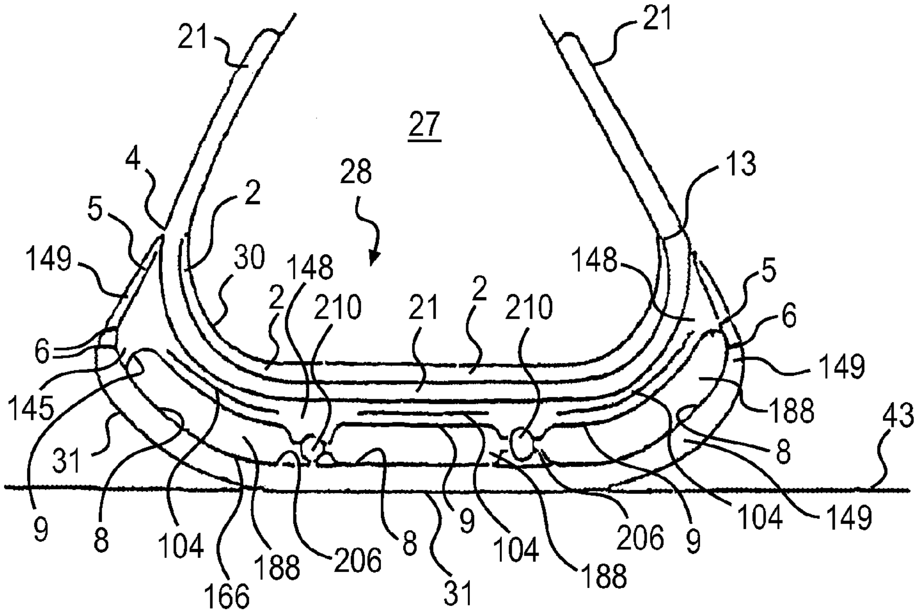


FIG. 11M
PRIOR ART

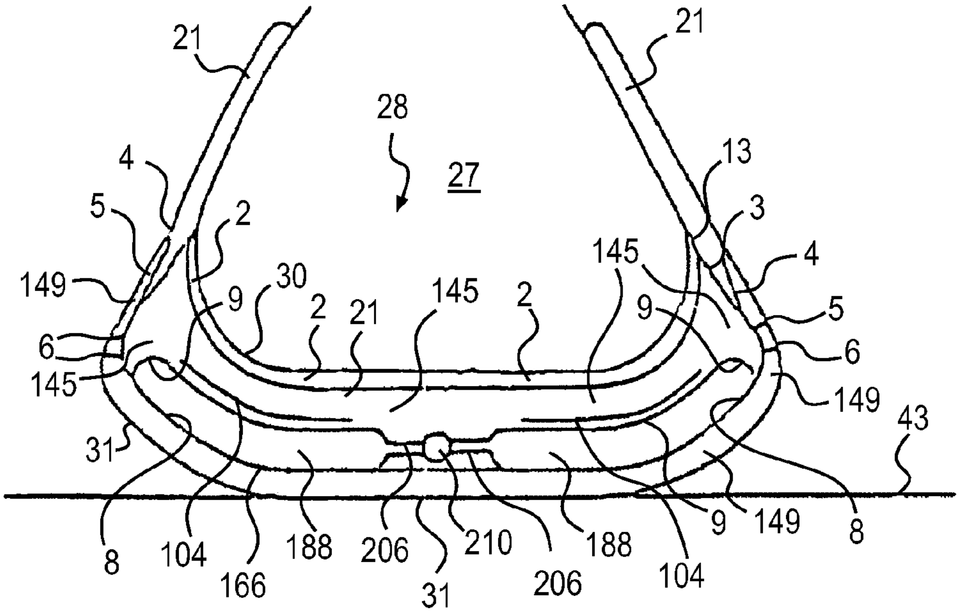


FIG. 11N
PRIOR ART

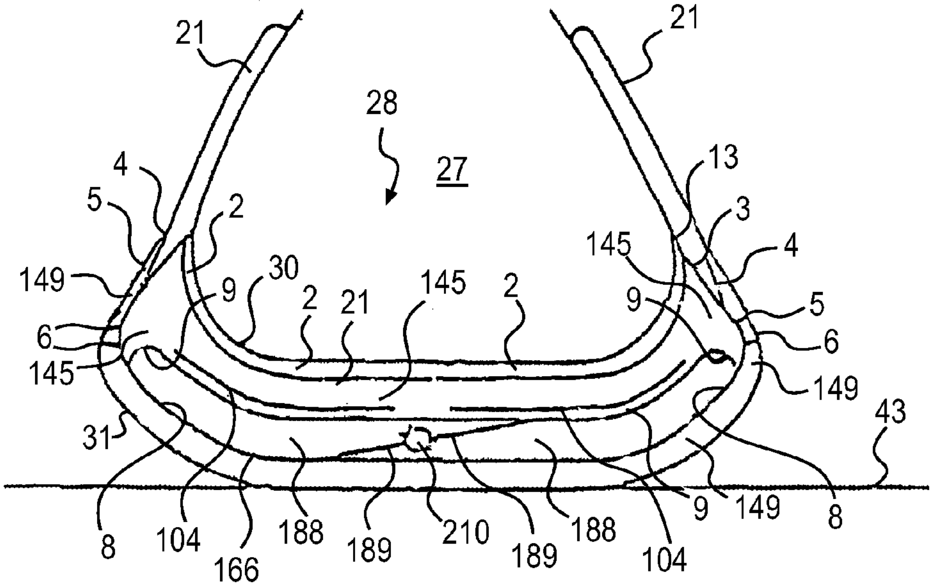


FIG. 11O
PRIOR ART

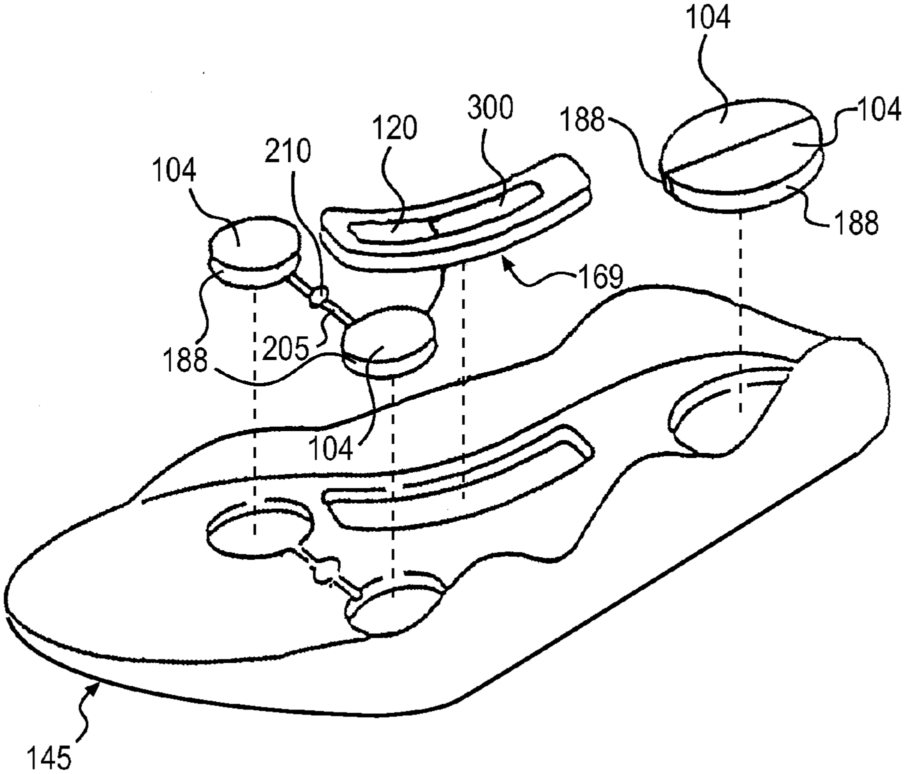


FIG. 11P
PRIOR ART

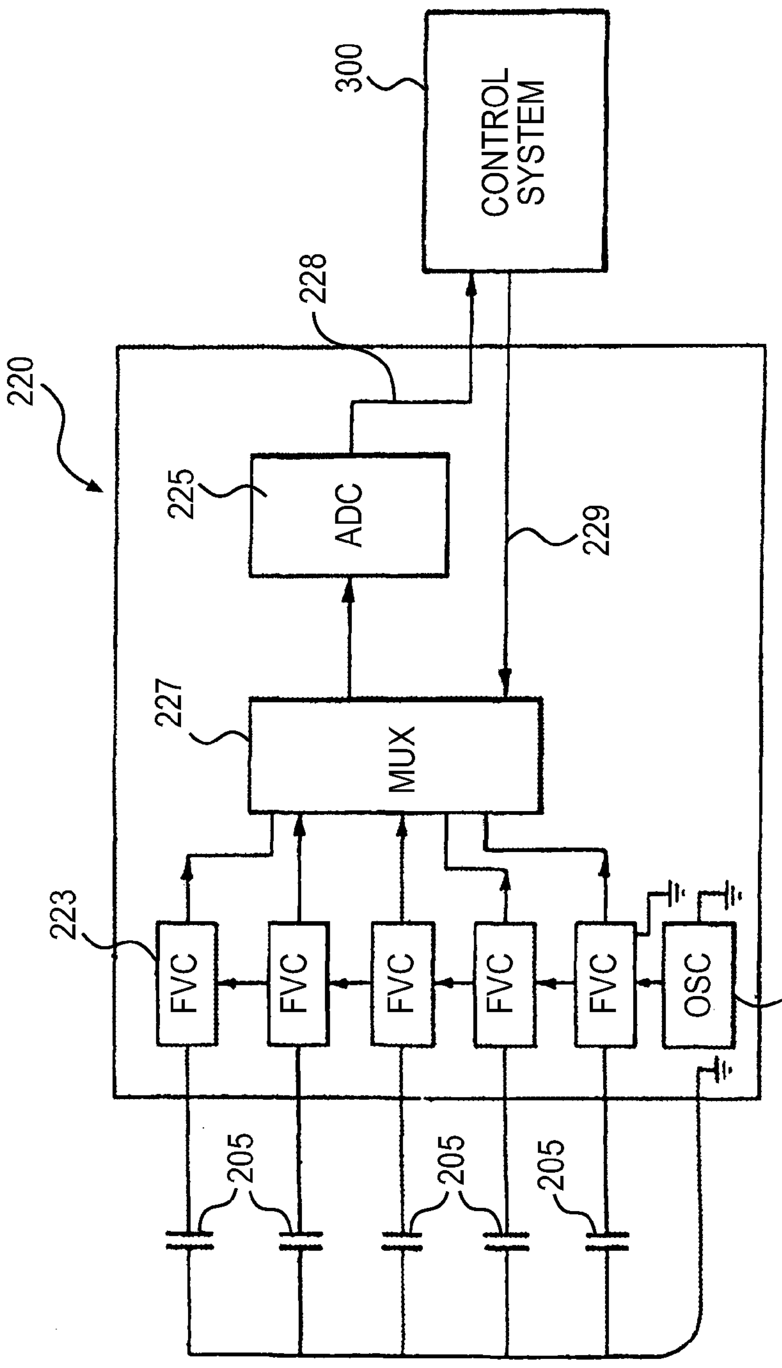


FIG. 11T
PRIOR ART

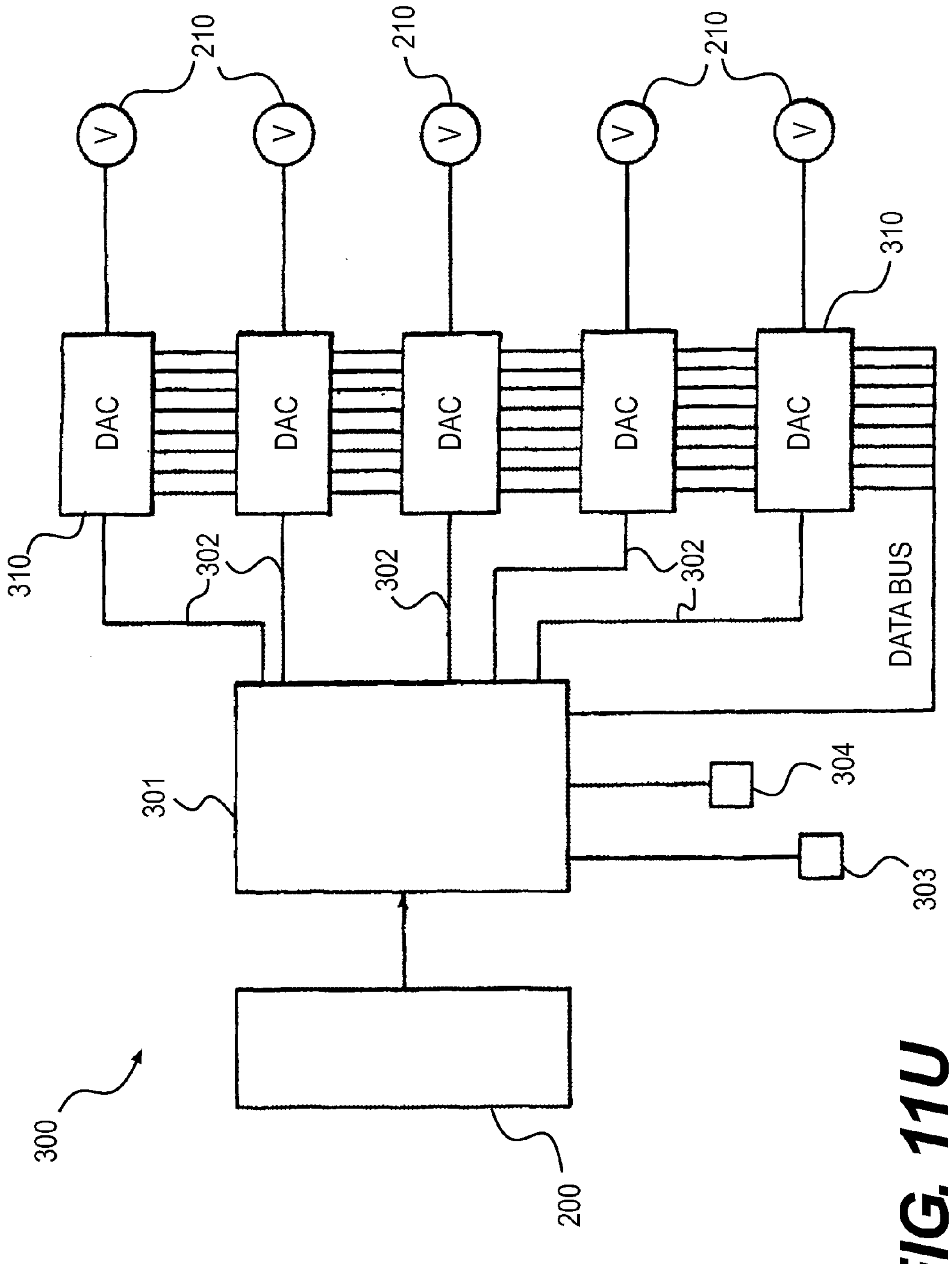


FIG. 11U
PRIOR ART

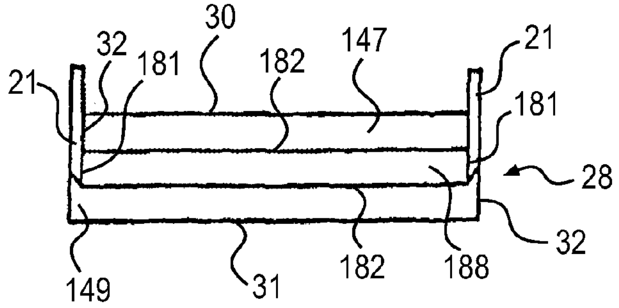


FIG. 12A
PRIOR ART

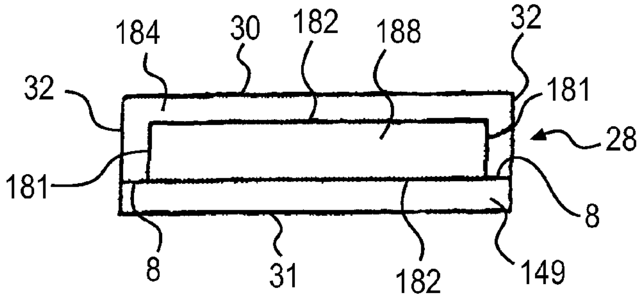


FIG. 12B
PRIOR ART

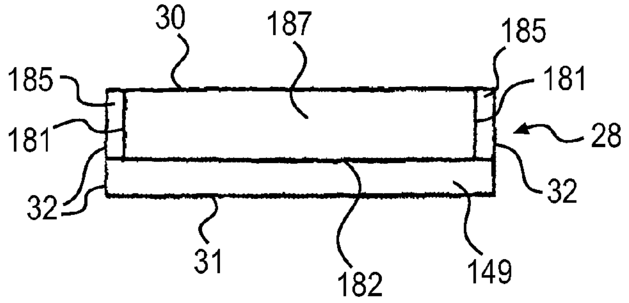


FIG. 12C
PRIOR ART

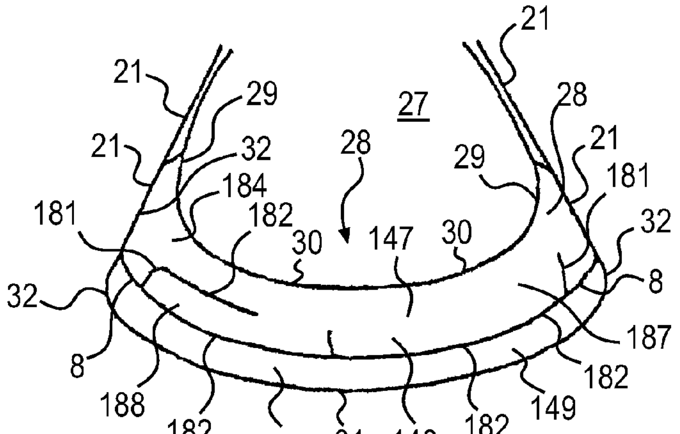


FIG. 12D
PRIOR ART

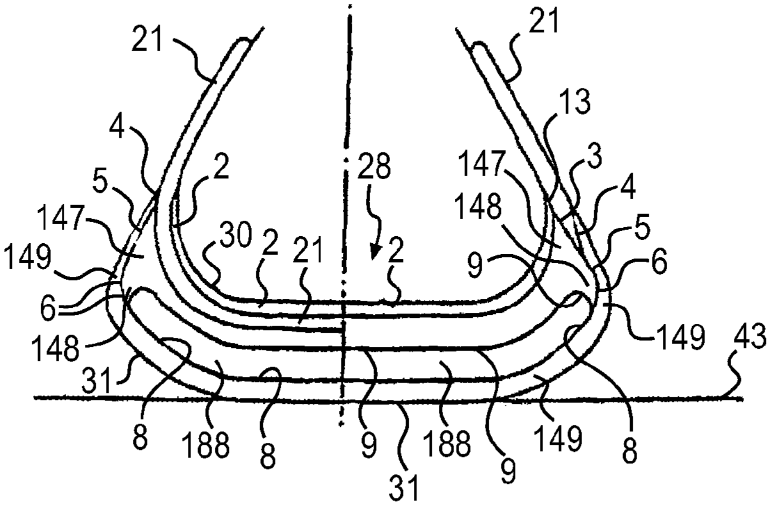


FIG. 13A
PRIOR ART

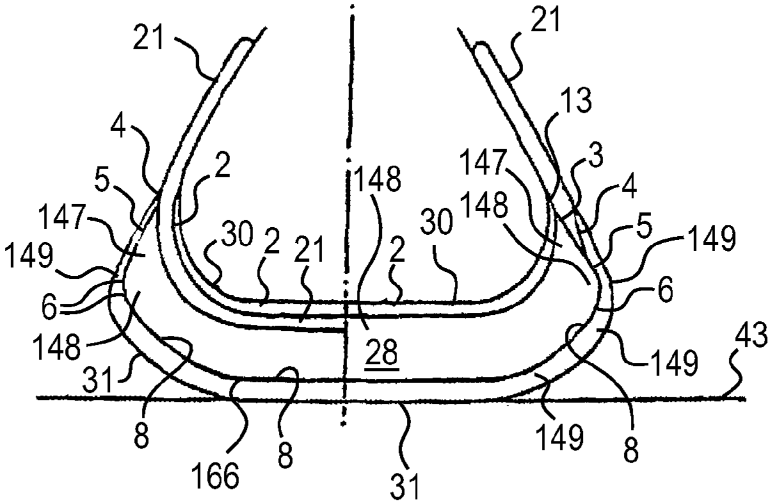


FIG. 13B
PRIOR ART

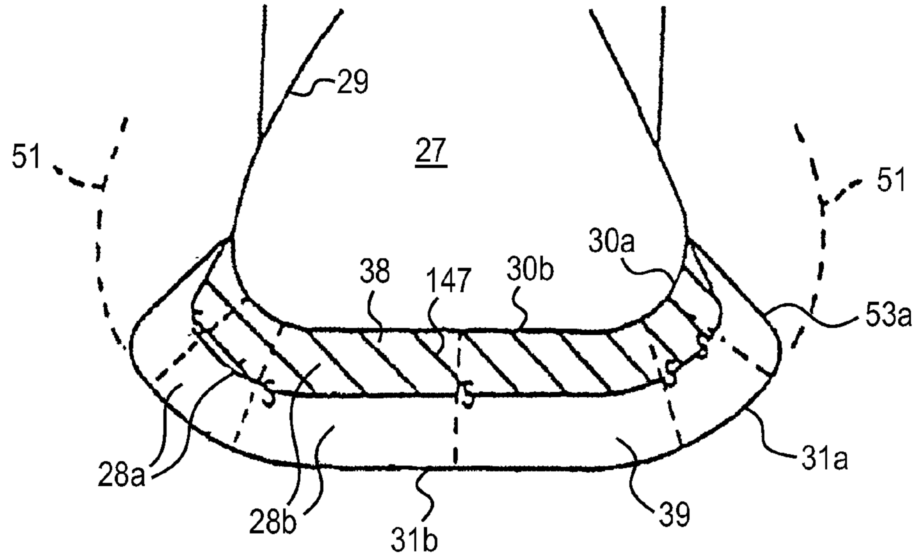


FIG. 14
PRIOR ART

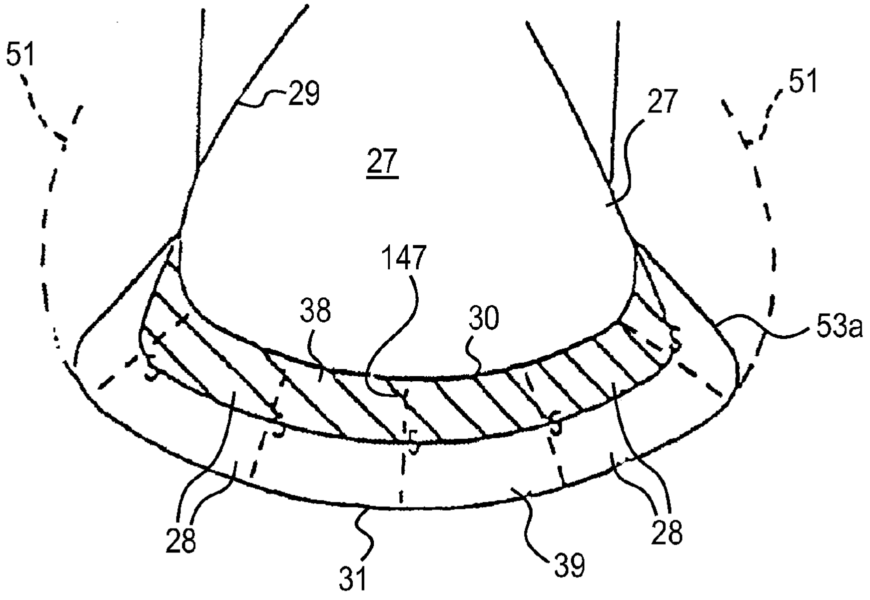


FIG. 15
PRIOR ART

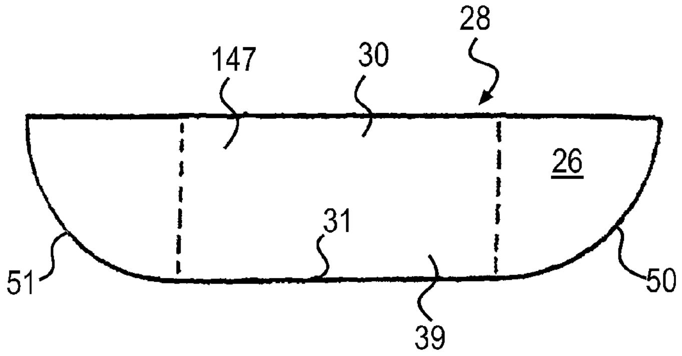


*FIG. 16A*
*PRIOR ART*

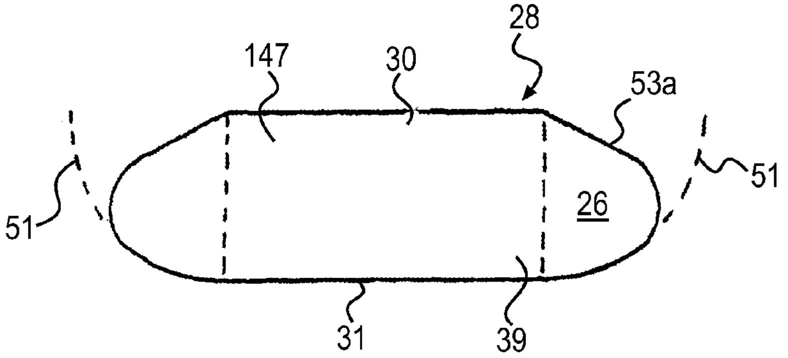


*FIG. 16B*
*PRIOR ART*

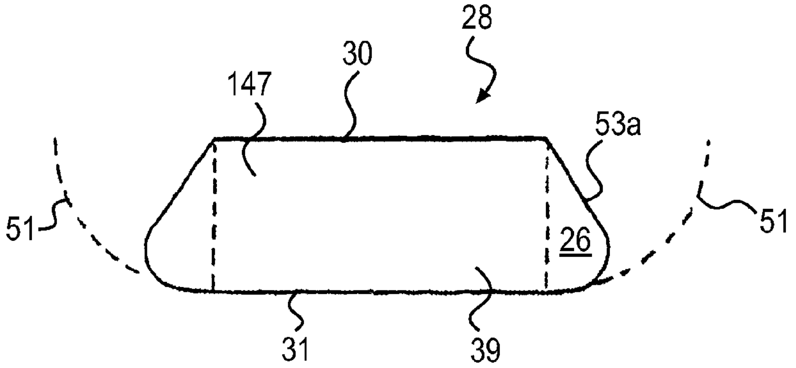


*FIG. 16C*
*PRIOR ART*

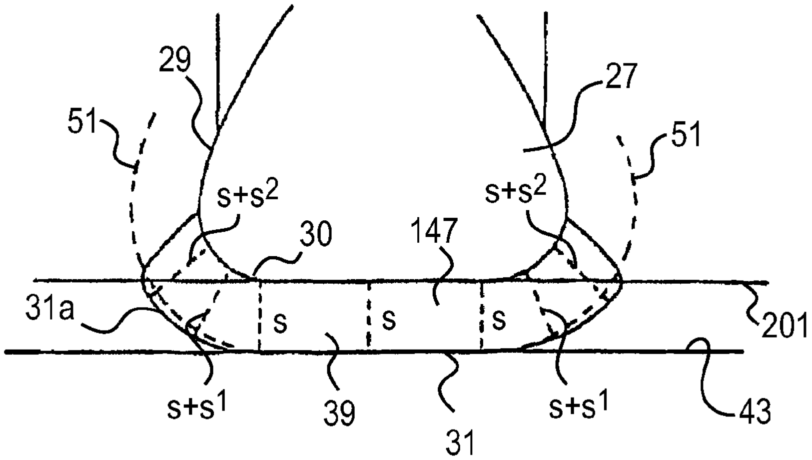


FIG. 17
PRIOR ART

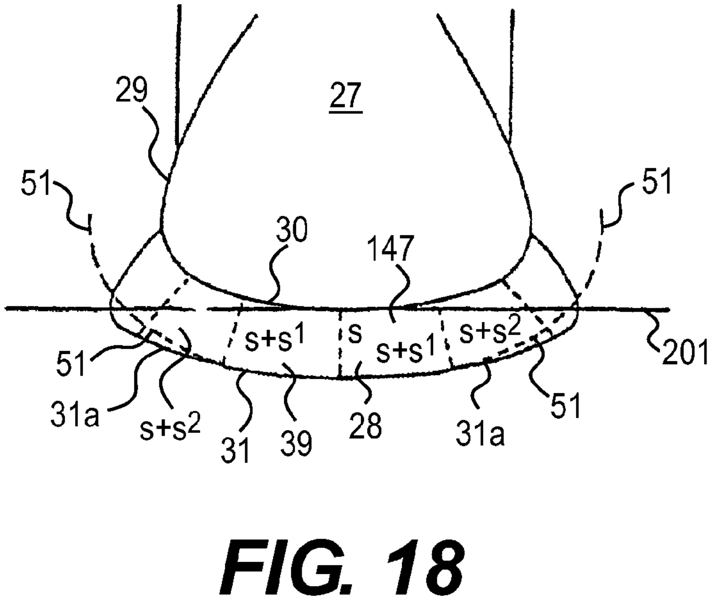


FIG. 18
PRIOR ART

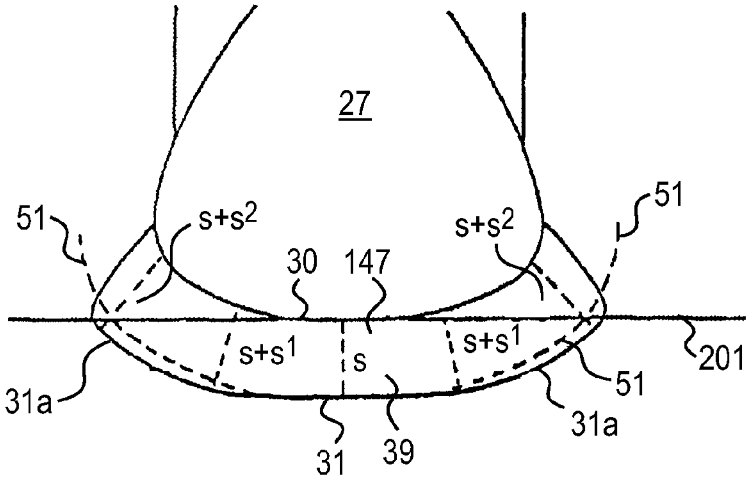


FIG. 19
PRIOR ART

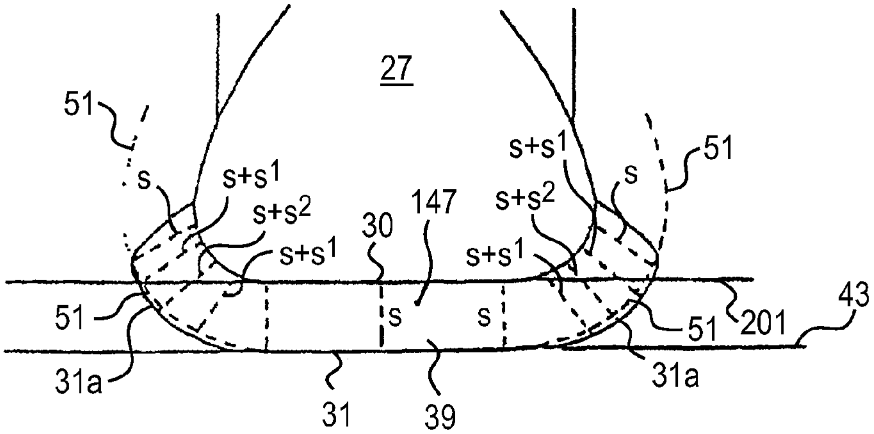


FIG. 20
PRIOR ART

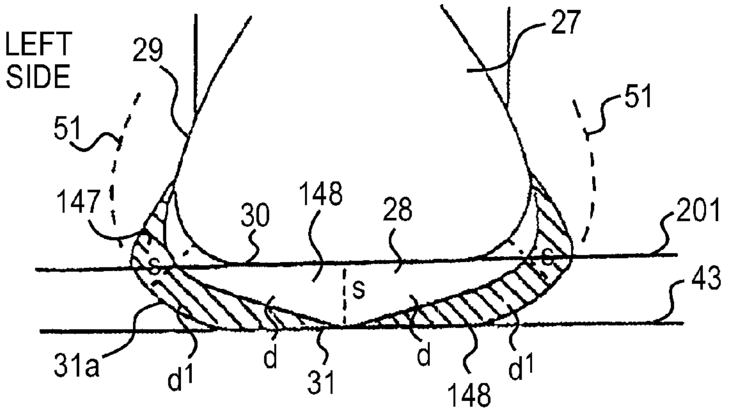


FIG. 21
PRIOR ART

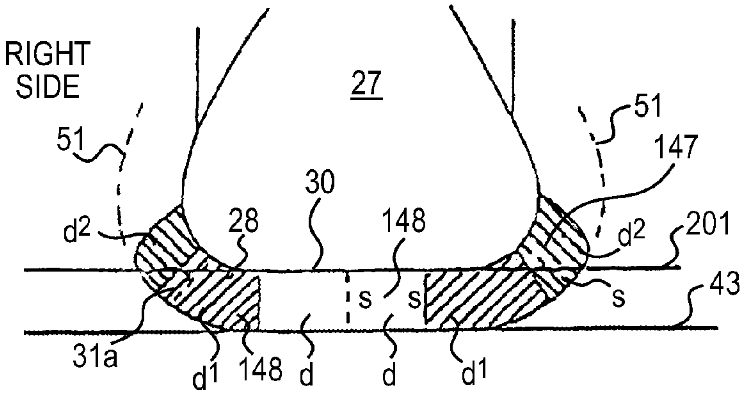


FIG. 22
PRIOR ART

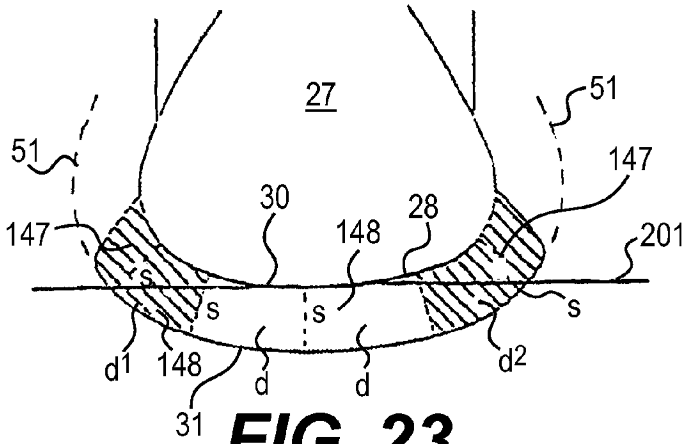


FIG. 23
PRIOR ART

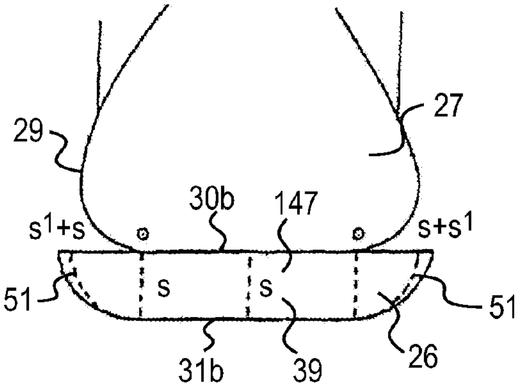


FIG. 24
PRIOR ART

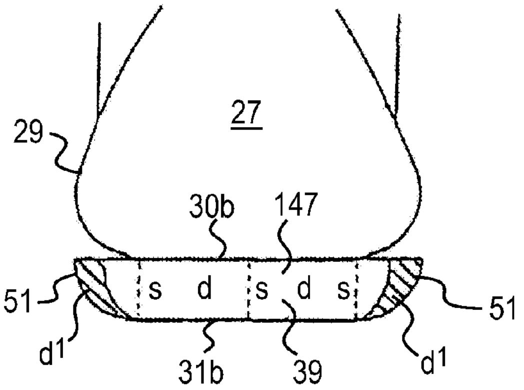


FIG. 25
PRIOR ART

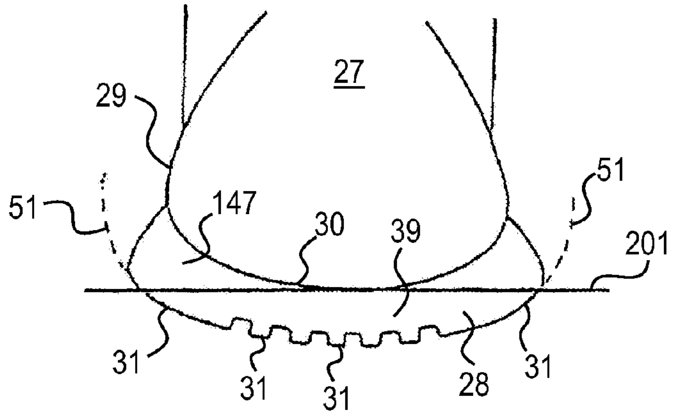


FIG. 26
PRIOR ART

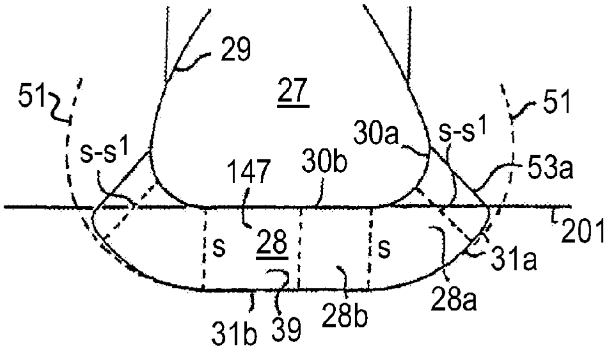


FIG. 27A
PRIOR ART

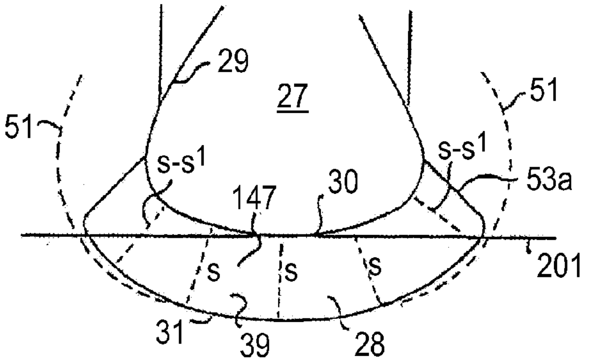


FIG. 27B
PRIOR ART

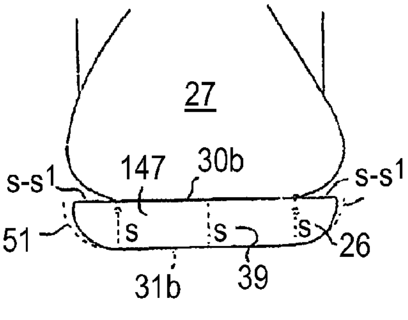


FIG. 27C
PRIOR ART

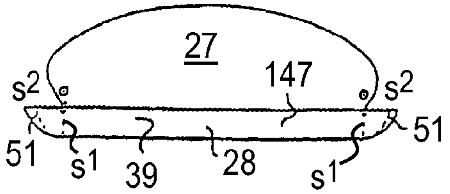


FIG. 28A
PRIOR ART

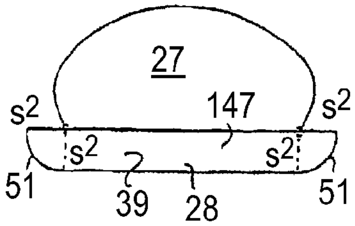


FIG. 28B
PRIOR ART

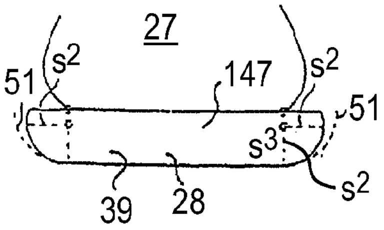


FIG. 28C
PRIOR ART

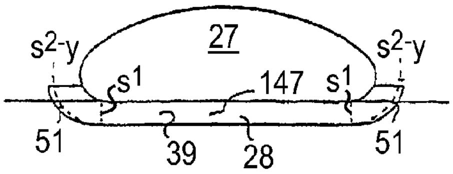


FIG. 28D
PRIOR ART

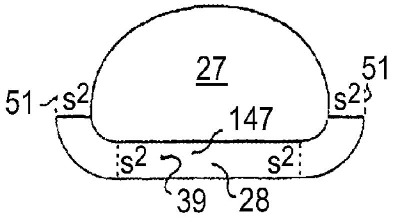


FIG. 28E
PRIOR ART

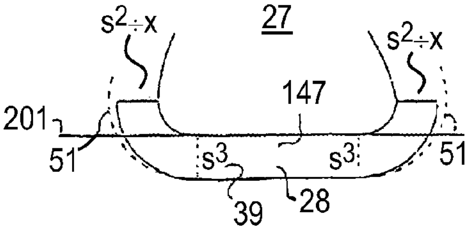


FIG. 28F
PRIOR ART

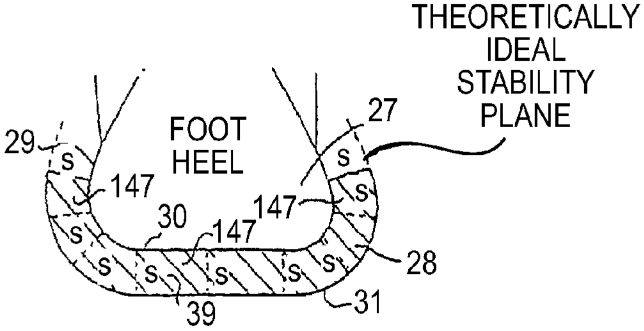


FIG. 29
PRIOR ART

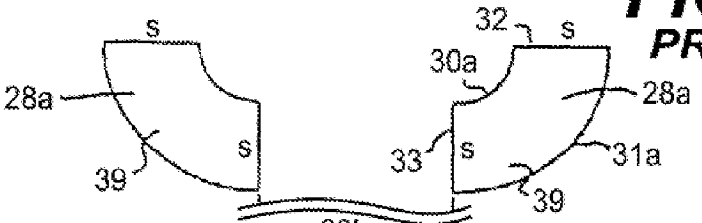


FIG. 30A
PRIOR ART

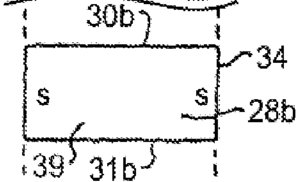


FIG. 30B
PRIOR ART

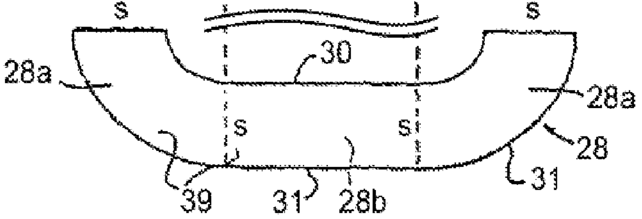


FIG. 30C
PRIOR ART

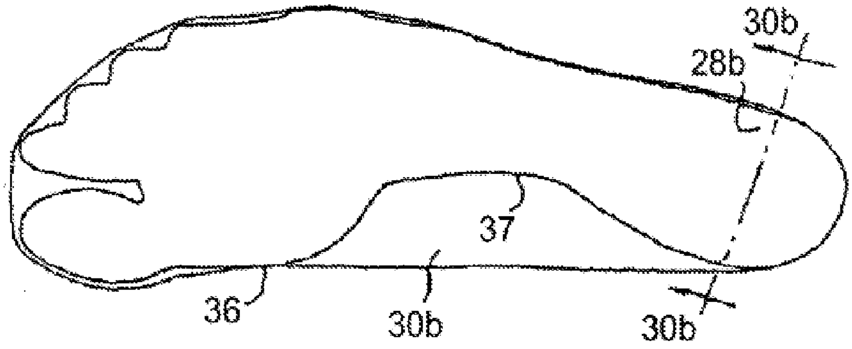


FIG. 30D
PRIOR ART

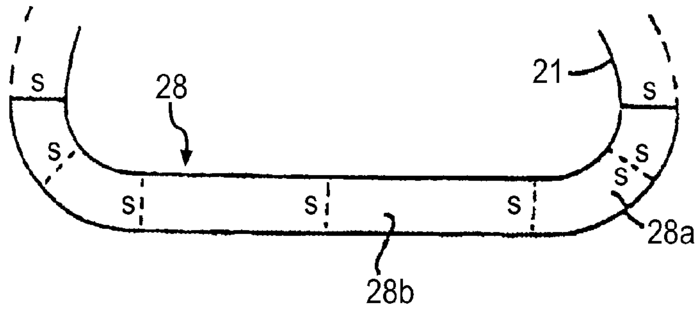


FIG. 31A
PRIOR ART

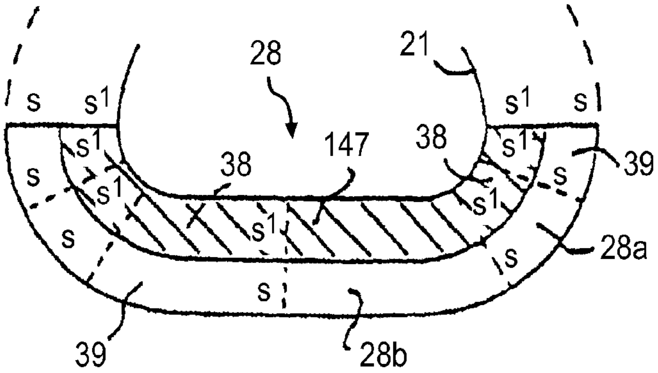


FIG. 31B
PRIOR ART

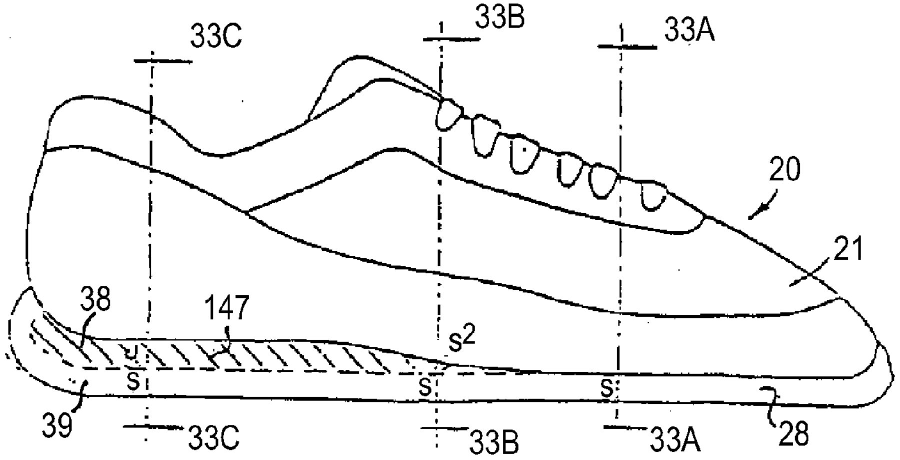


FIG. 32
PRIOR ART

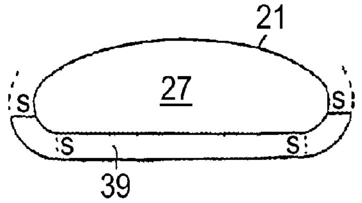


FIG. 33A
PRIOR ART

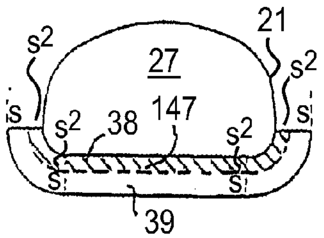


FIG. 33B
PRIOR ART

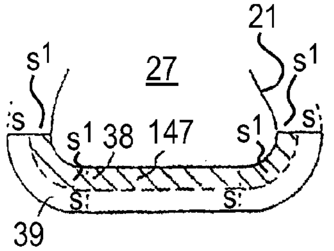


FIG. 33C
PRIOR ART

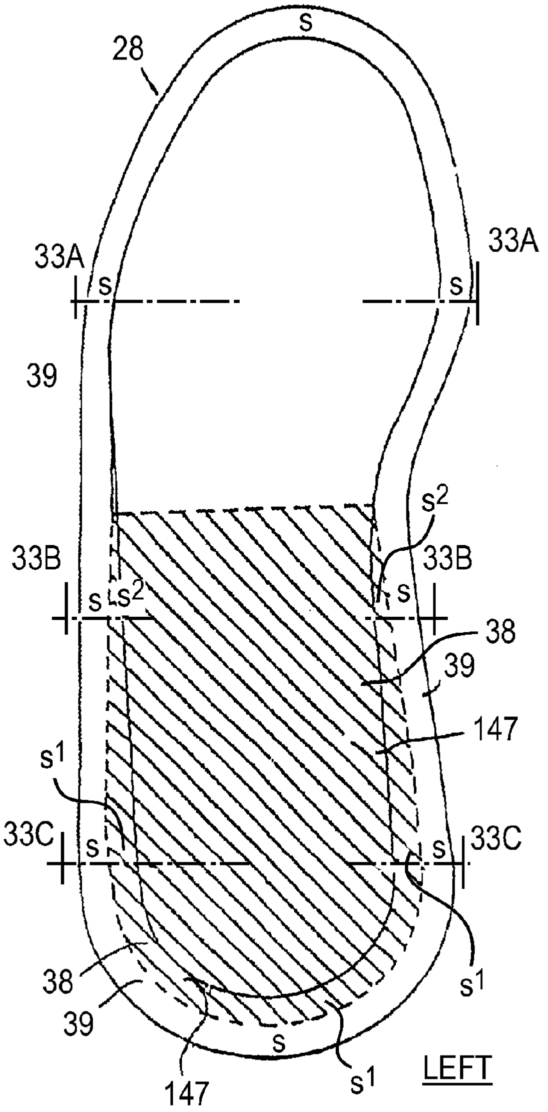


FIG. 33D
PRIOR ART

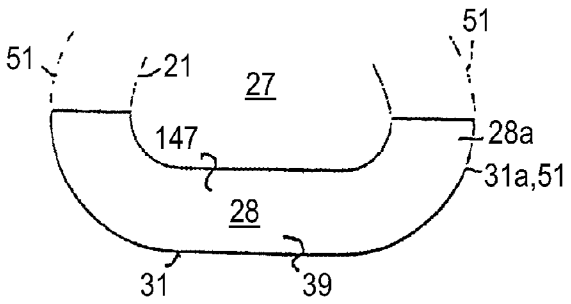


FIG. 34A
PRIOR ART

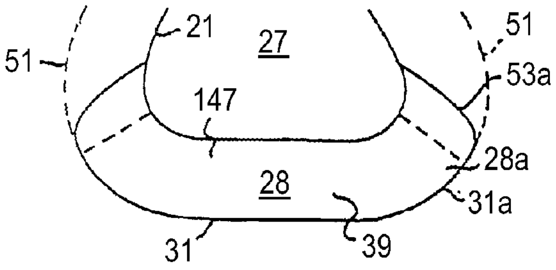


FIG. 34B
PRIOR ART

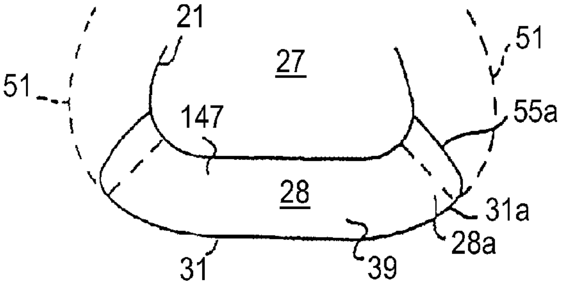


FIG. 34C
PRIOR ART

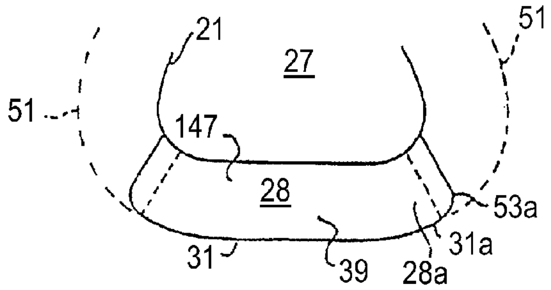


FIG. 34D
PRIOR ART

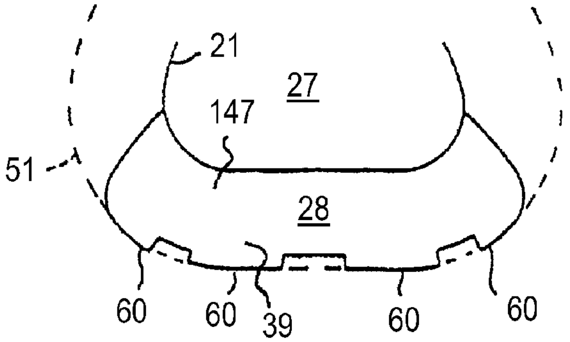


FIG. 35A
PRIOR ART

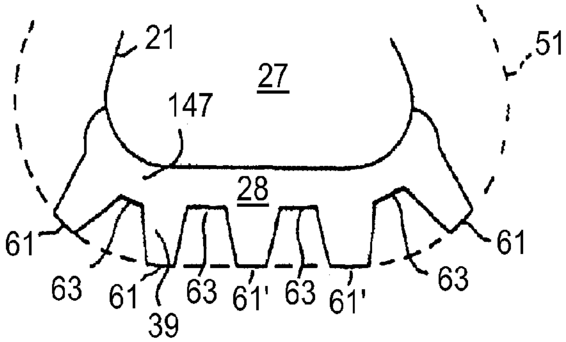


FIG. 35B
PRIOR ART

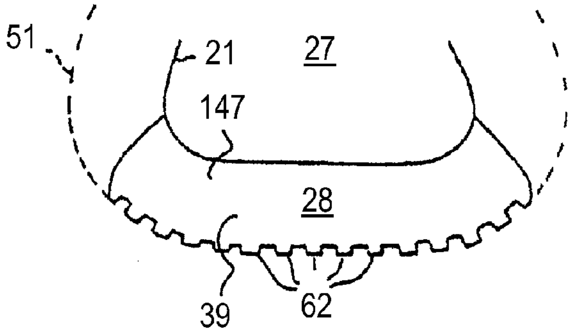


FIG. 35C
PRIOR ART

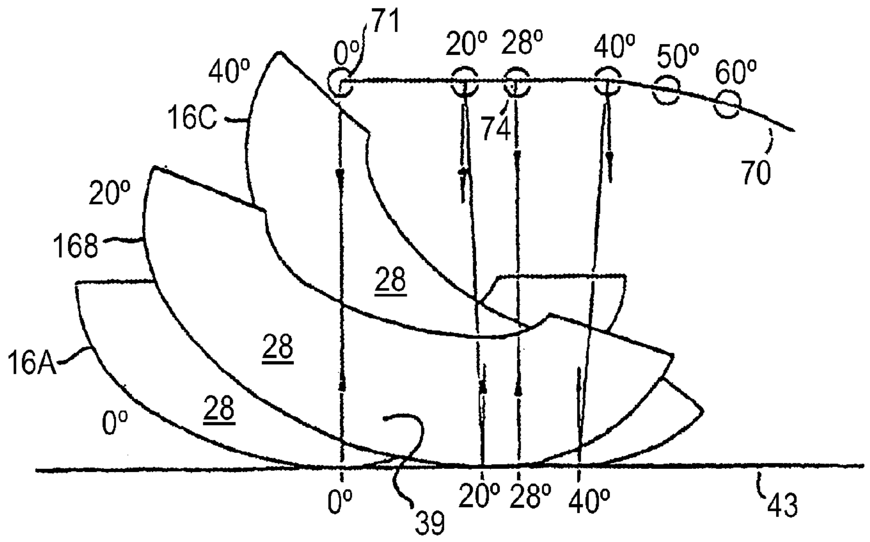


FIG. 36
PRIOR ART

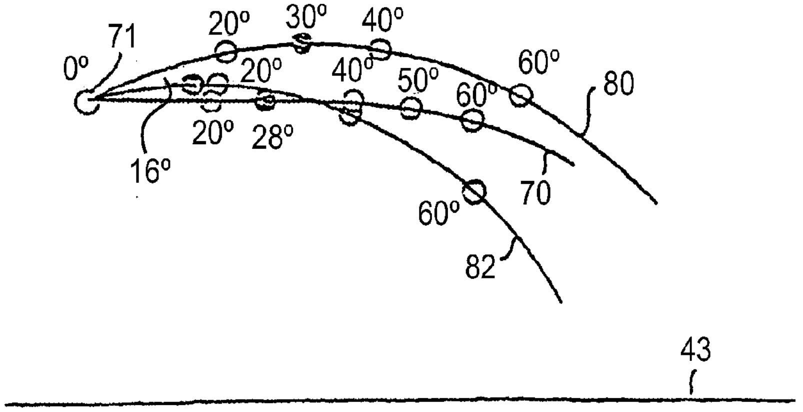


FIG. 37
PRIOR ART

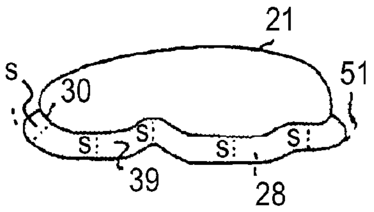


FIG. 38A
PRIOR ART

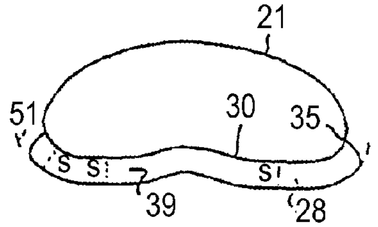


FIG. 38B
PRIOR ART

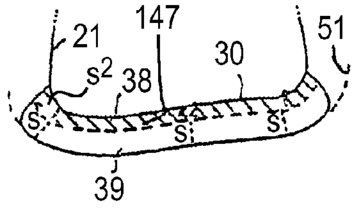


FIG. 38C
PRIOR ART

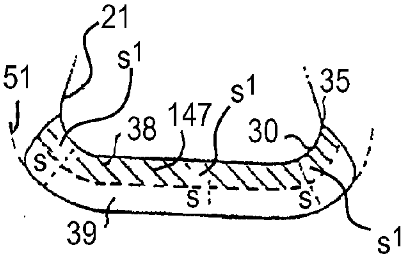


FIG. 38D
PRIOR ART

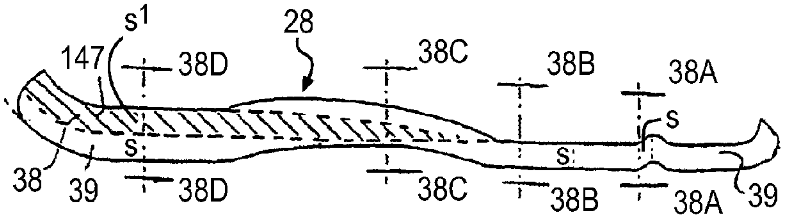


FIG. 38E
PRIOR ART

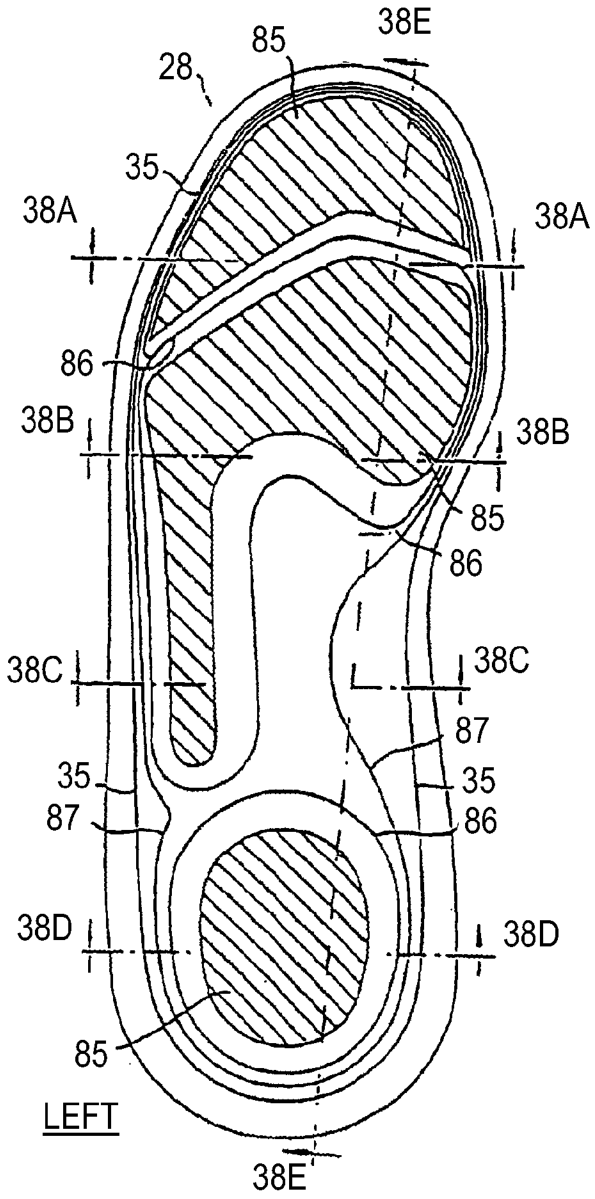


FIG. 38F
PRIOR ART

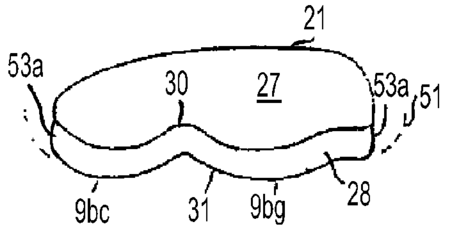


FIG. 39A
PRIOR ART

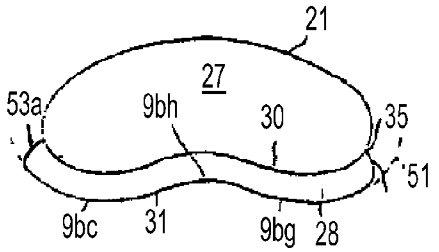


FIG. 39B
PRIOR ART

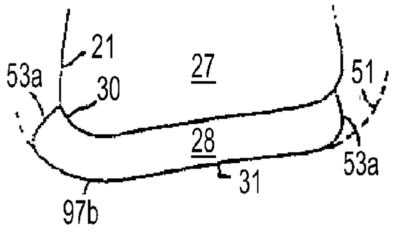


FIG. 39C
PRIOR ART

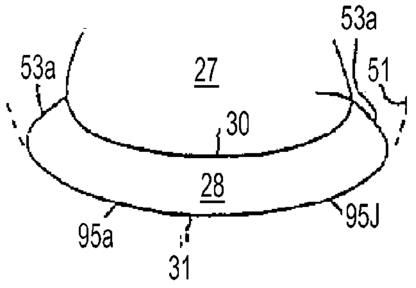


FIG. 39D
PRIOR ART

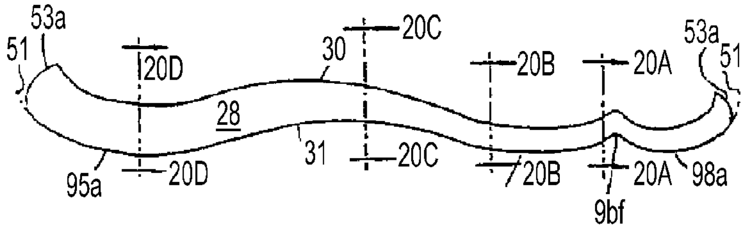


FIG. 39E
PRIOR ART

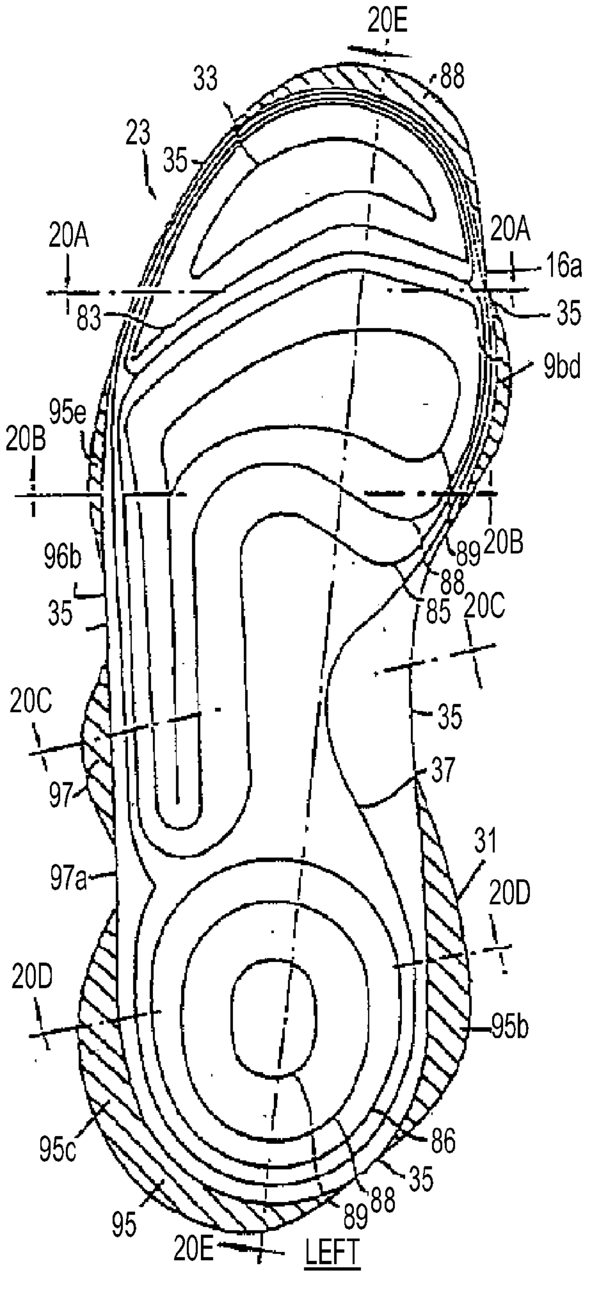


FIG. 40
PRIOR ART

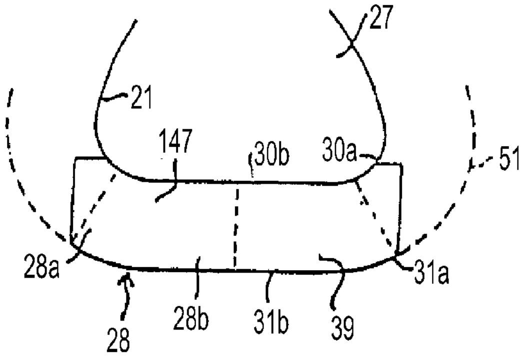


FIG. 41A
PRIOR ART

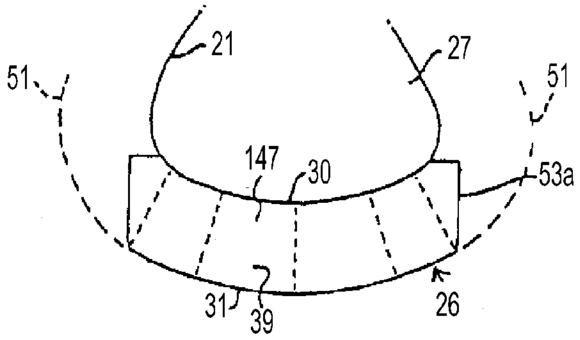


FIG. 41B
PRIOR ART

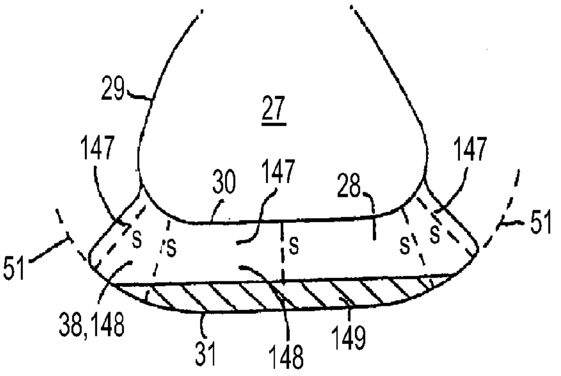


FIG. 42A
PRIOR ART

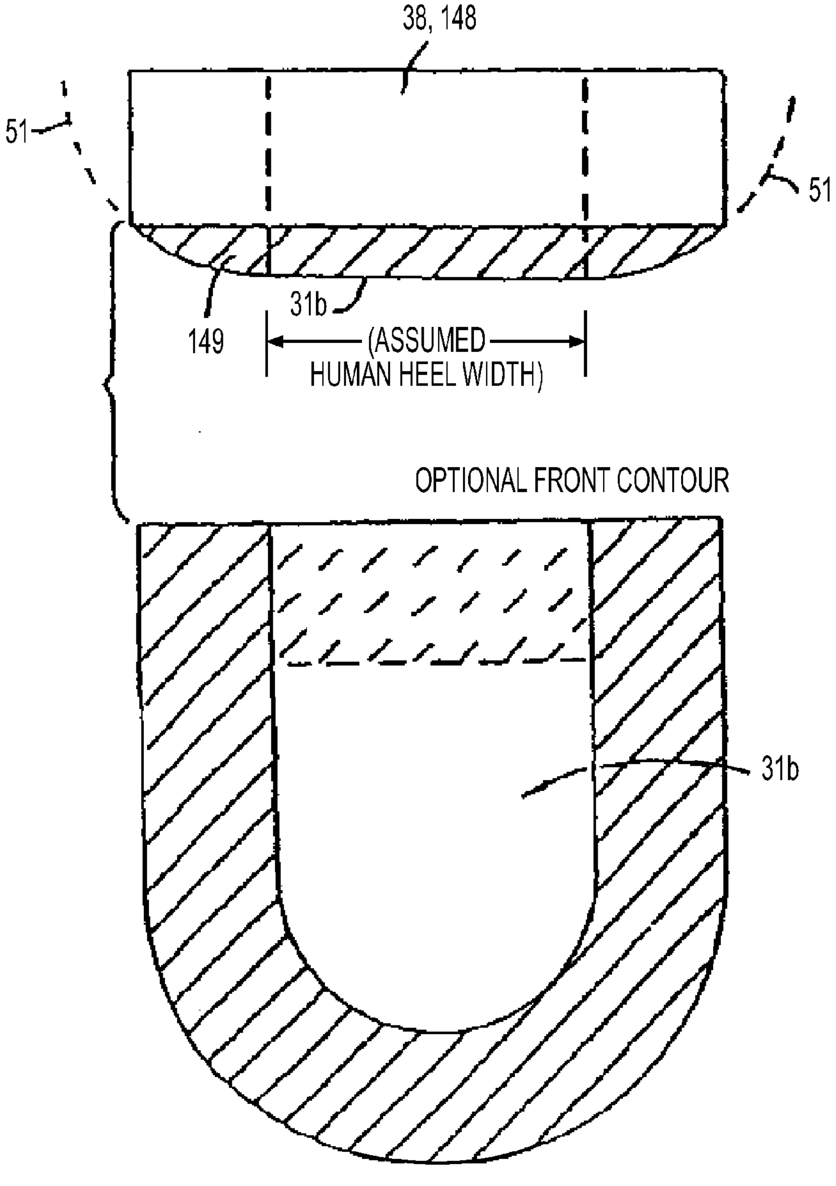


FIG. 42B
PRIOR ART

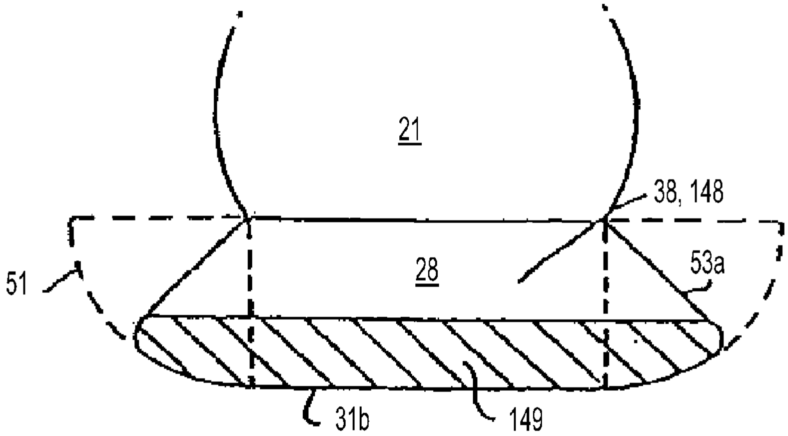


FIG. 42C
PRIOR ART

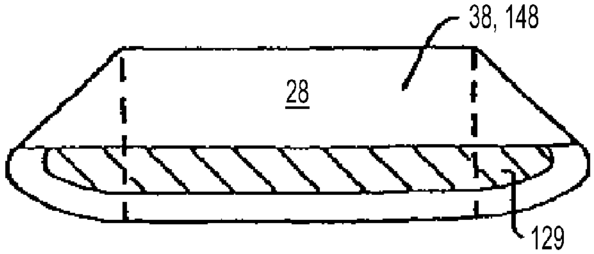


FIG. 42D
PRIOR ART

**FIG. 43**
**PRIOR ART**

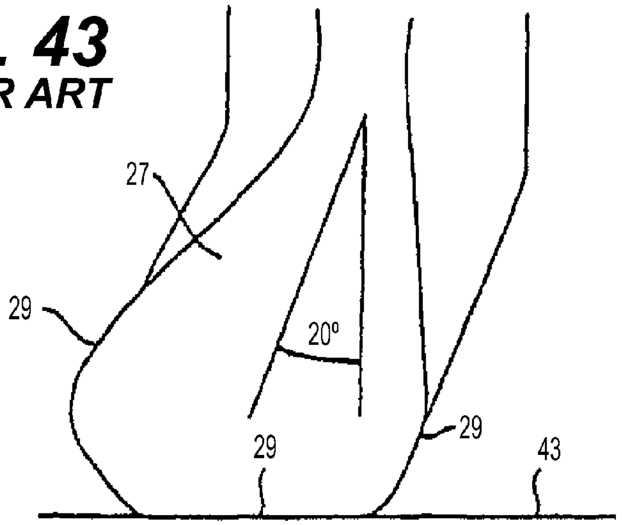
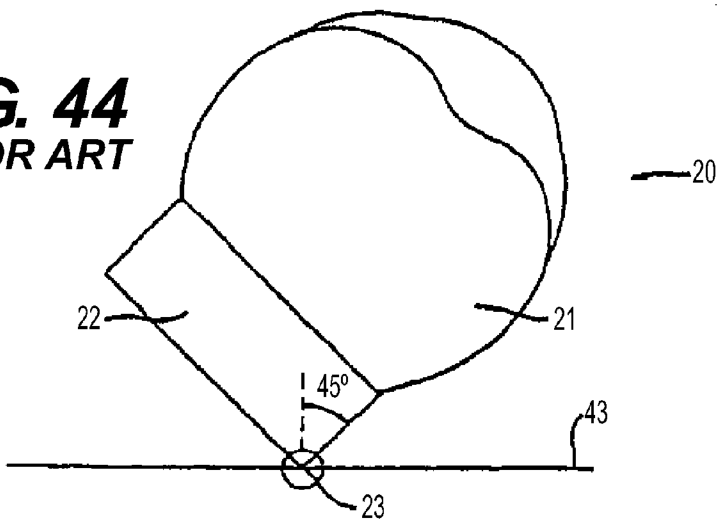


**FIG. 44**
**PRIOR ART**



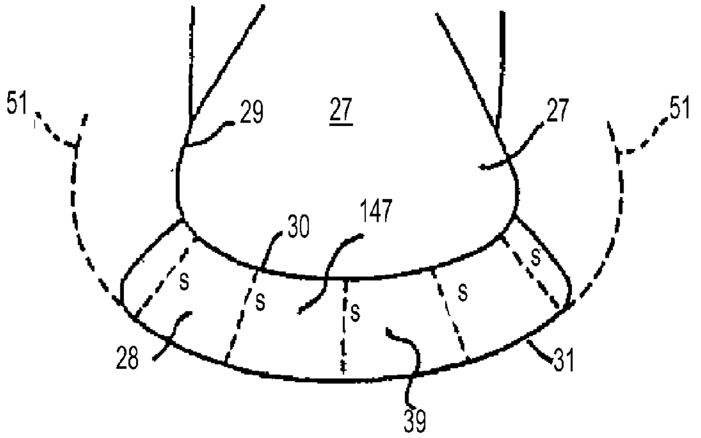


FIG. 45A
PRIOR ART

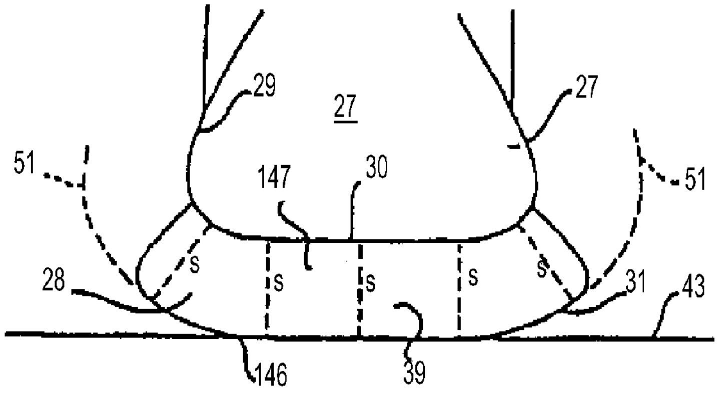


FIG. 45B
PRIOR ART

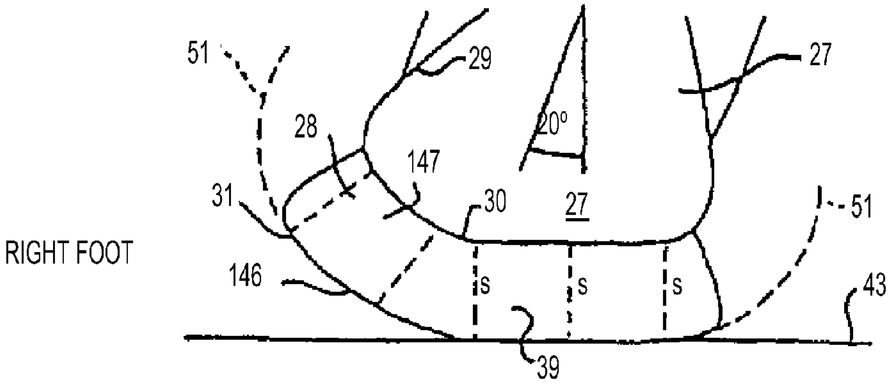


FIG. 45C
PRIOR ART

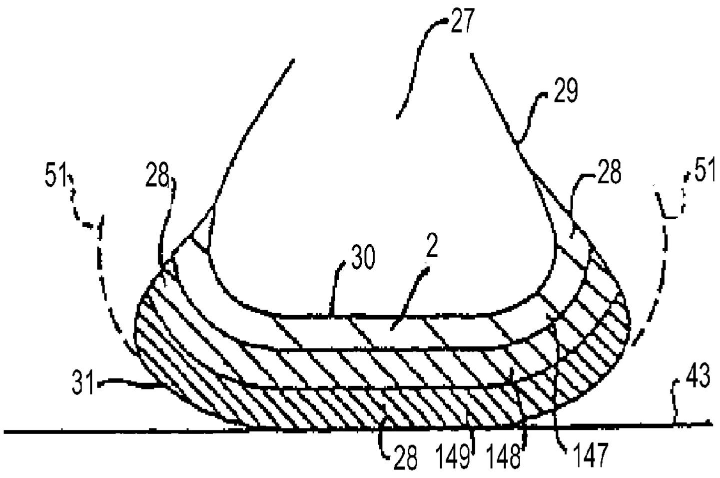


FIG. 46
PRIOR ART

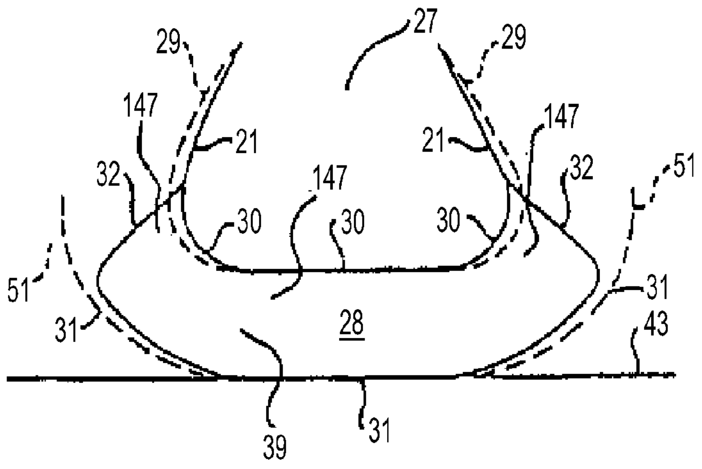


FIG. 47
PRIOR ART

**FIG. 48A**
**PRIOR ART**

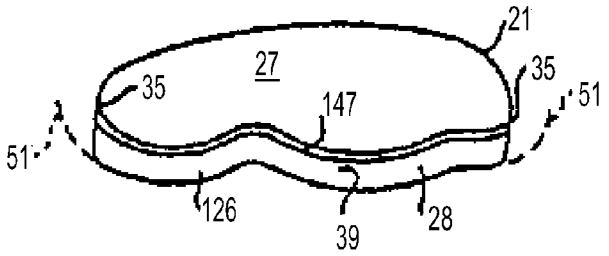


**FIG. 48B**
**PRIOR ART**

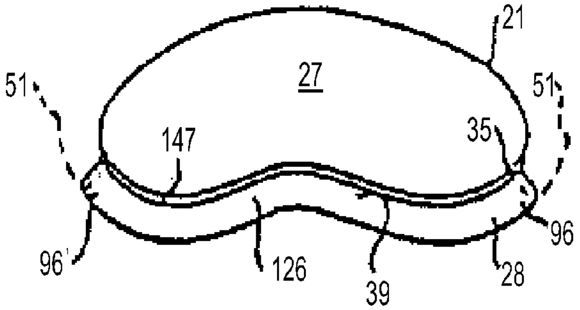


**FIG. 48C**
**PRIOR ART**

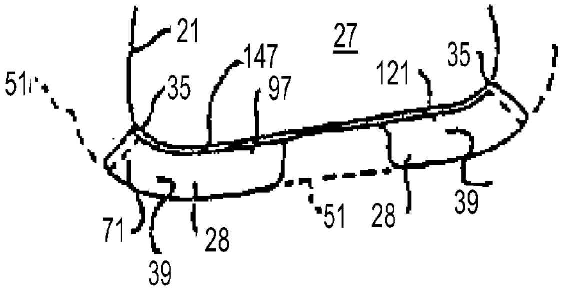
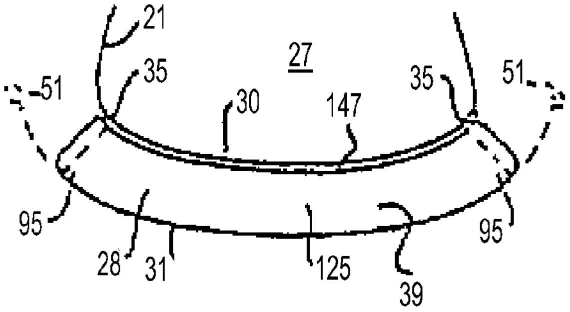


**FIG. 48D**
**PRIOR ART**



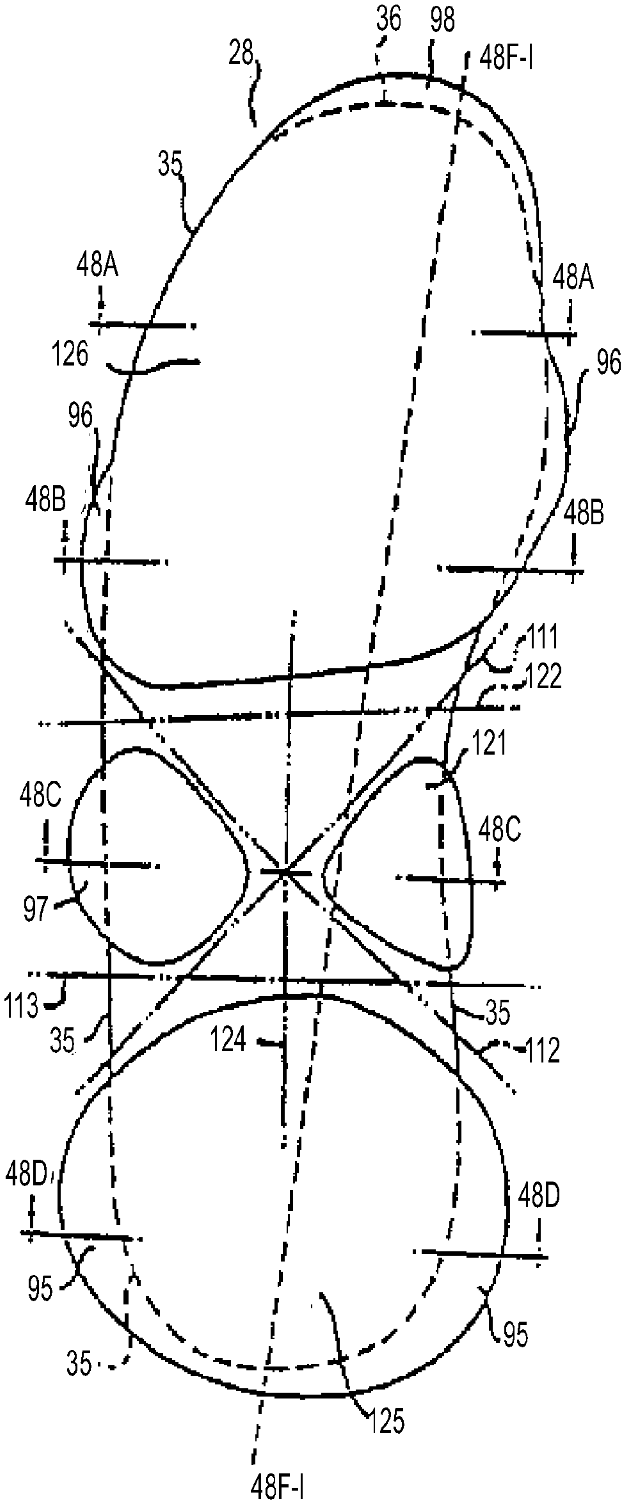


FIG. 48E
PRIOR ART

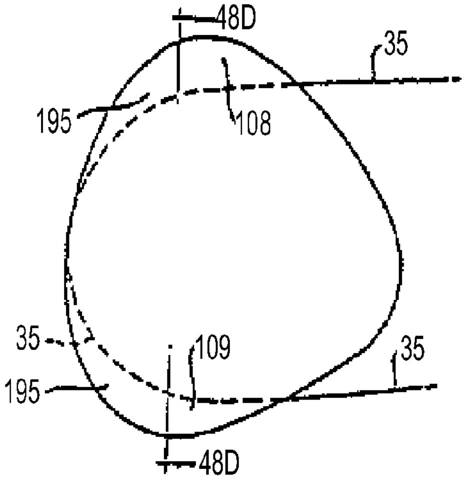


FIG. 48E'
PRIOR ART

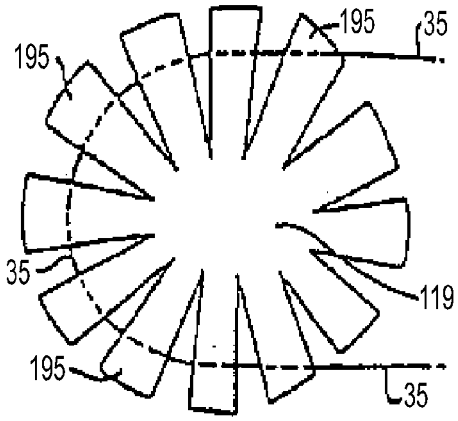


FIG. 48J
PRIOR ART

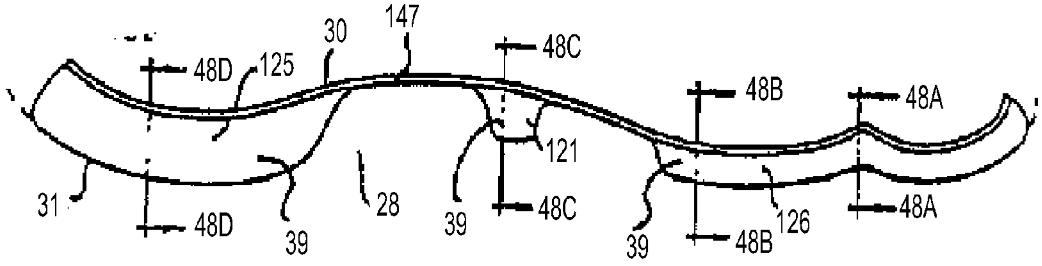


FIG. 48F
PRIOR ART

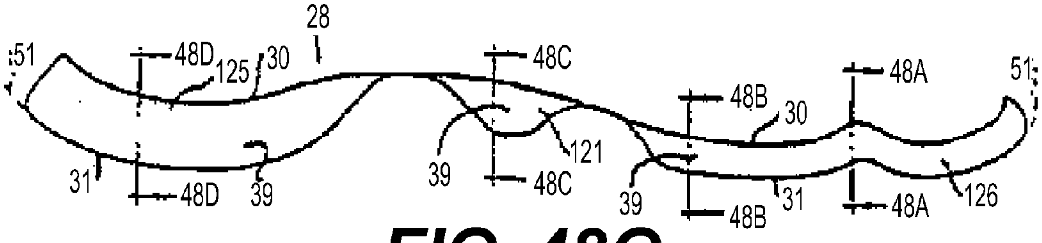


FIG. 48G
PRIOR ART

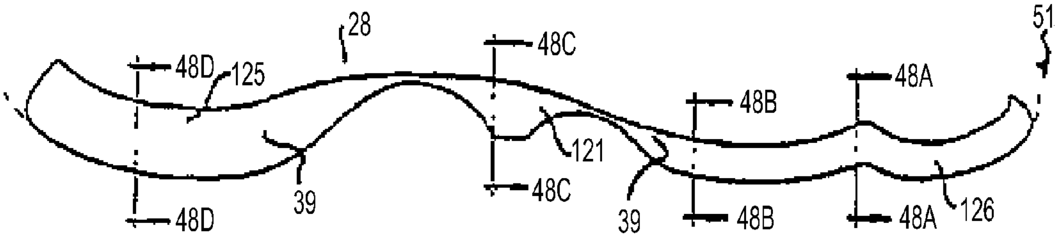


FIG. 48H
PRIOR ART

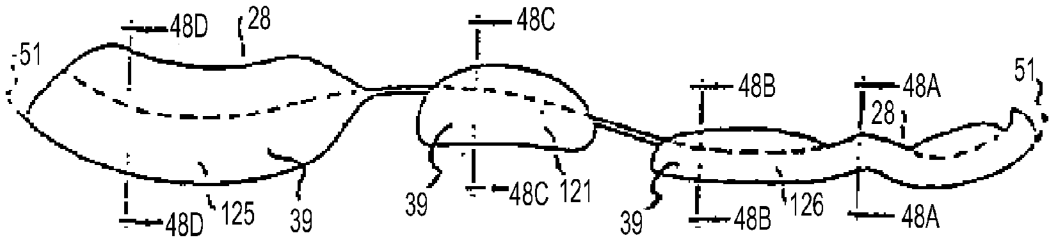


FIG. 48I
PRIOR ART

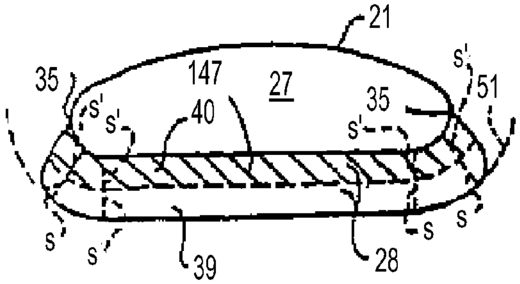


FIG. 49A
PRIOR ART

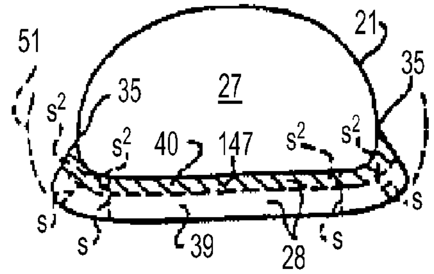


FIG. 49B
PRIOR ART

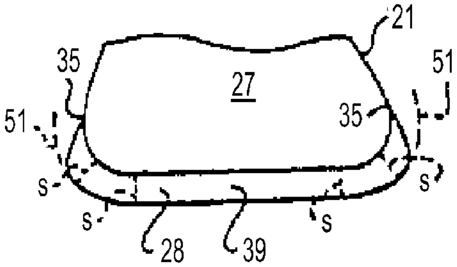


FIG. 49C
PRIOR ART

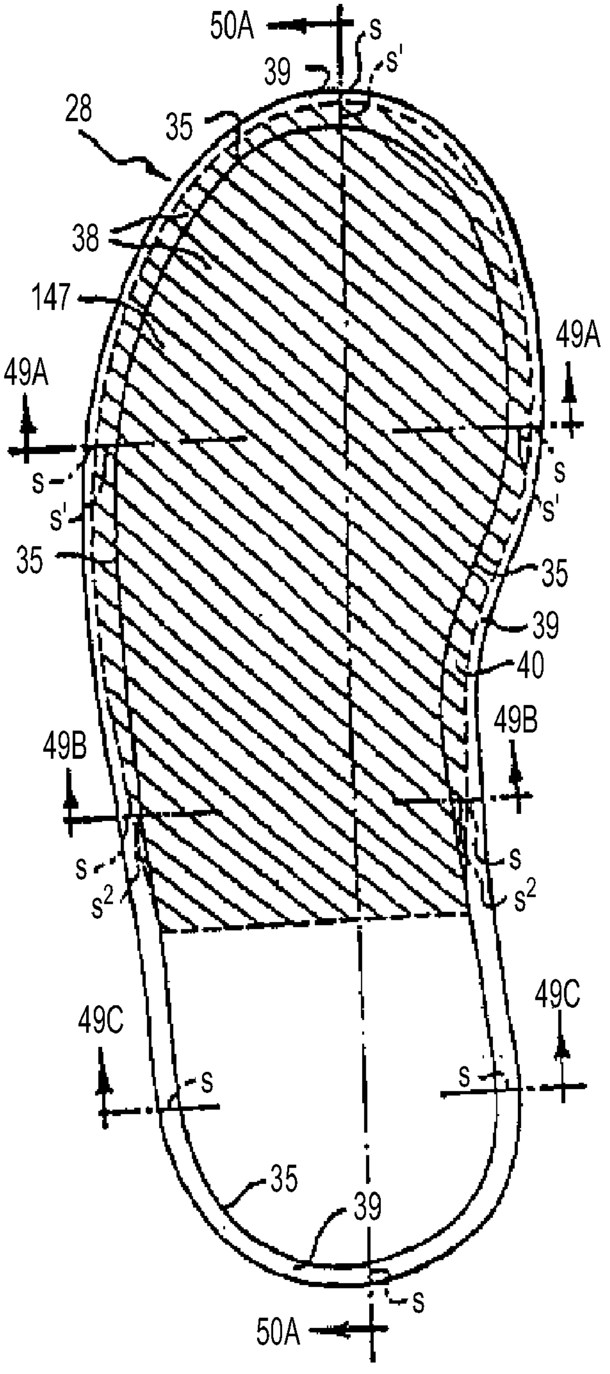


FIG. 49D
PRIOR ART

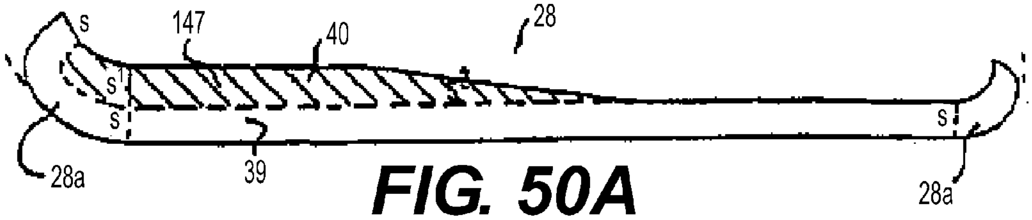


FIG. 50A
PRIOR ART

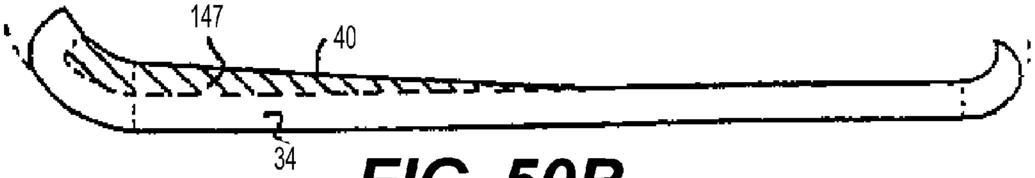


FIG. 50B
PRIOR ART

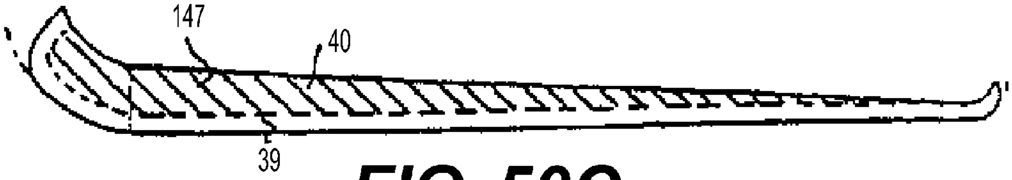


FIG. 50C
PRIOR ART

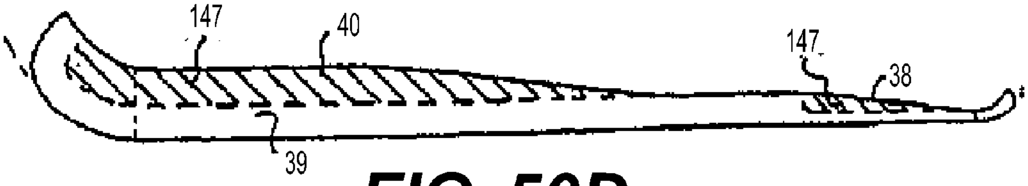


FIG. 50D
PRIOR ART

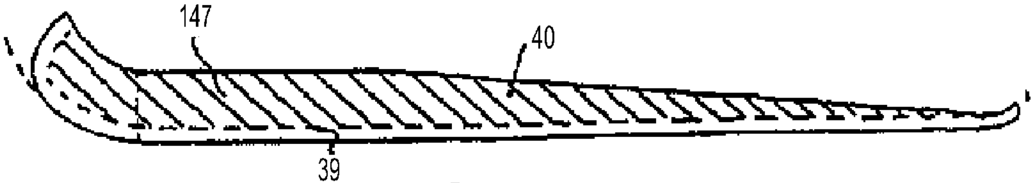


FIG. 50E
PRIOR ART

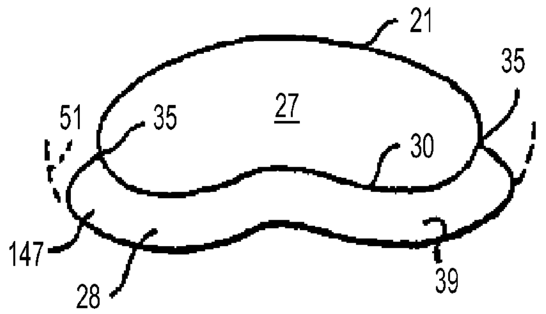


FIG. 51A
PRIOR ART

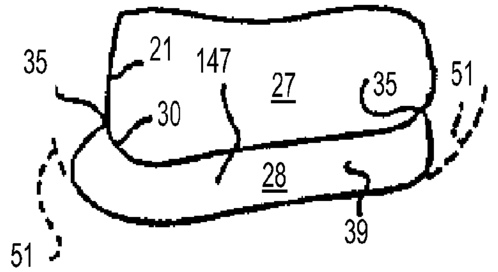


FIG. 51B
PRIOR ART

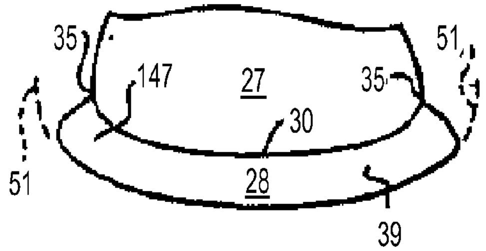


FIG. 51C
PRIOR ART

FIG. 51D
PRIOR ART

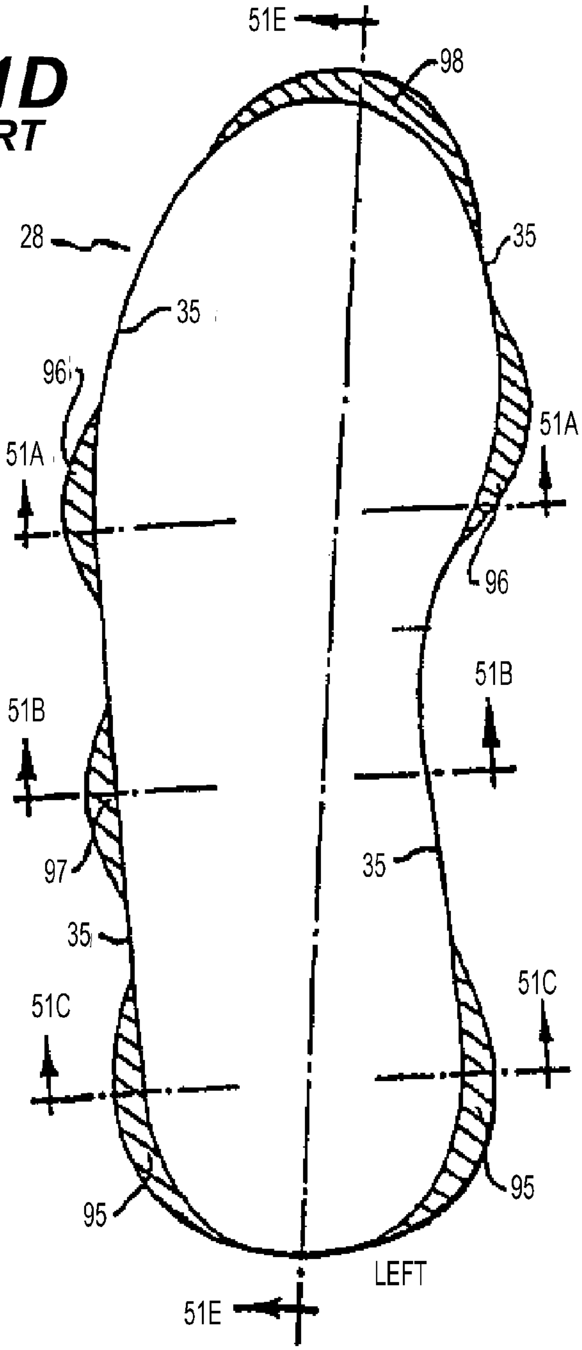
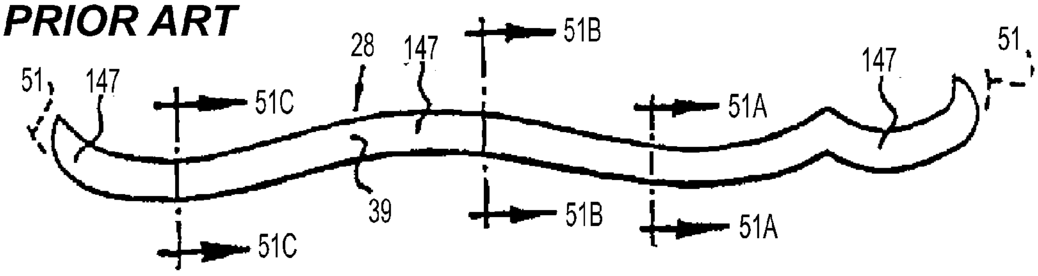


FIG. 51E
PRIOR ART



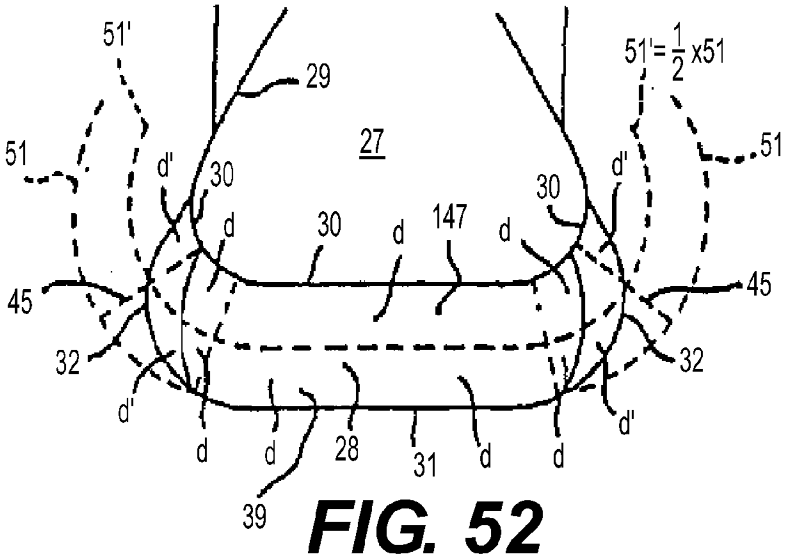
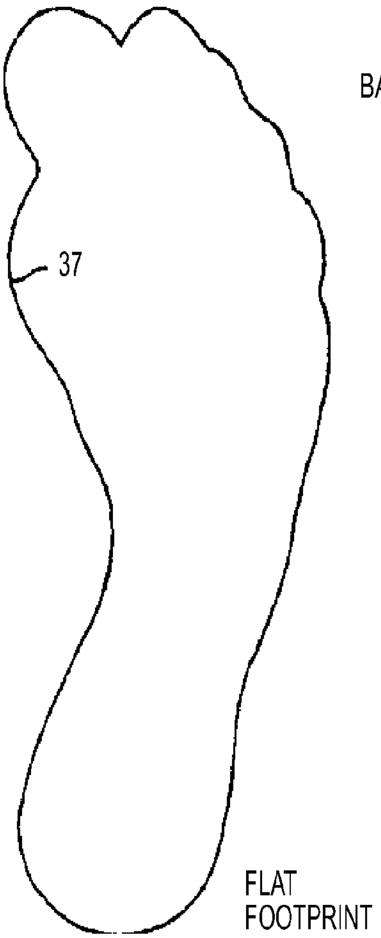
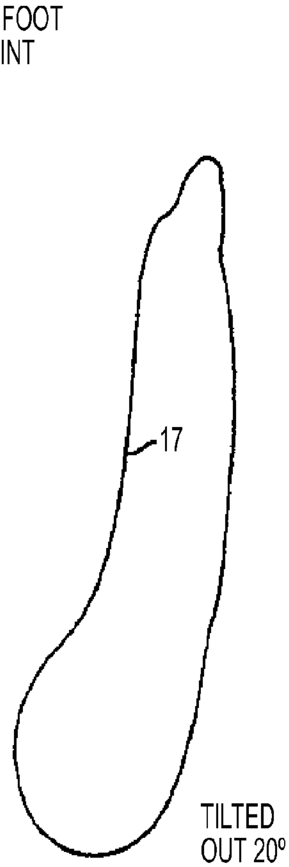


FIG. 52
PRIOR ART





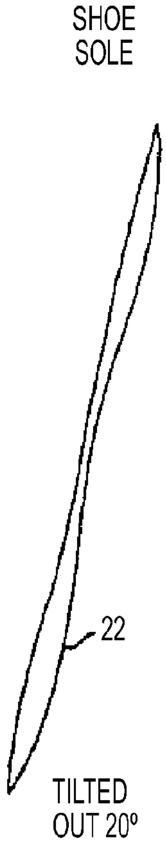


FIG. 53A
PRIOR ART

FIG. 53B
PRIOR ART

FIG. 53C
PRIOR ART

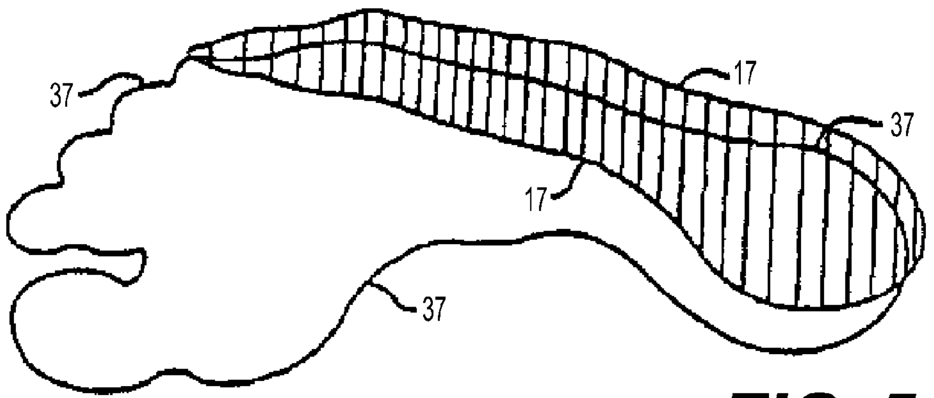


FIG. 54
PRIOR ART

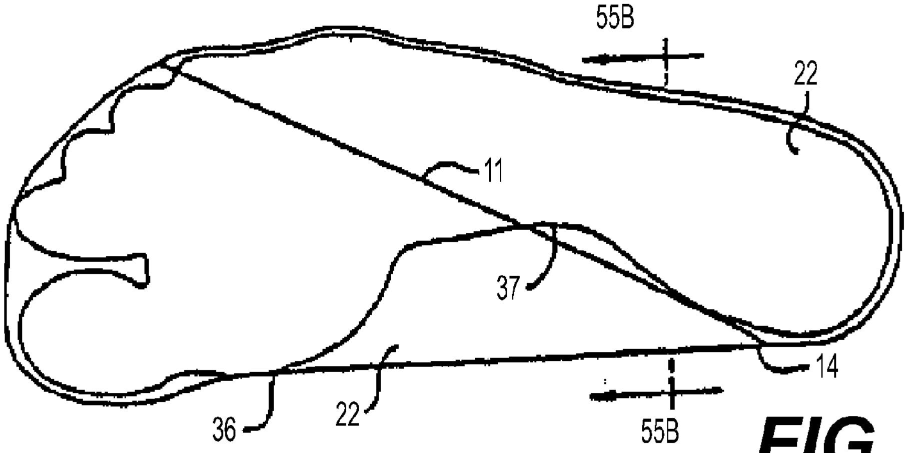


FIG. 55A
PRIOR ART

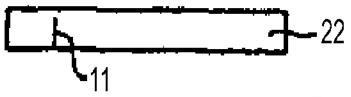


FIG. 55B
PRIOR ART

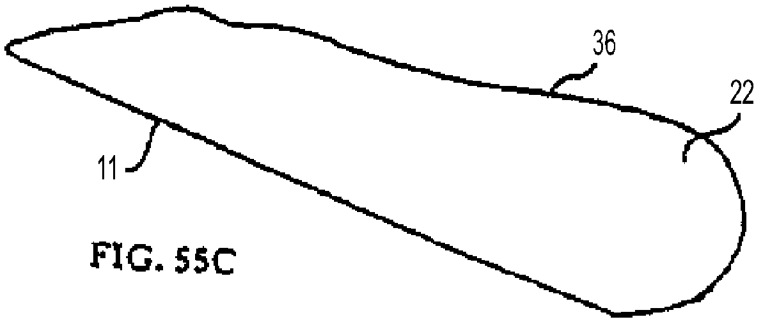


FIG. 55C
PRIOR ART

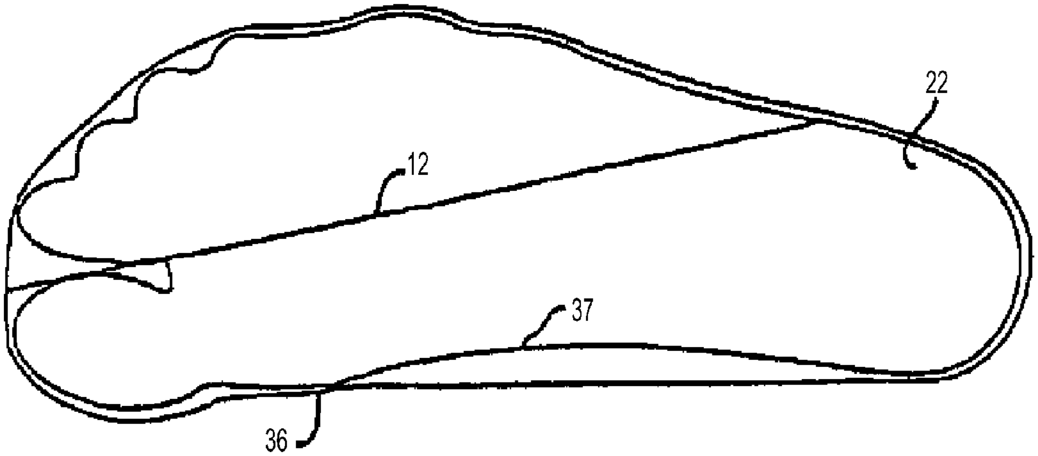


FIG. 56
PRIOR ART

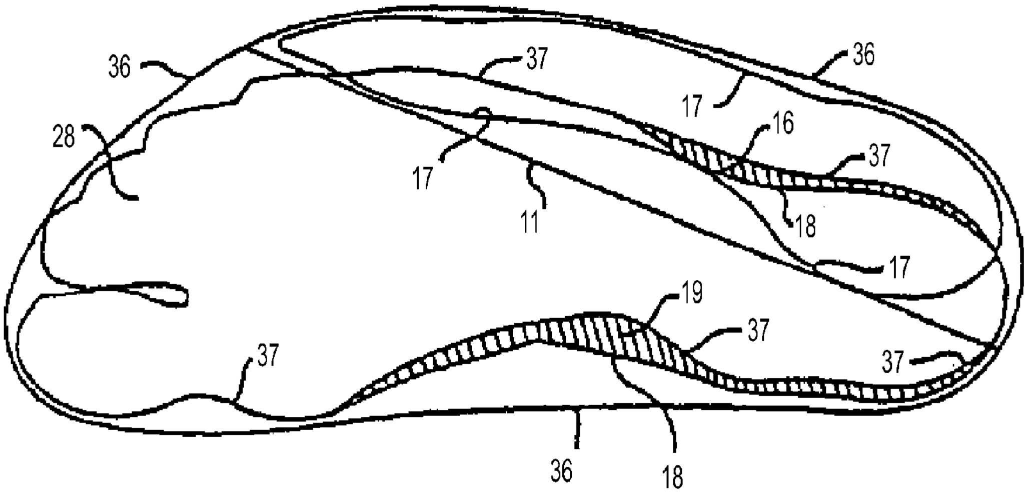


FIG. 57
PRIOR ART

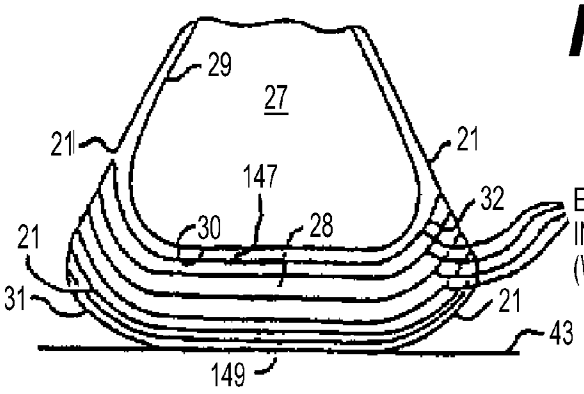


FIG. 58A
PRIOR ART

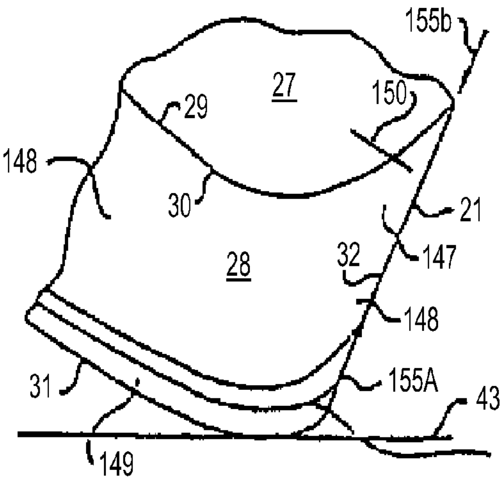


FIG. 58B
PRIOR ART

FIG. 58D
PRIOR ART

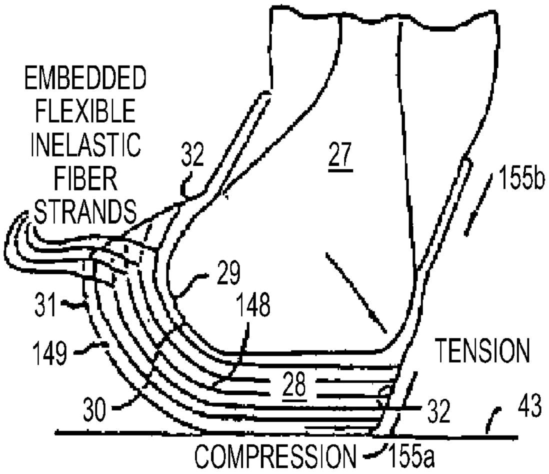


FIG. 58C

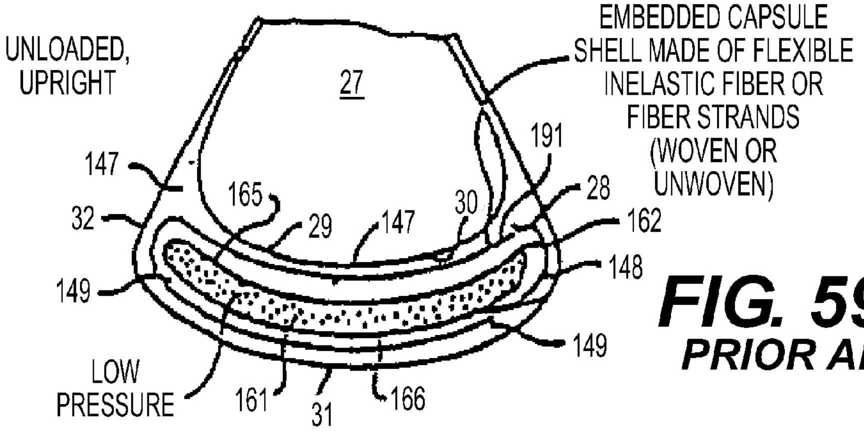


**FIG. 59A**
**PRIOR ART**

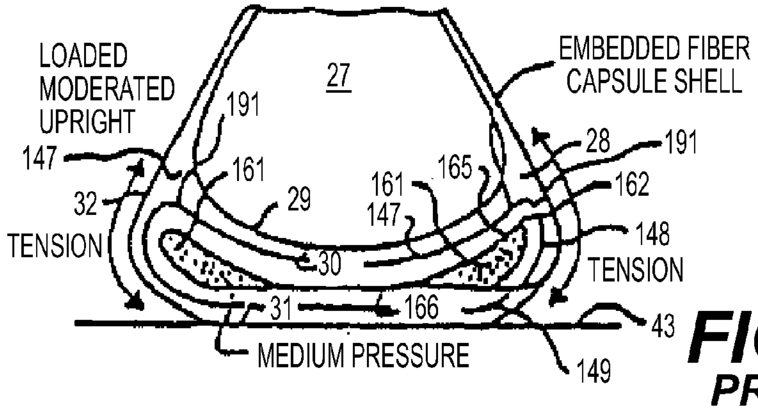


**FIG. 59B**
**PRIOR ART**

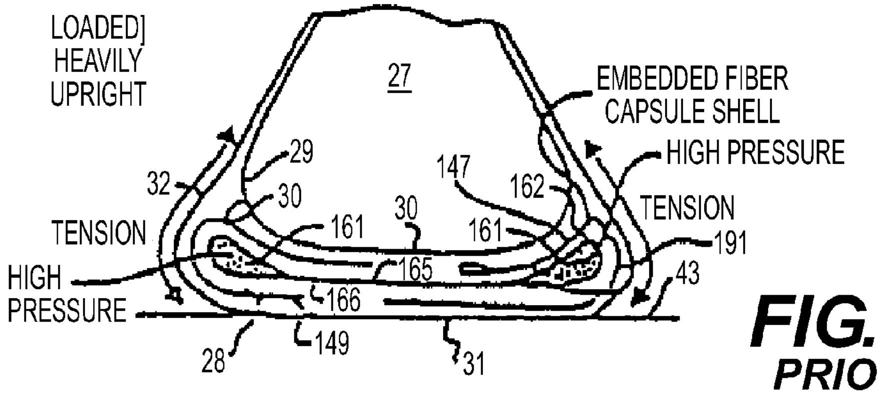


**FIG. 59C**
**PRIOR ART**

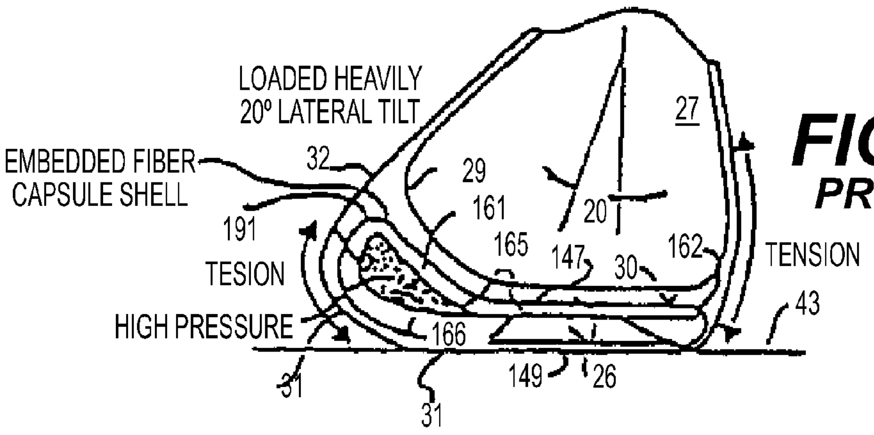


**FIG. 59D**
**PRIOR ART**

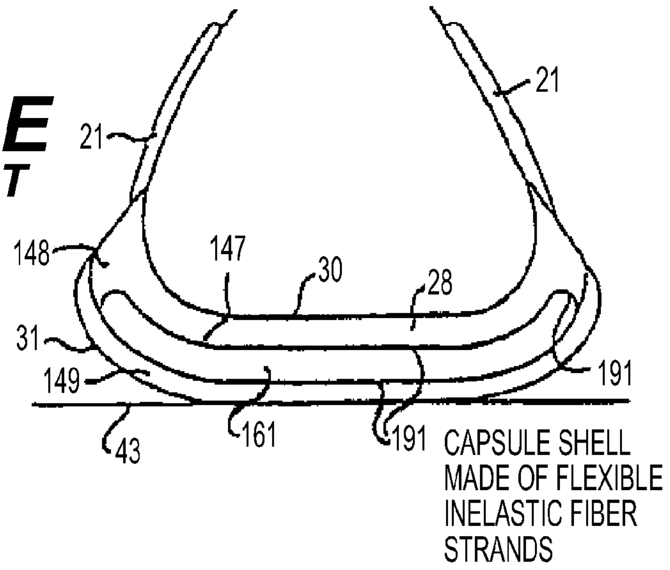


FIG. 59E
PRIOR ART

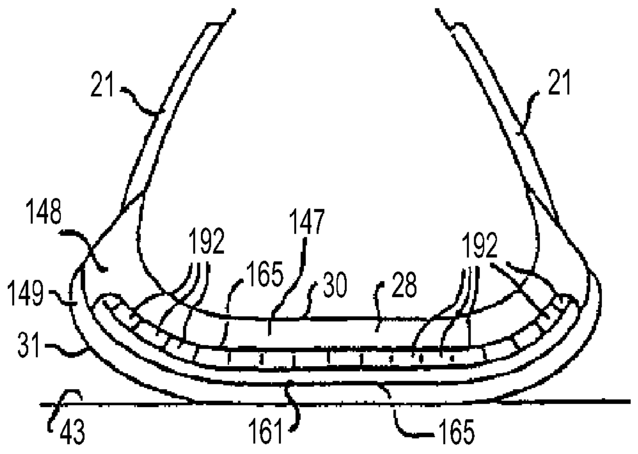


FIG. 59F
PRIOR ART

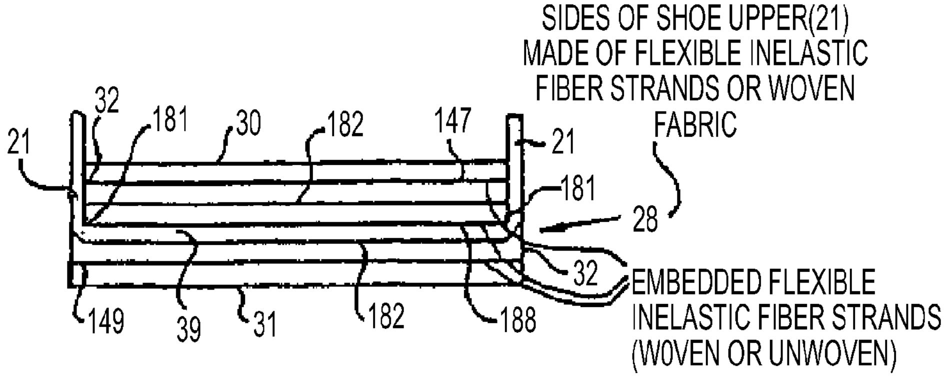


FIG. 60A
PRIOR ART

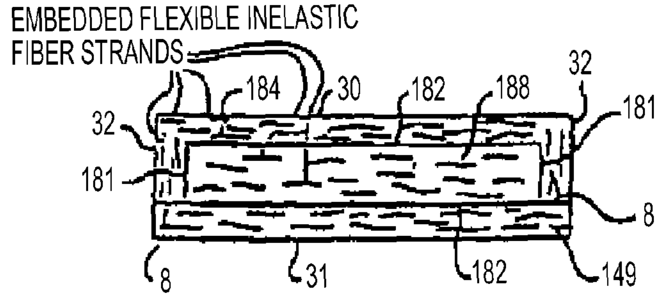


FIG. 60B
PRIOR ART

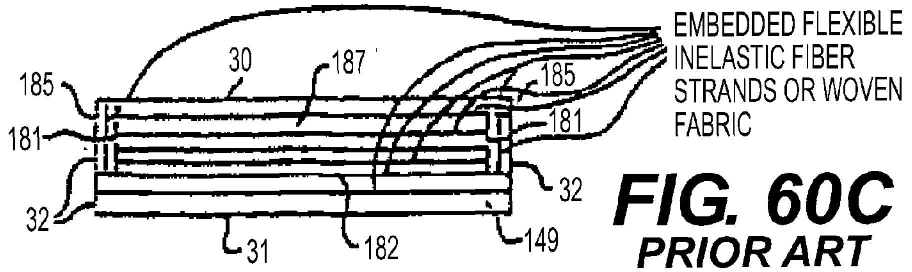


FIG. 60C
PRIOR ART

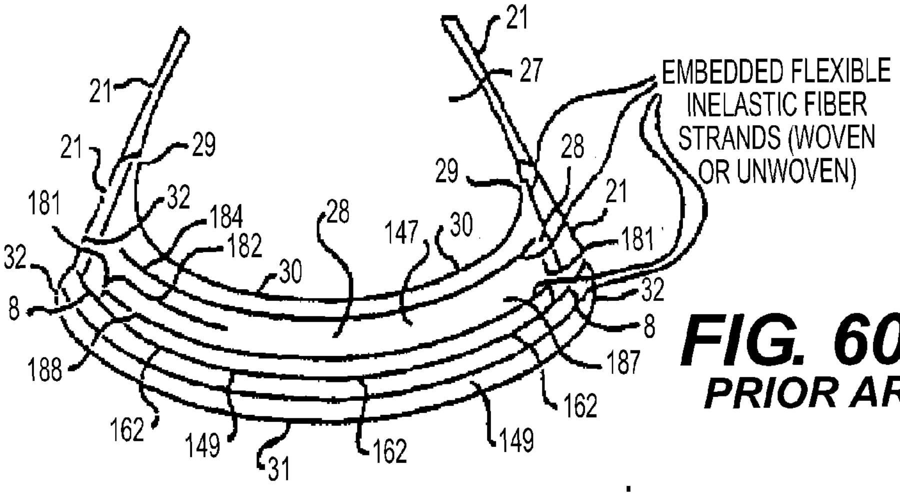


FIG. 60D
PRIOR ART

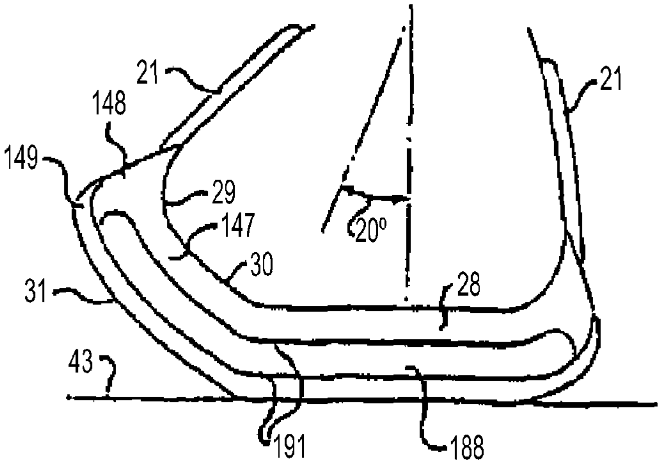
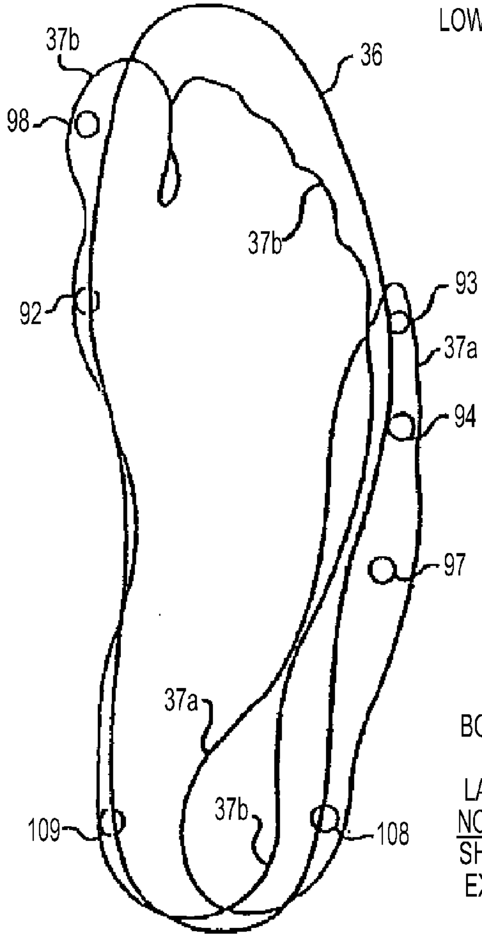


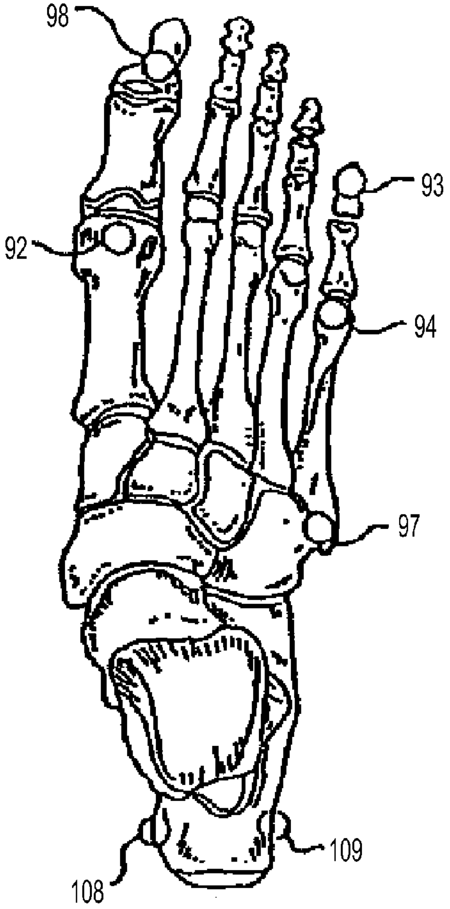
FIG. 60E
PRIOR ART



LOW ARCH (PRONATOR)
FOOT SHOWN

BONE STRUCTURES
ESSENTIAL FOR
LATERAL STABILITY
NOT SUPPORTED BY
SHOE SOLE DURING
EXTREME LATERAL
MOTION

FIG. 61A
PRIOR ART



BONES OF THE FOOT

FIG. 61B
PRIOR ART

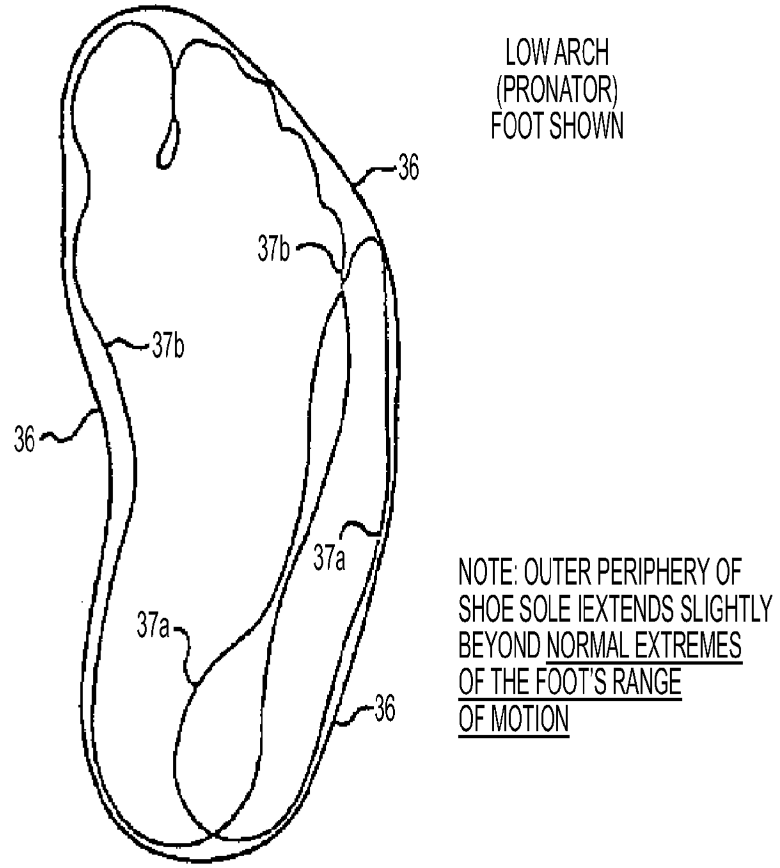


FIG. 62
PRIOR ART

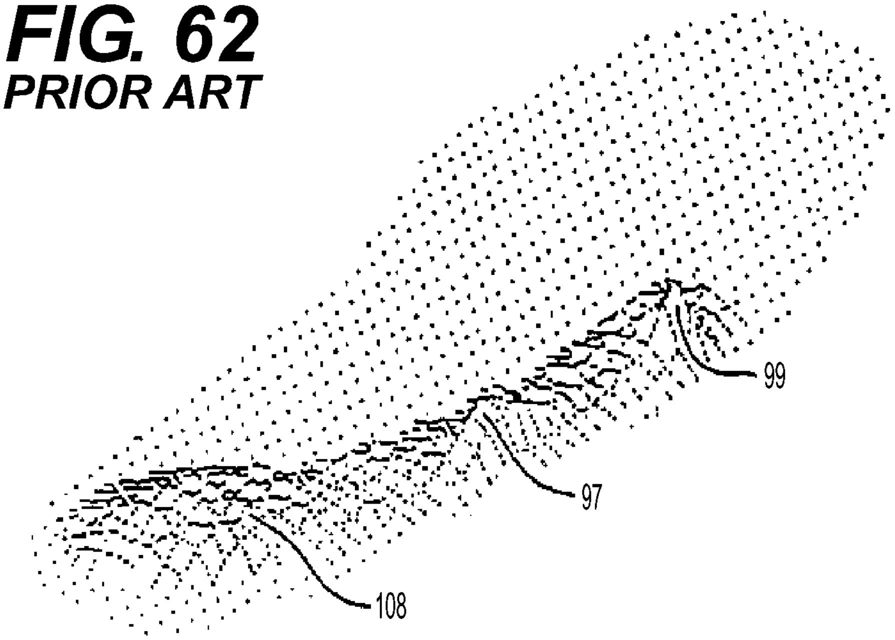


FIG. 63
PRIOR ART

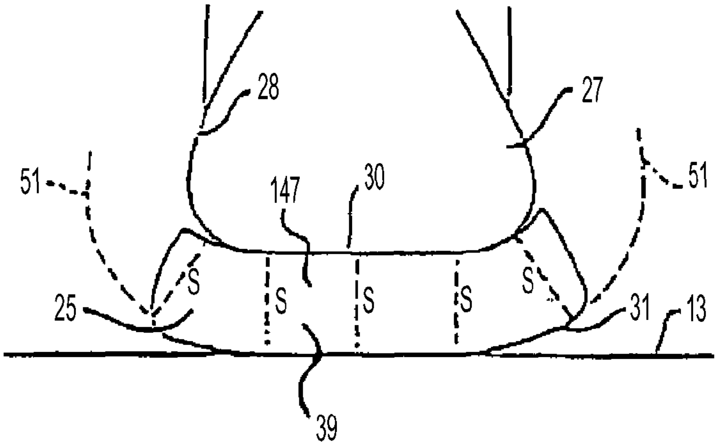


FIG. 64
PRIOR ART

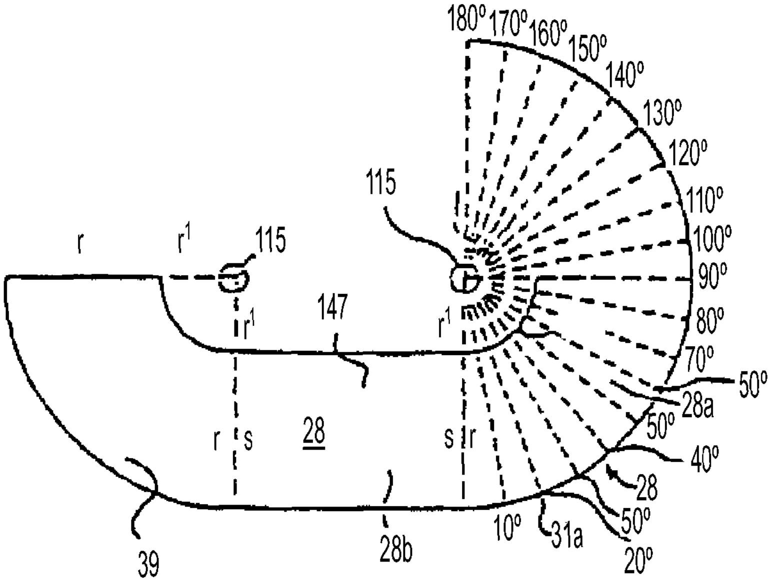


FIG. 65
PRIOR ART

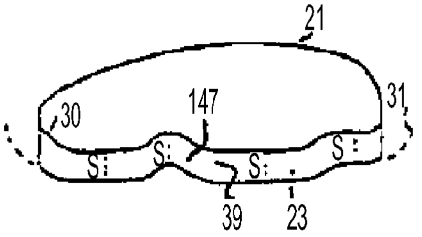


FIG. 66A
PRIOR ART

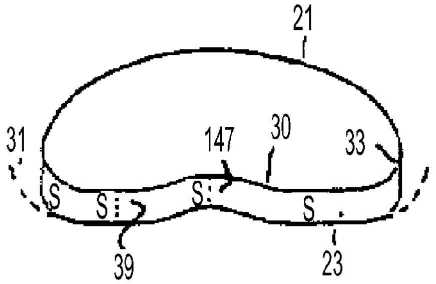


FIG. 66B
PRIOR ART

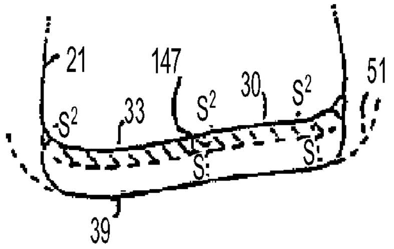


FIG. 66C
PRIOR ART

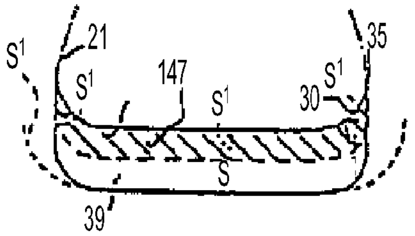


FIG. 66D
PRIOR ART

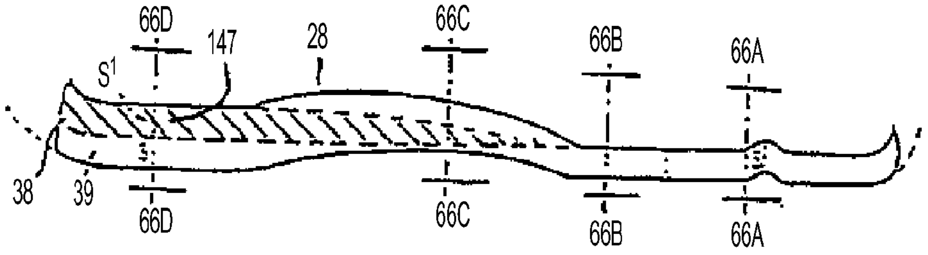


FIG. 66E
PRIOR ART

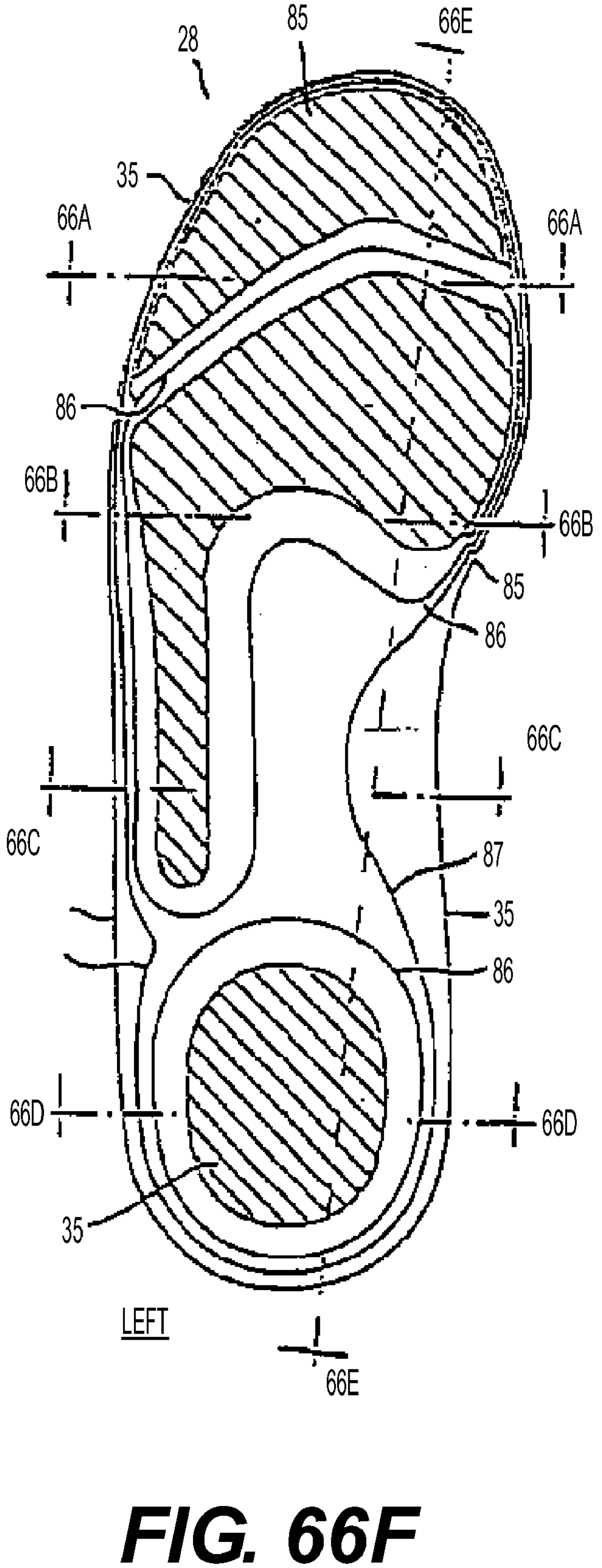


FIG. 66F
PRIOR ART

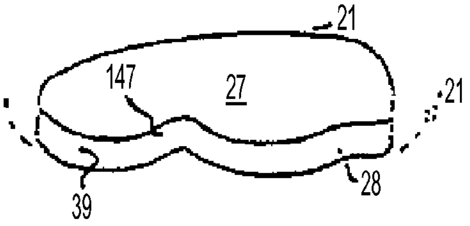


FIG. 67A
PRIOR ART

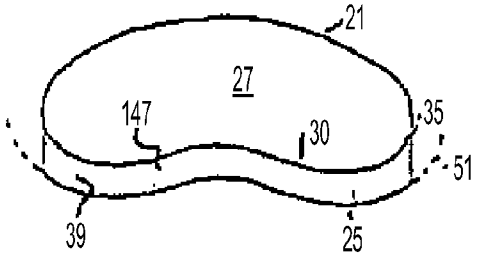


FIG. 67B
PRIOR ART

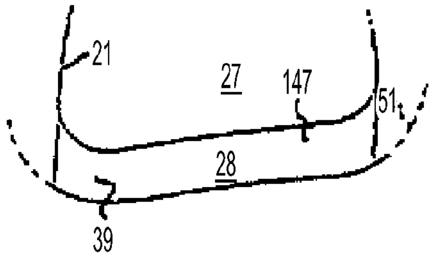


FIG. 67C
PRIOR ART

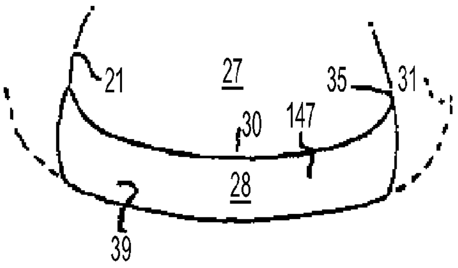


FIG. 67D
PRIOR ART

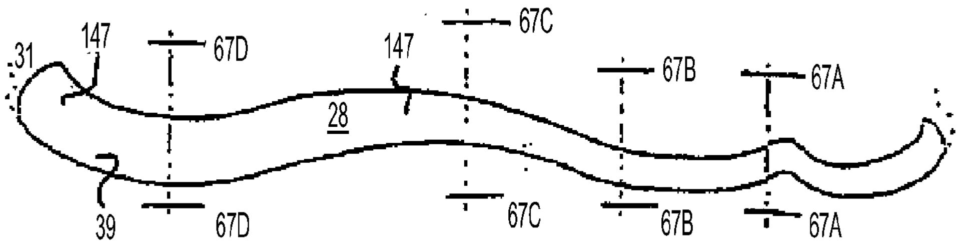


FIG. 67E
PRIOR ART

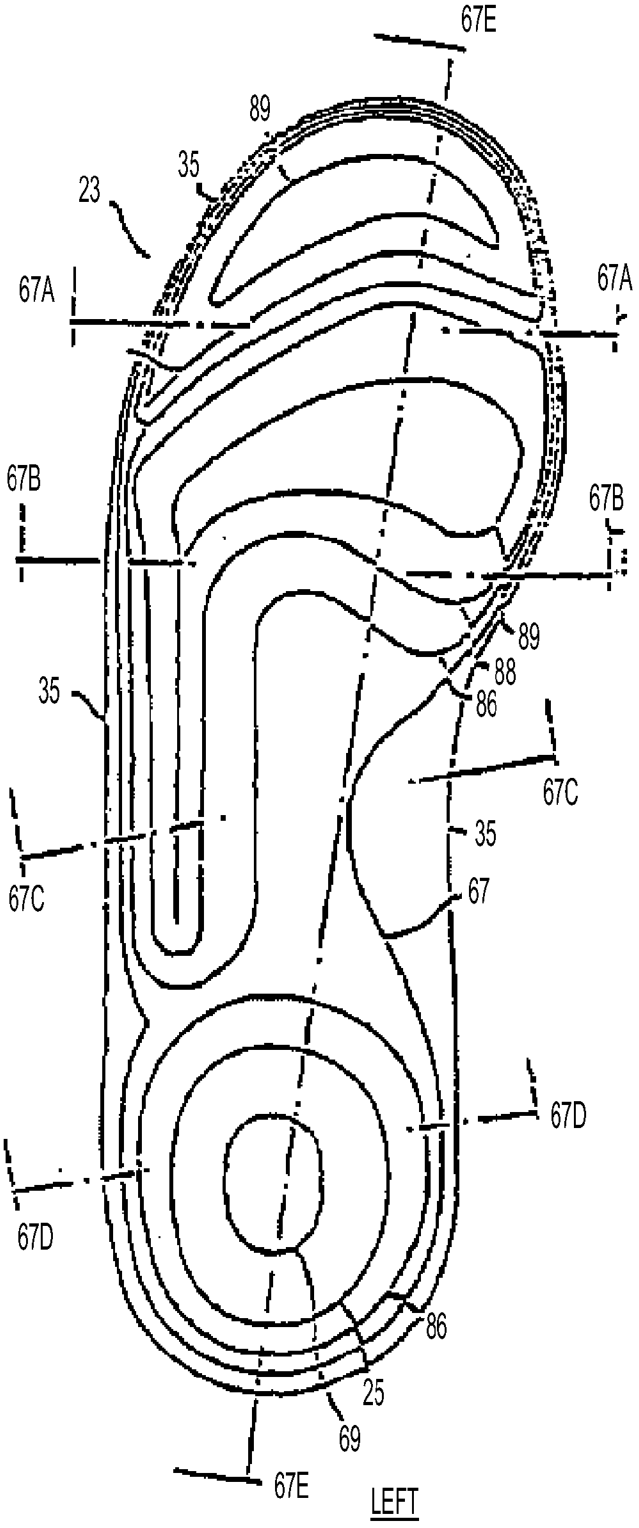


FIG. 68
PRIOR ART

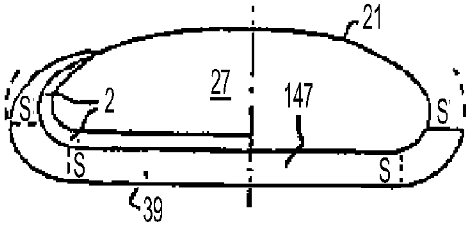


FIG. 69A
PRIOR ART

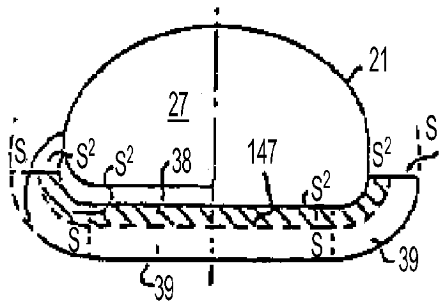


FIG. 69B
PRIOR ART

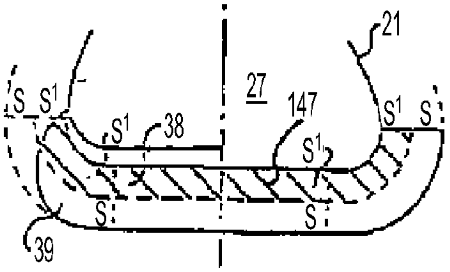


FIG. 69C
PRIOR ART

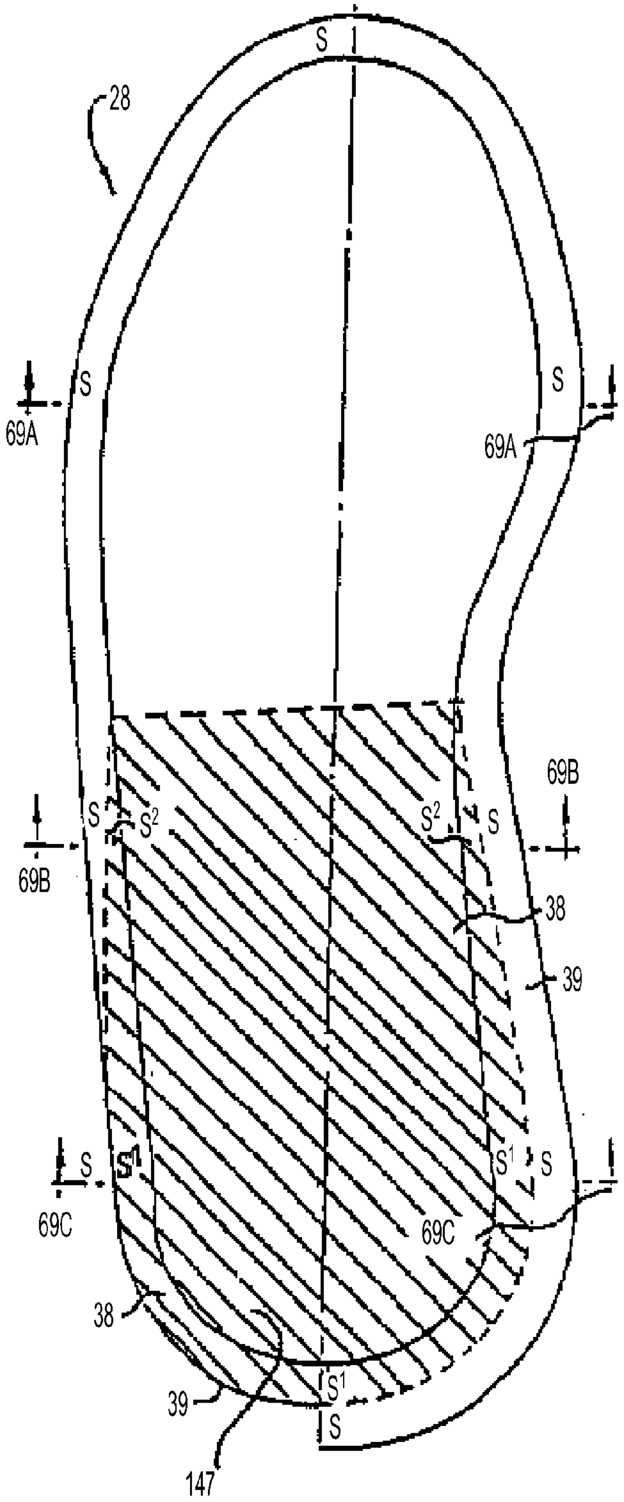


FIG. 69D
PRIOR ART

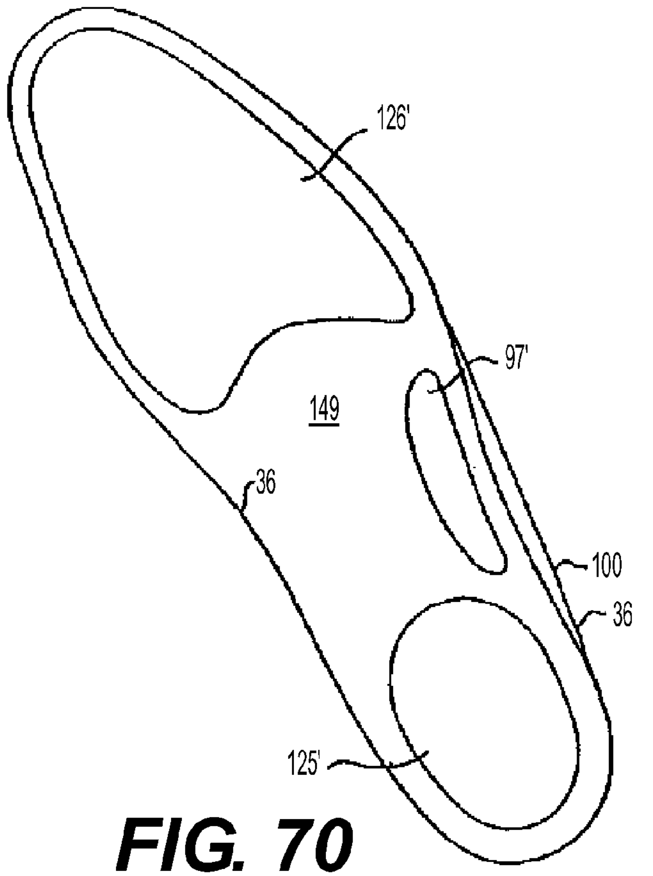


FIG. 70
PRIOR ART

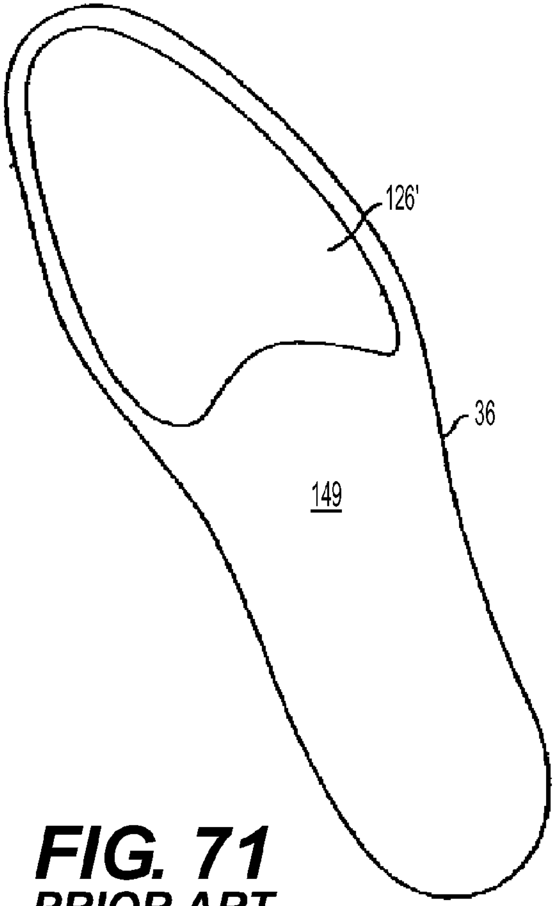


FIG. 71
PRIOR ART

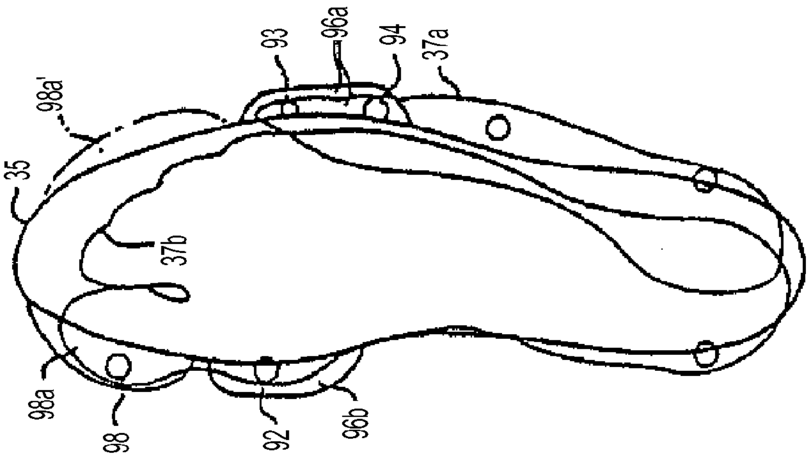


FIG. 72A
PRIOR ART

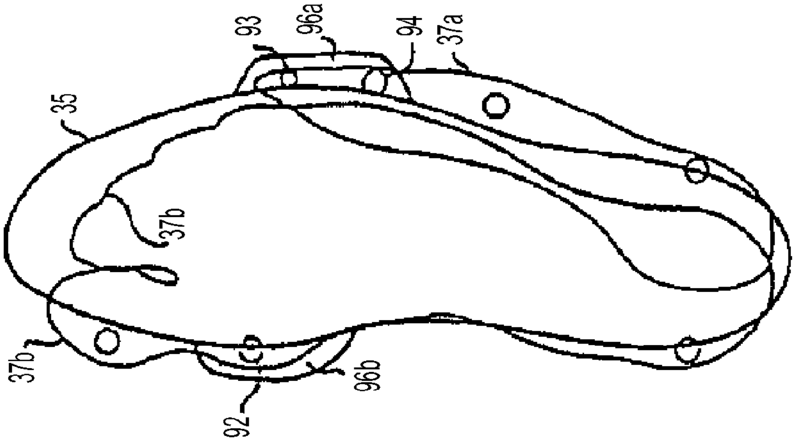


FIG. 72B
PRIOR ART

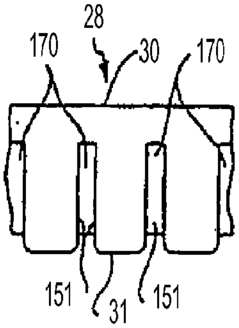


FIG. 73A
PRIOR ART

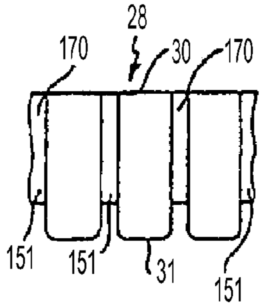


FIG. 73B
PRIOR ART

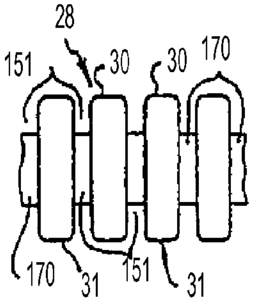


FIG. 73C
PRIOR ART

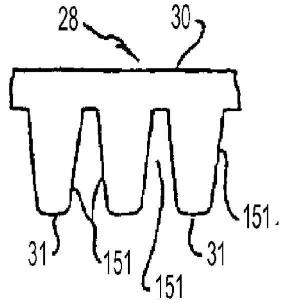


FIG. 73D
PRIOR ART

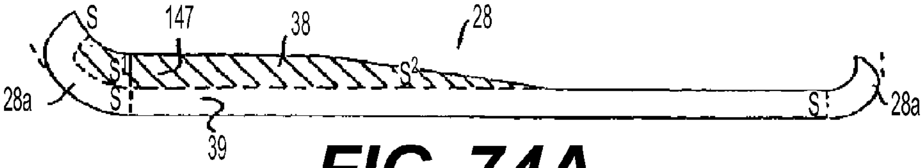


FIG. 74A
PRIOR ART

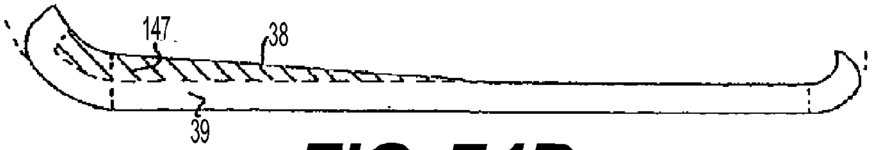


FIG. 74B
PRIOR ART

FIG. 74C
PRIOR ART

FIG. 74D
PRIOR ART

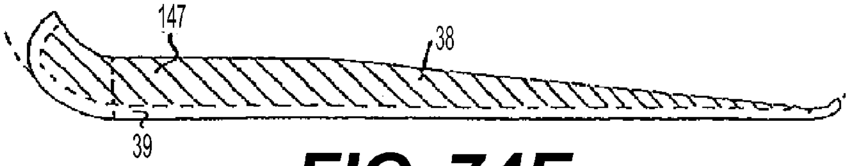


FIG. 74E
PRIOR ART

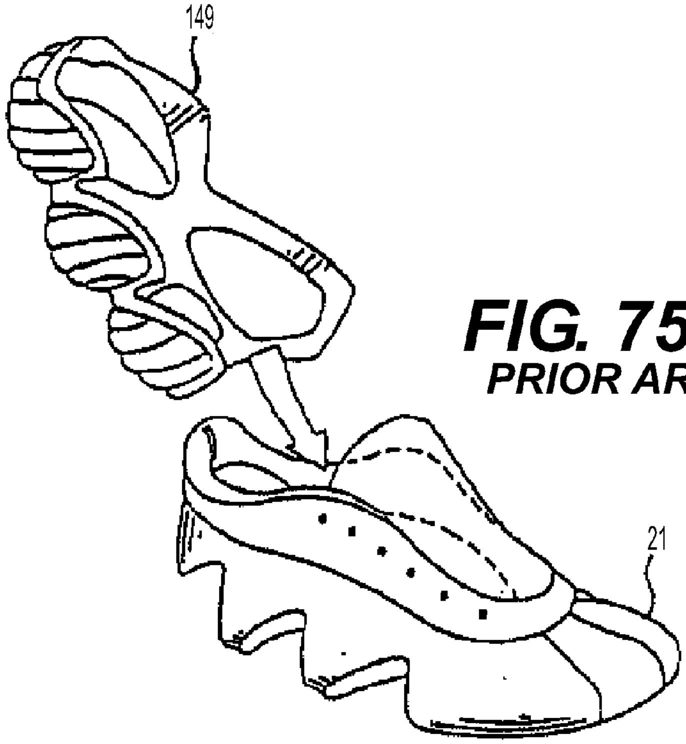
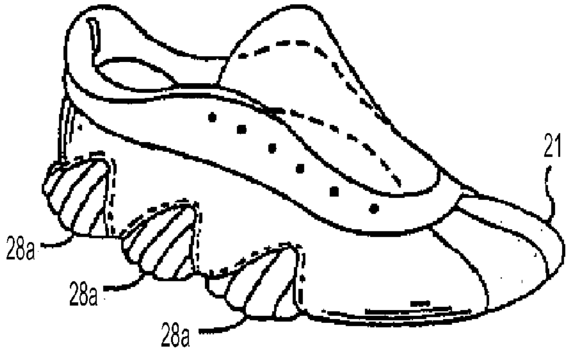


FIG. 75A
PRIOR ART

FIG. 75B
PRIOR ART



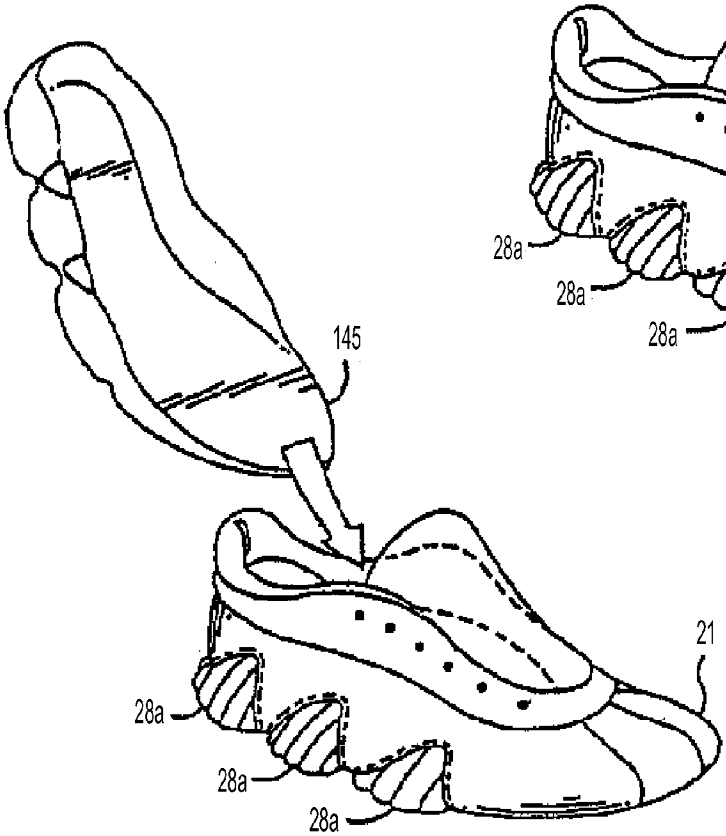


FIG. 75C
PRIOR ART

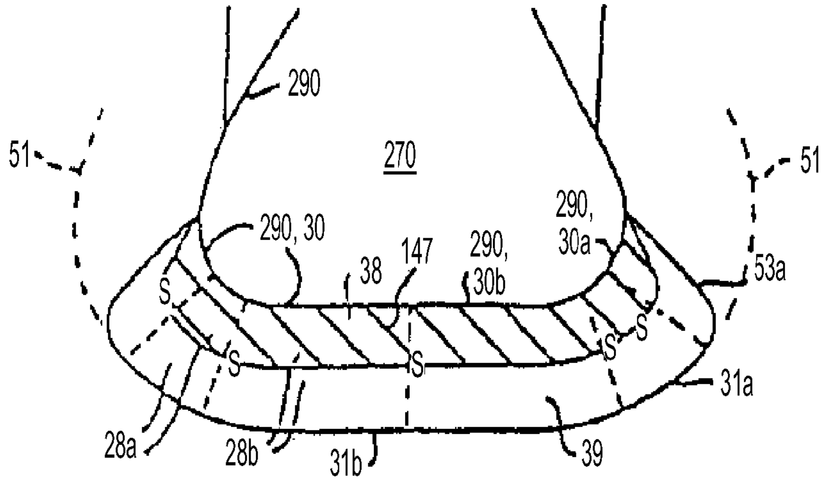


FIG. 76
PRIOR ART

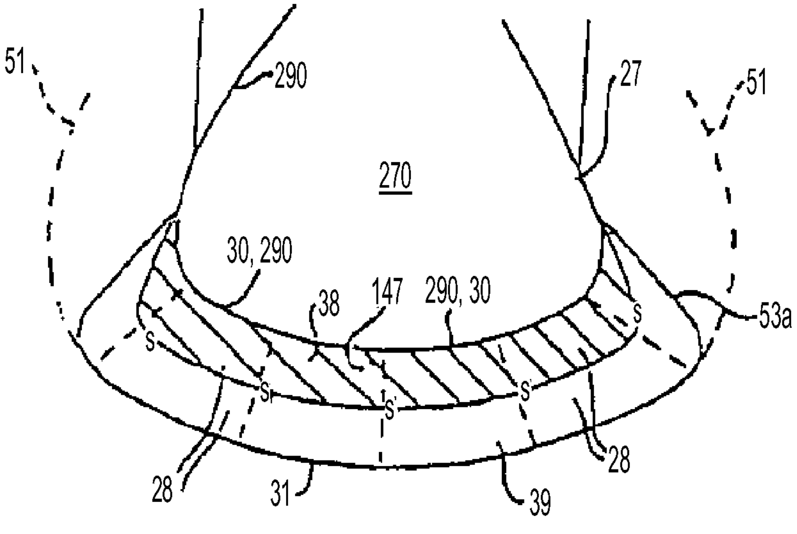


FIG. 77
PRIOR ART

**FIG. 78A**
**PRIOR ART**

HEEL
(FP: CROSS SECTION)

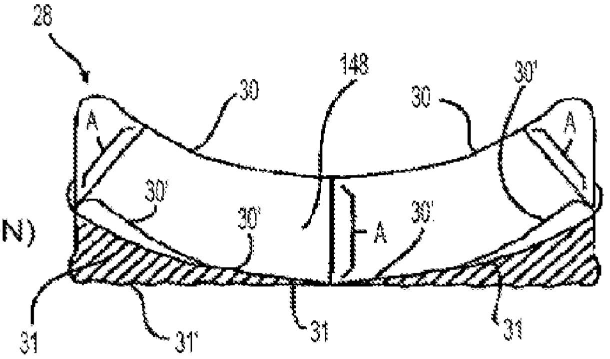


**FIG. 78B**
**PRIOR ART**

BASE OF 5TH
METATARSAL
(FP: CROSS SECTION)

(SIZE 10 ADILETTE)

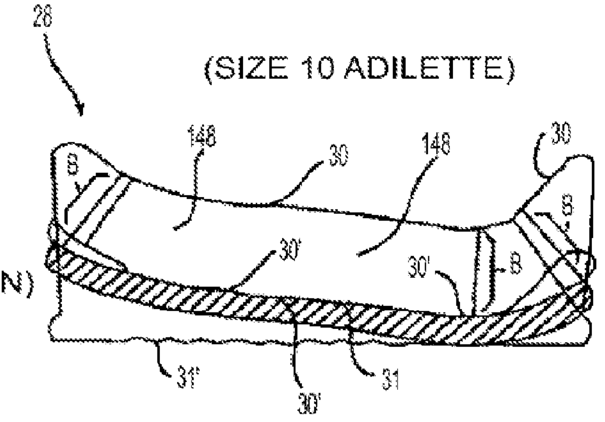


**FIG. 78C**
**PRIOR ART**

FOREFOOT
METATARSAL
HEADS

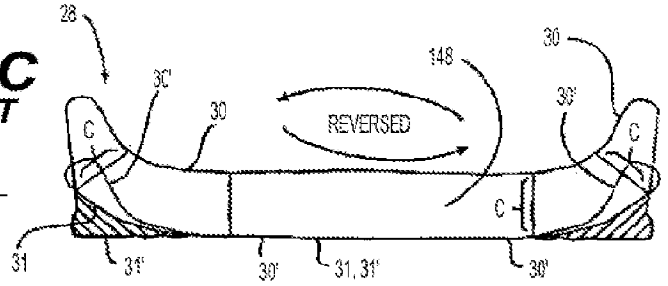


**FIG. 78D**

REAR FOREFOOT

FRONTAL PLANE
CROSS SECTION

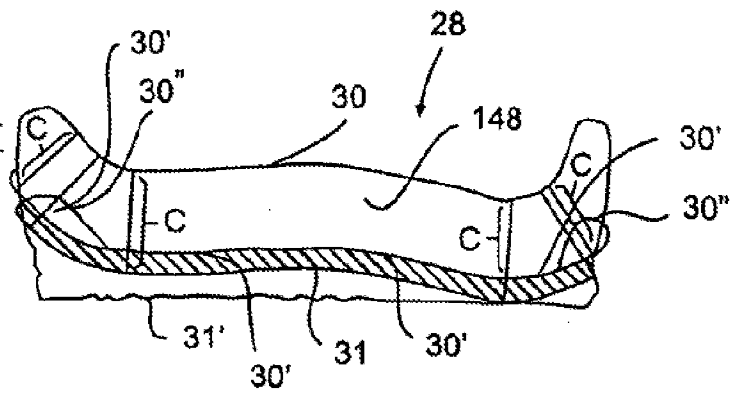
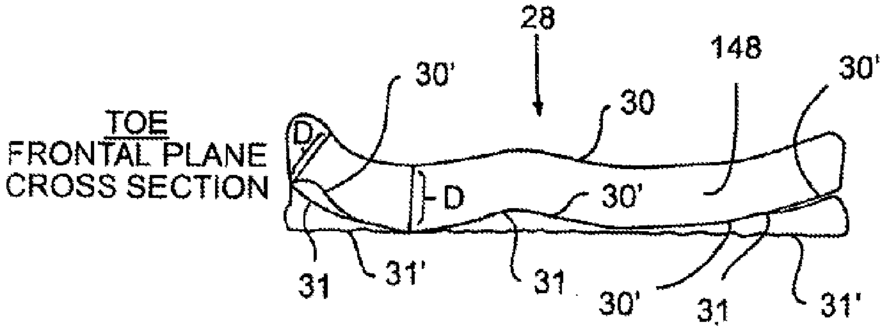


FIG. 78E



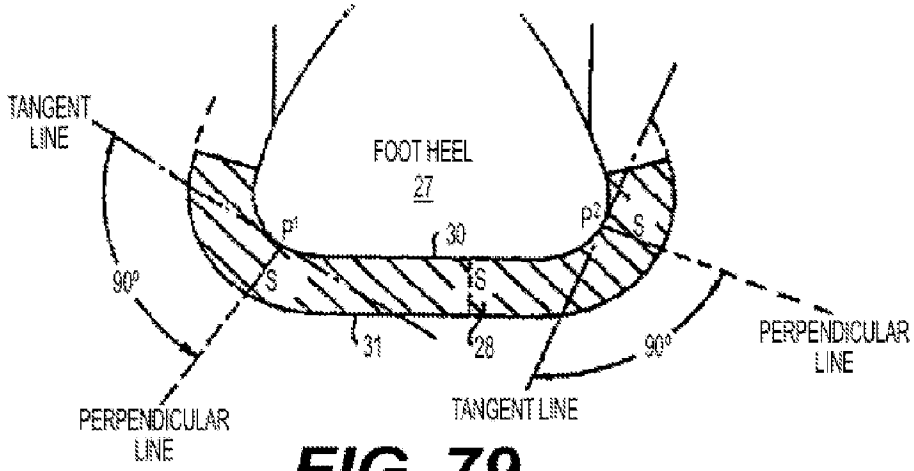


FIG. 79
PRIOR ART

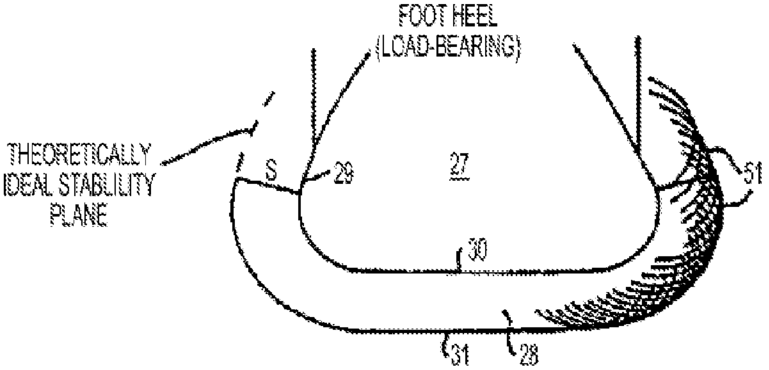


FIG. 80
PRIOR ART

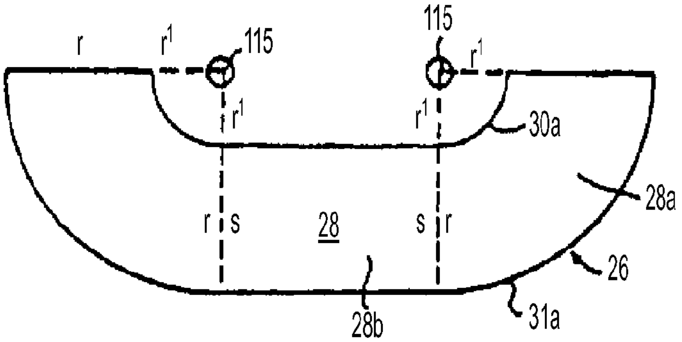


FIG. 81
PRIOR ART

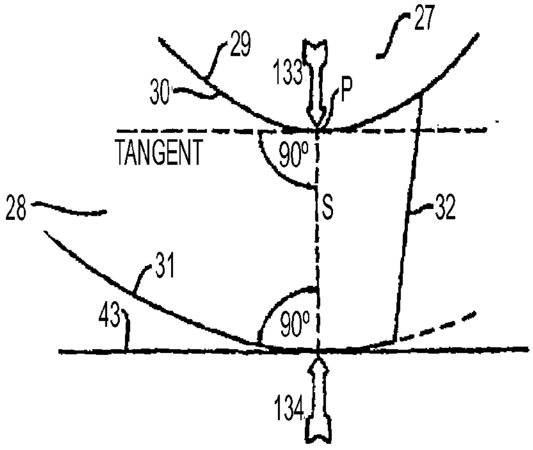


FIG. 82
PRIOR ART

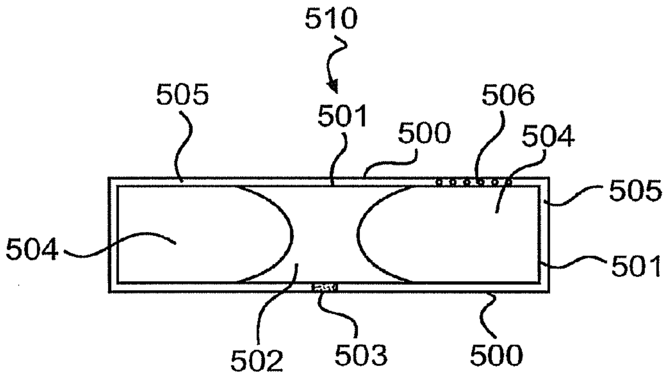


FIG. 83A

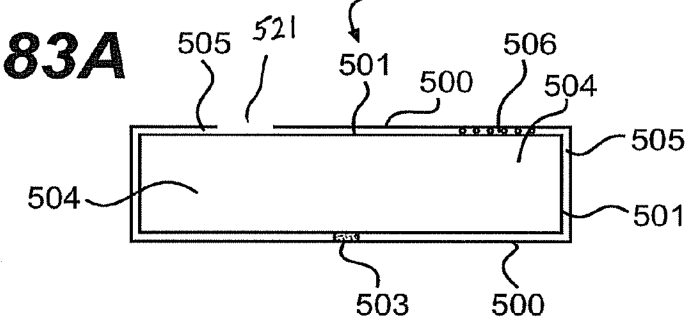


FIG. 84A

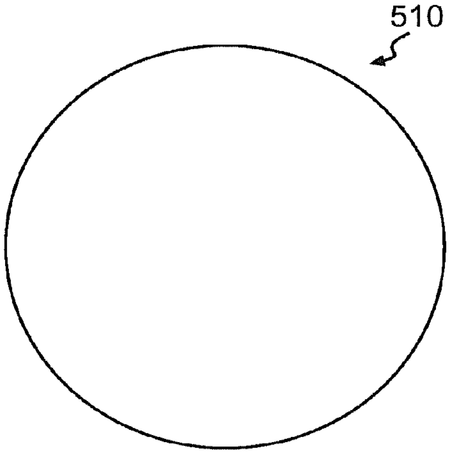


FIG. 83B

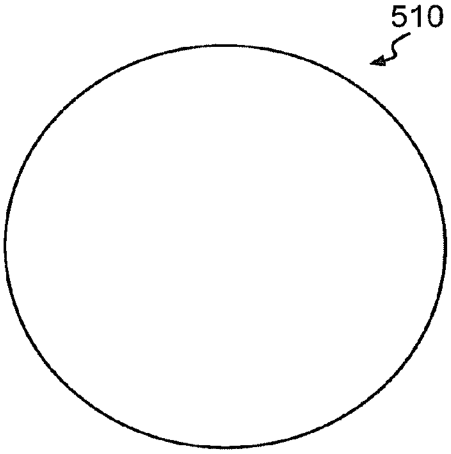


FIG. 84B

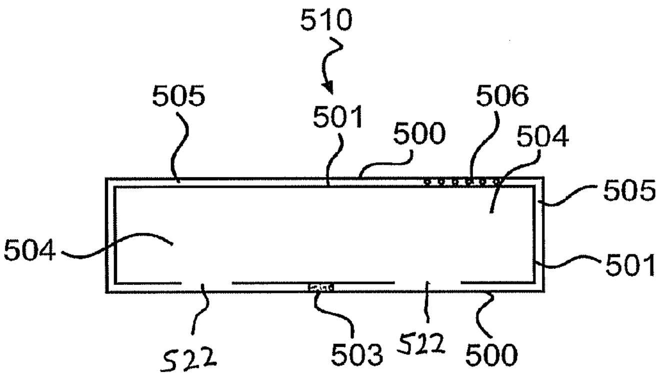


FIG. 85A

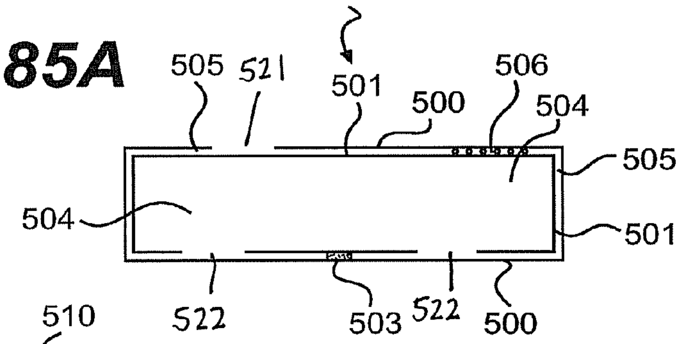


FIG. 86A

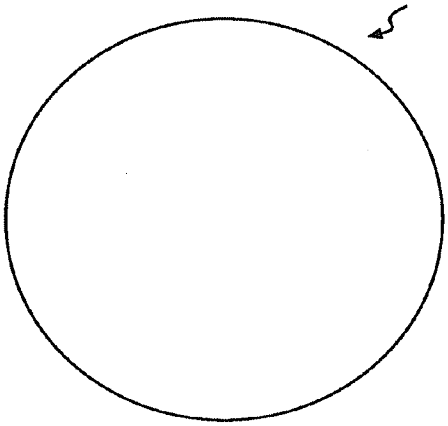


FIG. 85B

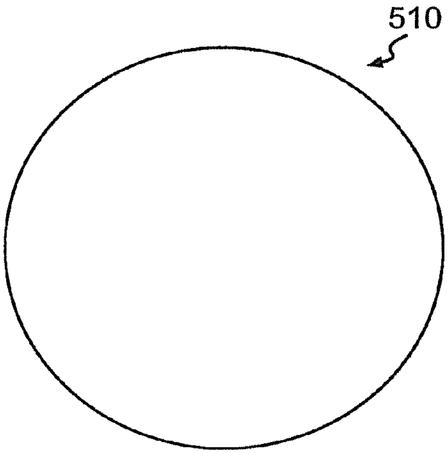


FIG. 86B

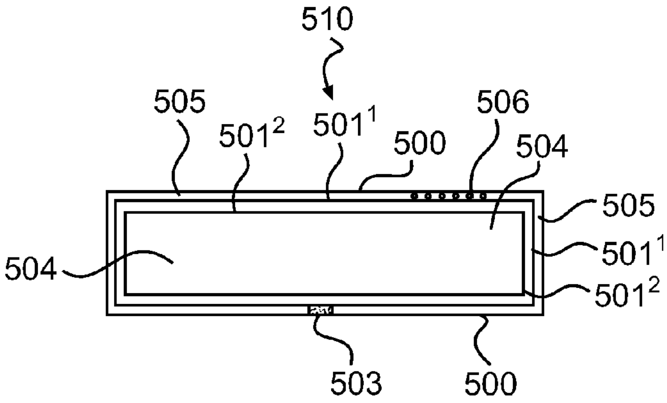


FIG. 87A

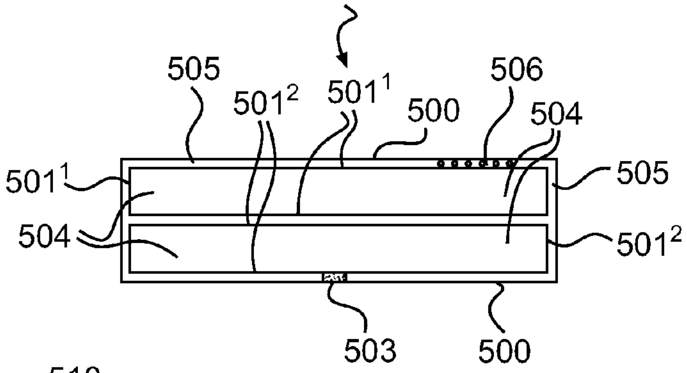


FIG. 88A

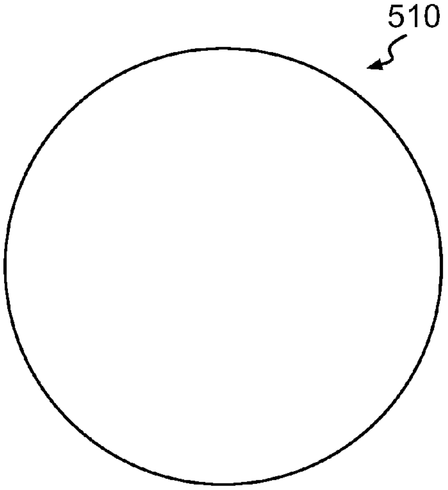


FIG. 87B

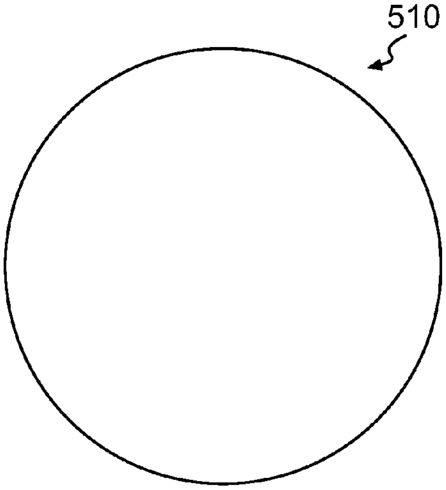


FIG. 88B

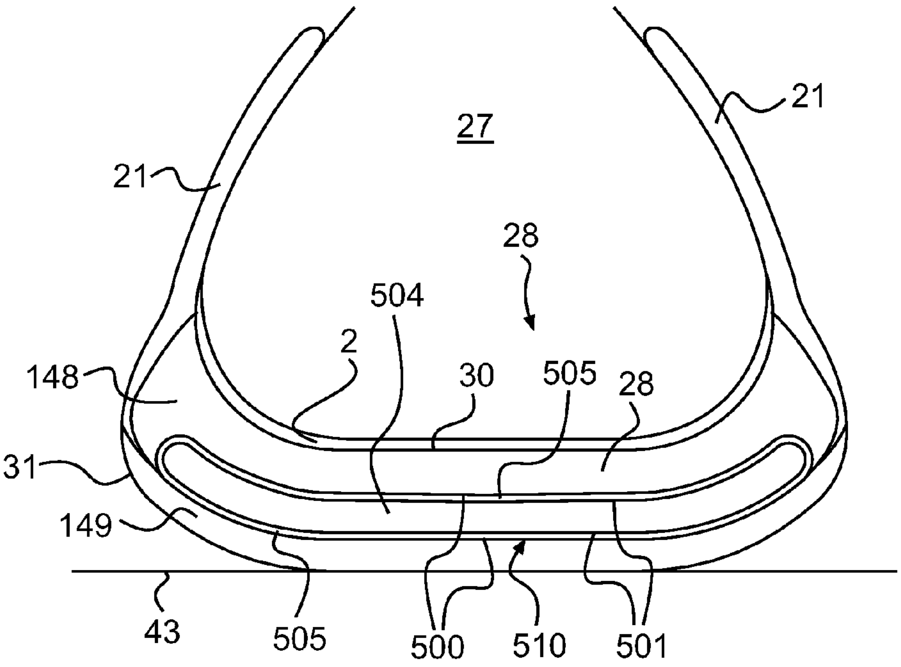


FIG. 89

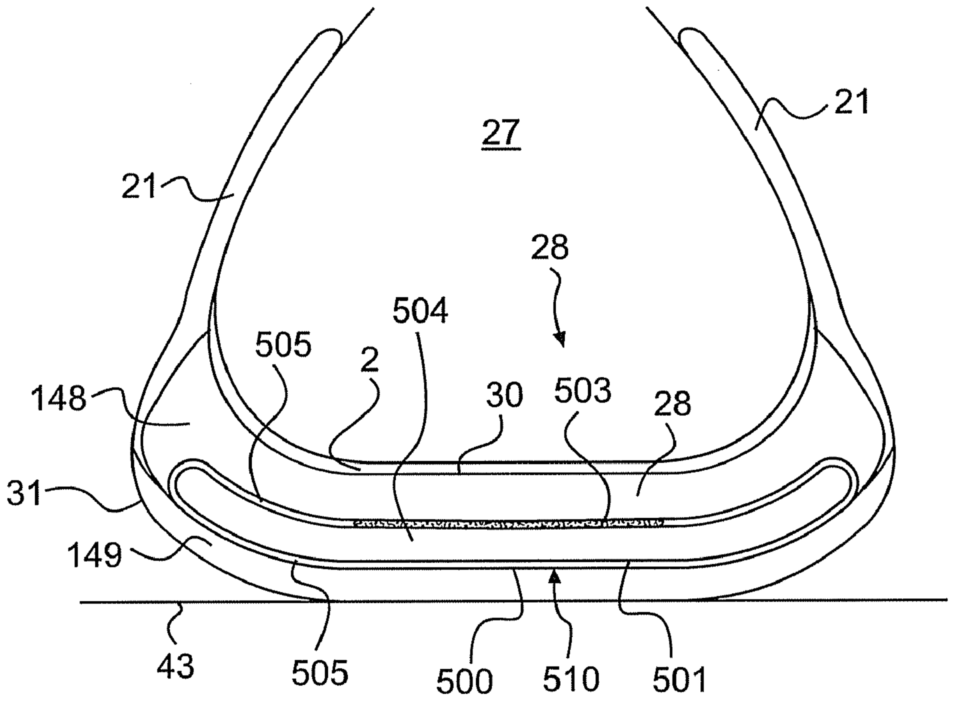
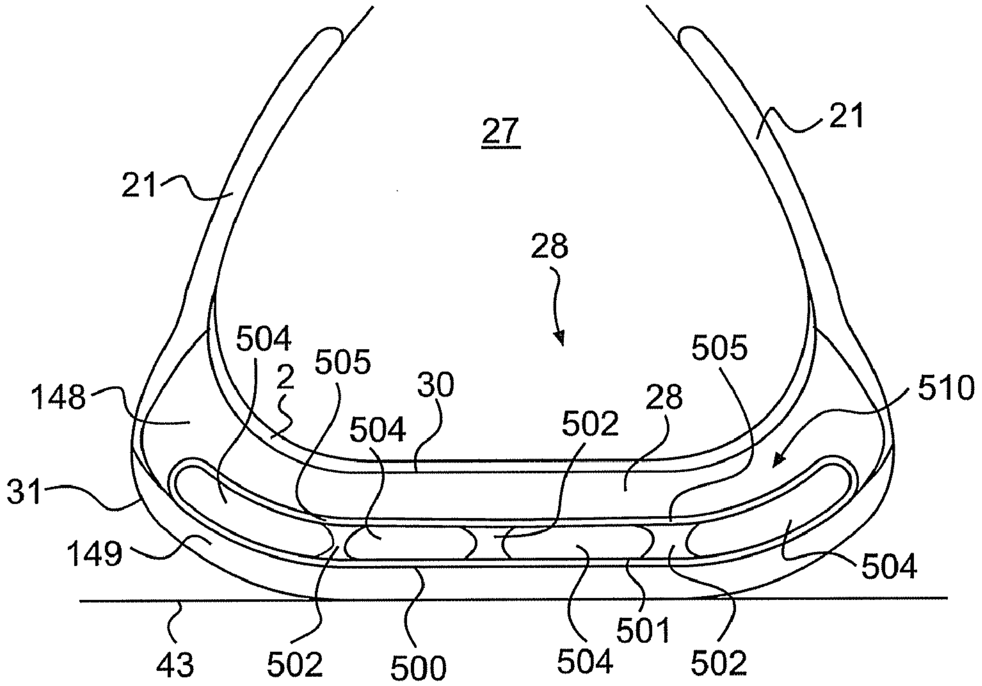

27
21
21
28
504
505
2
148
30
503
28
31
149
43
505
500
510
501

FIG. 90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502
28
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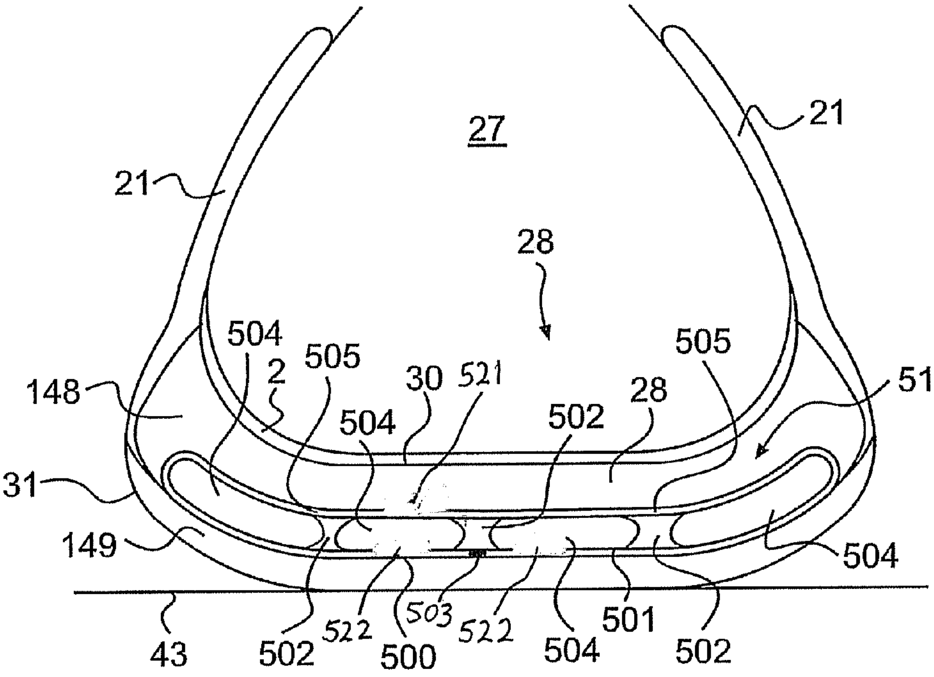
149
504
43
502
500
504
501
502

FIG. 91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502
522
500
503
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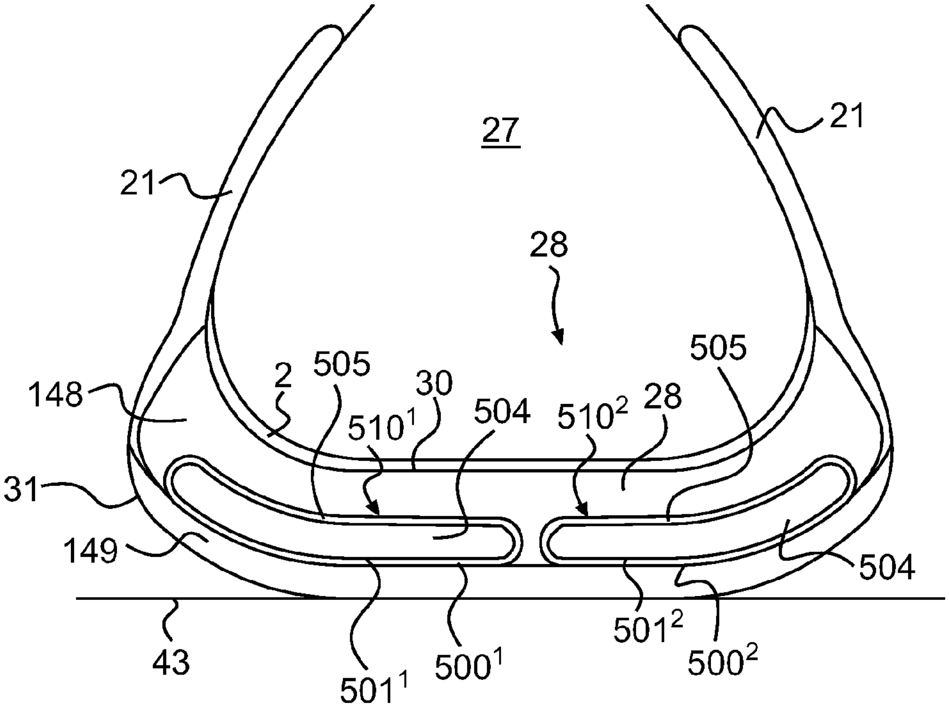
FIG. 91A


27
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$510^1$
$510^2$
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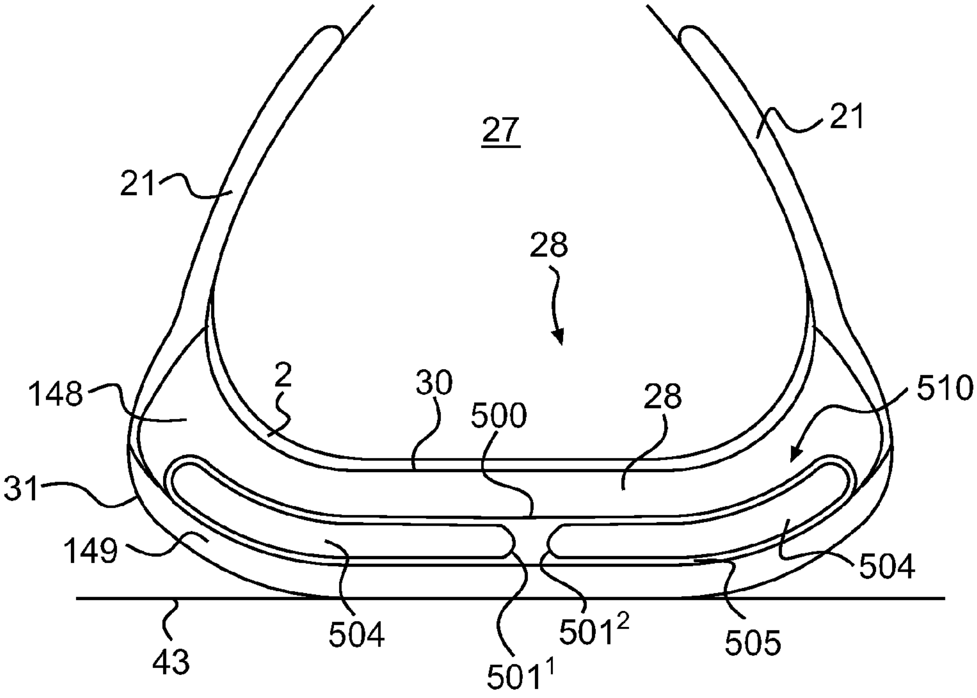
504
43
$501^1$
$500^1$
$501^2$
$500^2$

FIG. 92


27
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148
2
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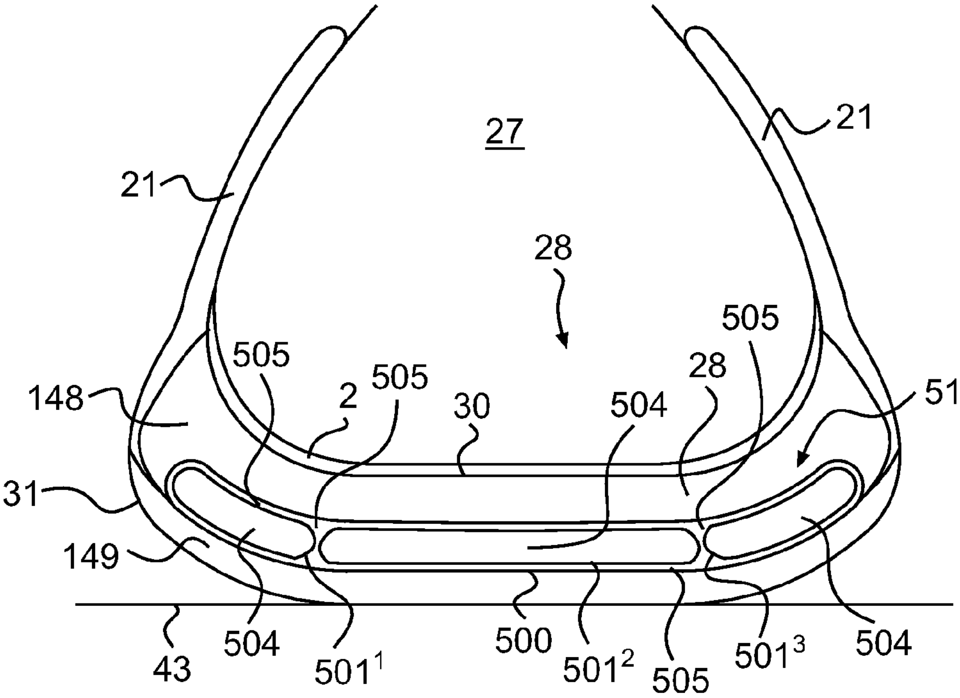
510
31
149
504
504
43
$501^1$
$501^2$
505

FIG. 93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504
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510
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149
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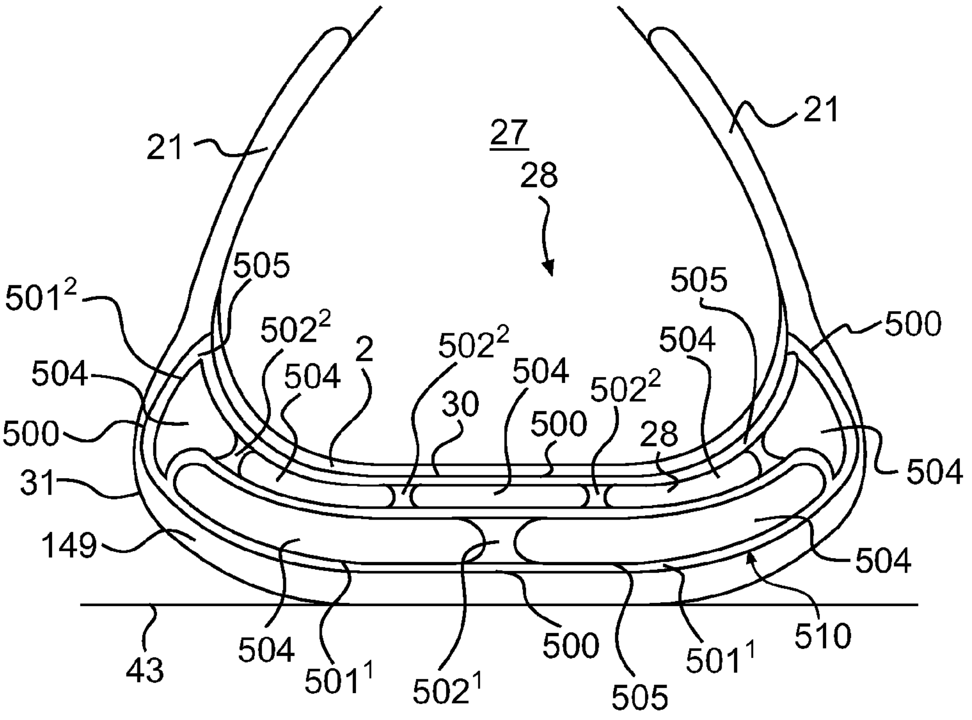
504
$501^1$
500
$501^2$
505
$501^3$
504

FIG. 94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$502^2$
$502^2$
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$502^2$
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$501^1$
$502^1$
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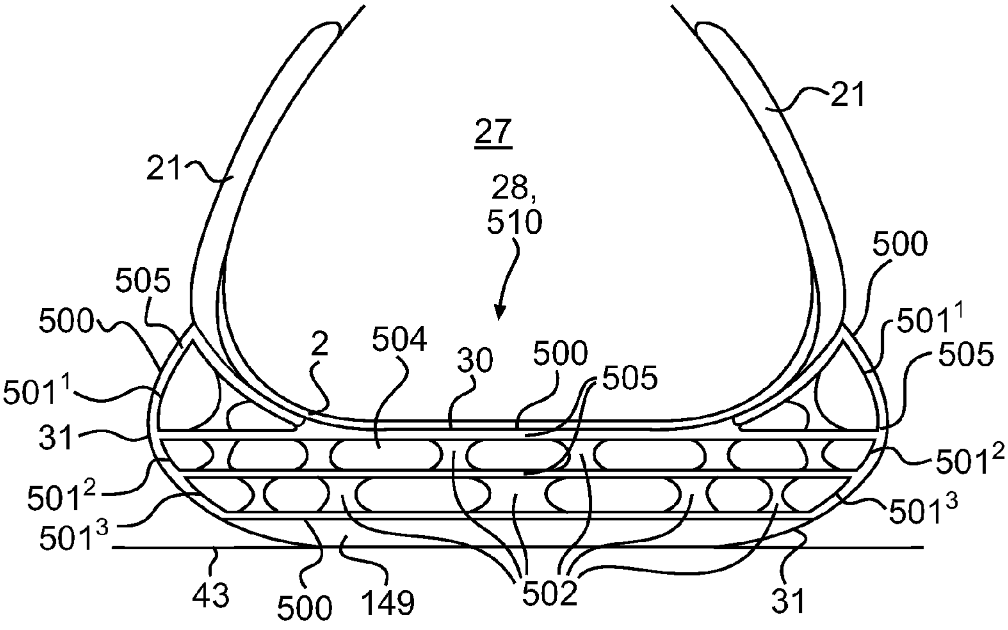
$501^1$
510

FIG. 95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501¹
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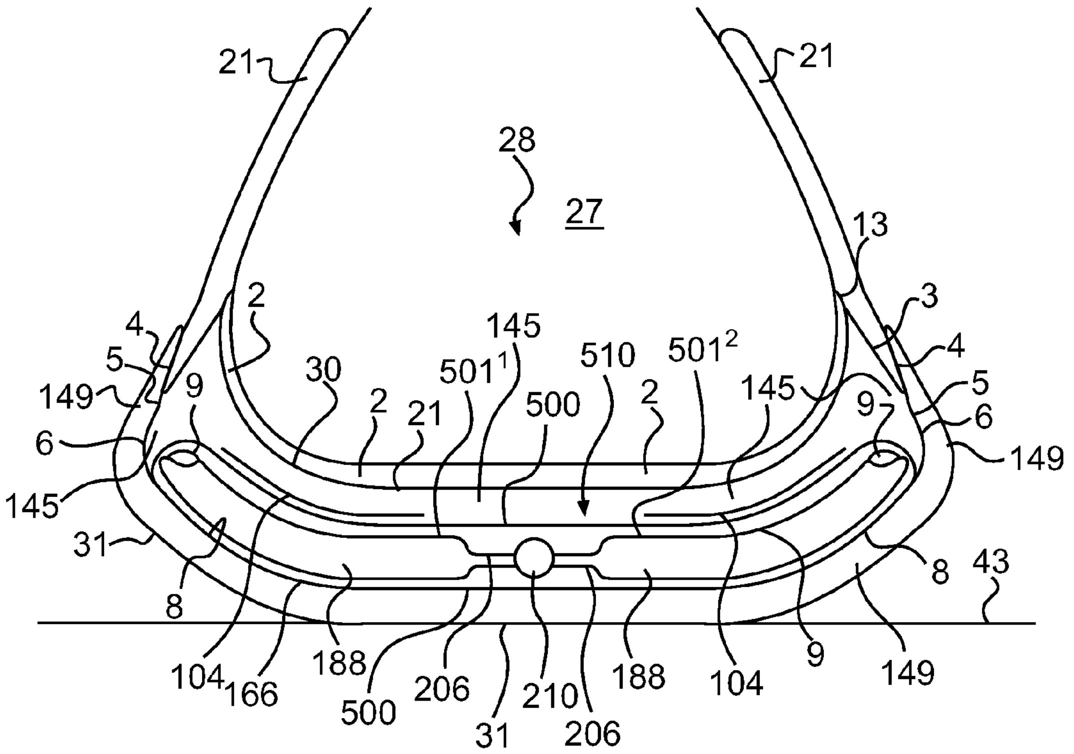
501²
501²
501³
501³
43
500
149
502
31

FIG. 96


21
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501²
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145
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500
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210
206
188
104
9
149

FIG. 97

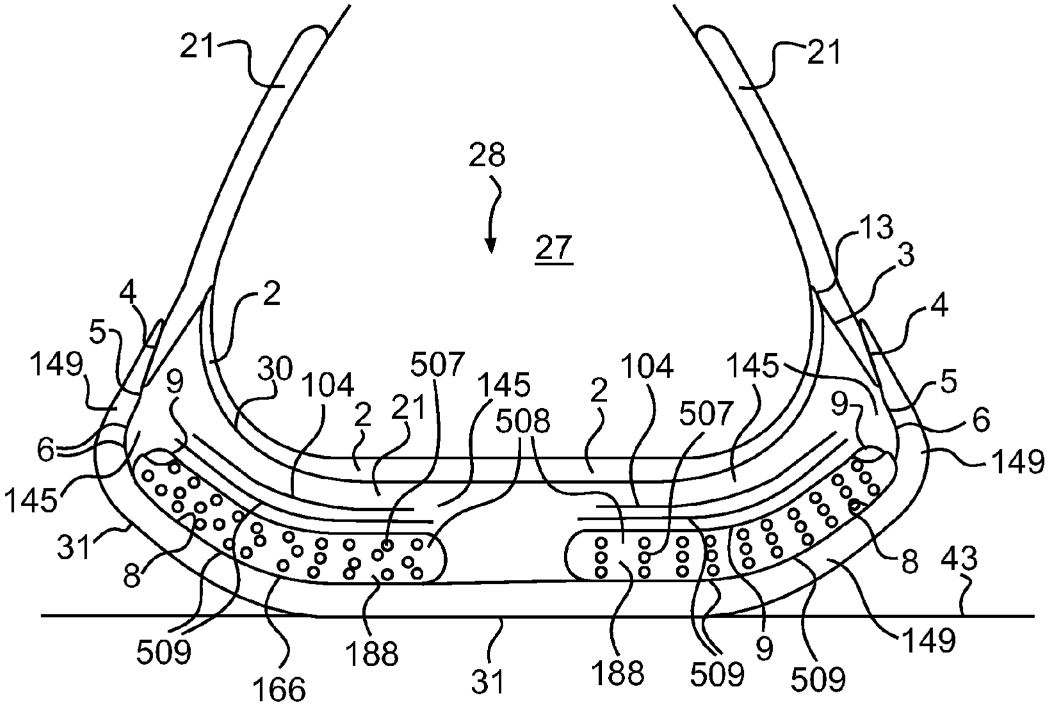


FIG. 98

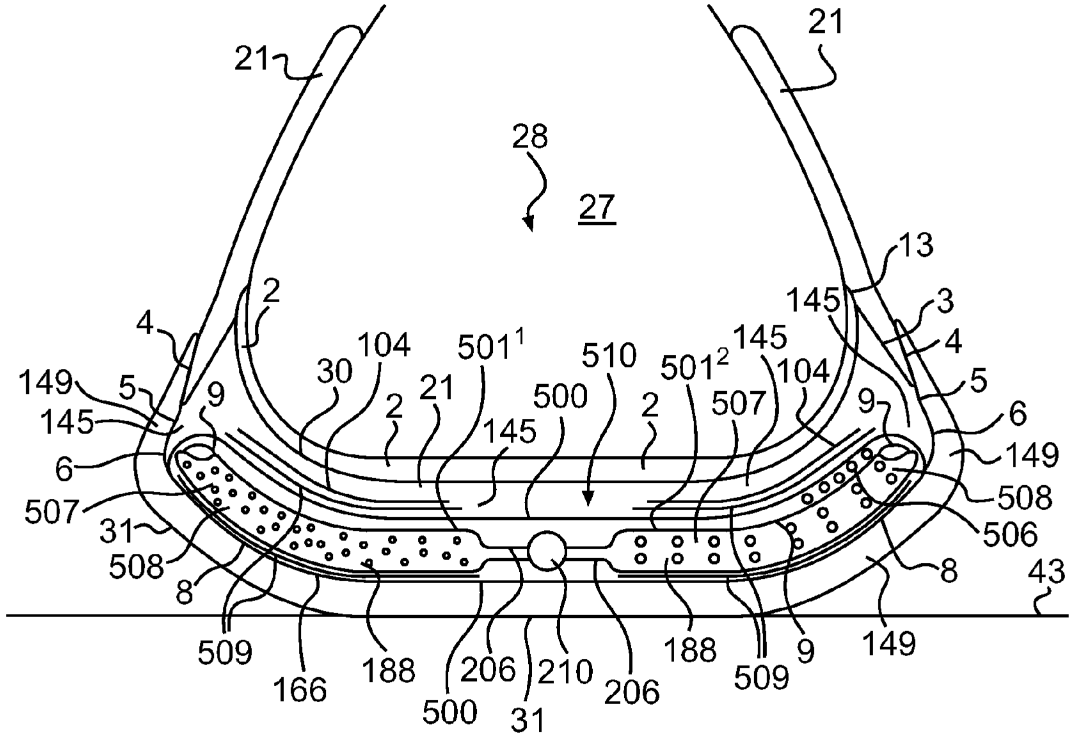
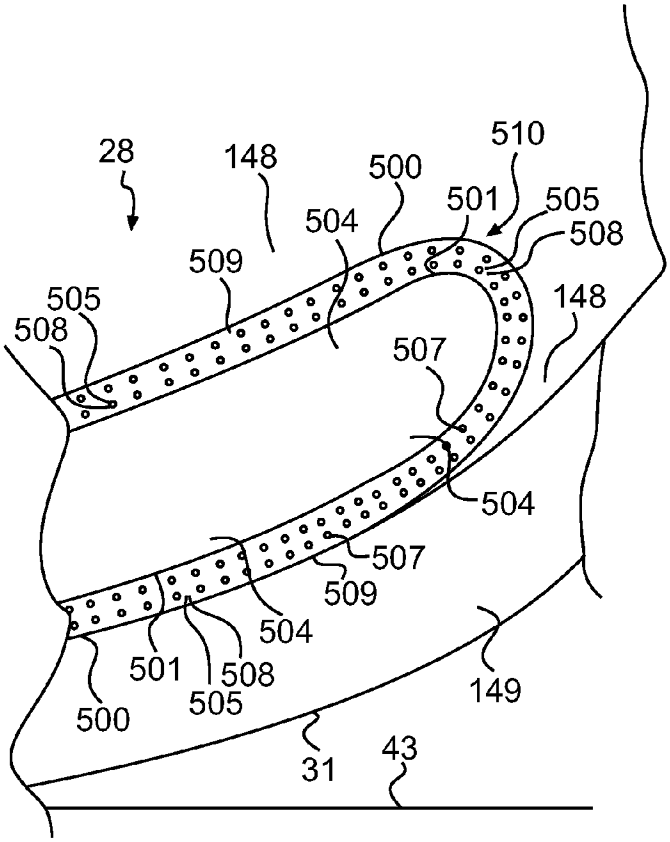


FIG. 99A


28
148
500
510
501
505
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504
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148
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31
43

FIG. 99B

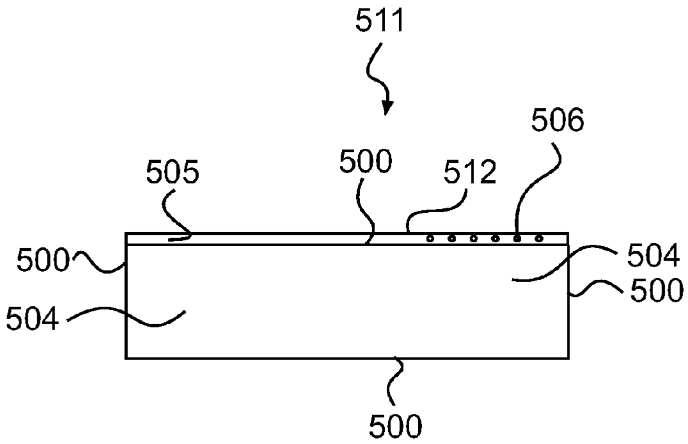


FIG. 100A

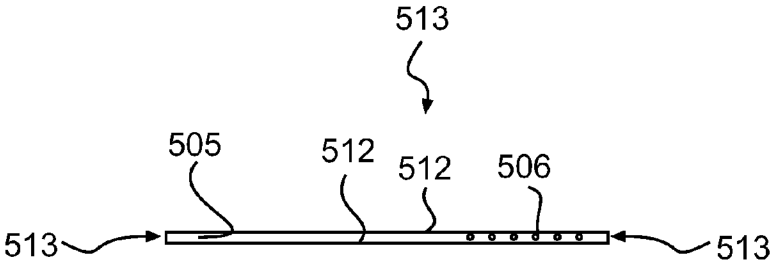


FIG. 101A

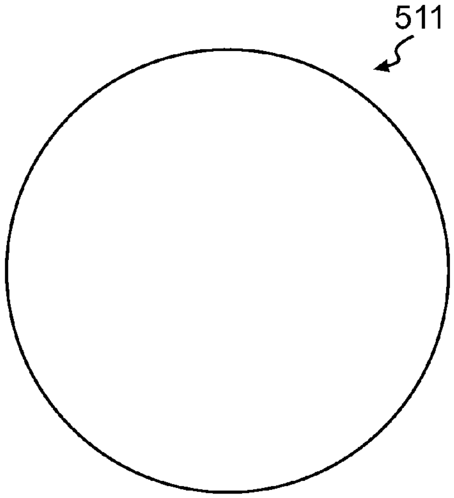


FIG. 100B

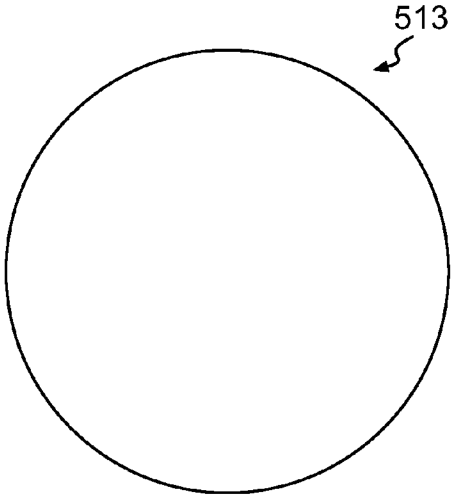


FIG. 101B

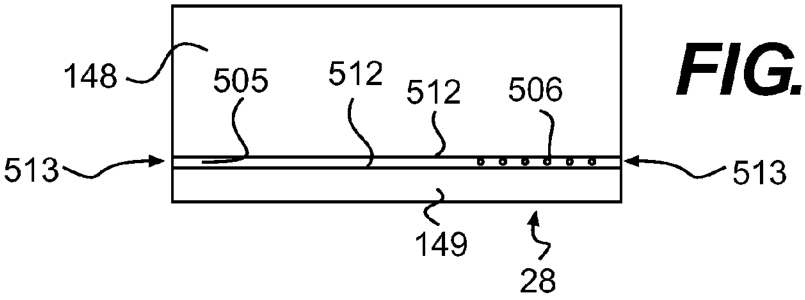
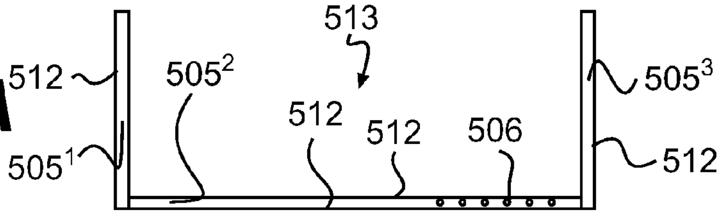


FIG. 102A

FIG. 103A



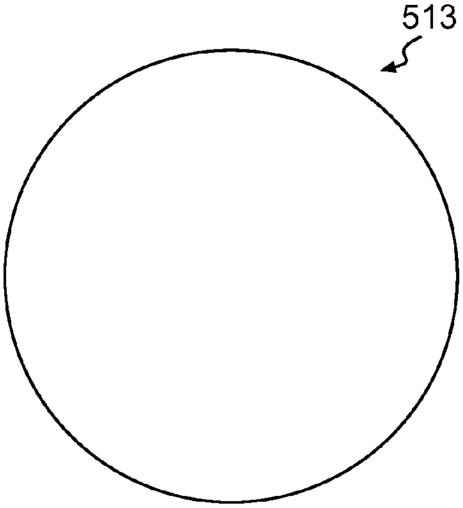


FIG. 102B

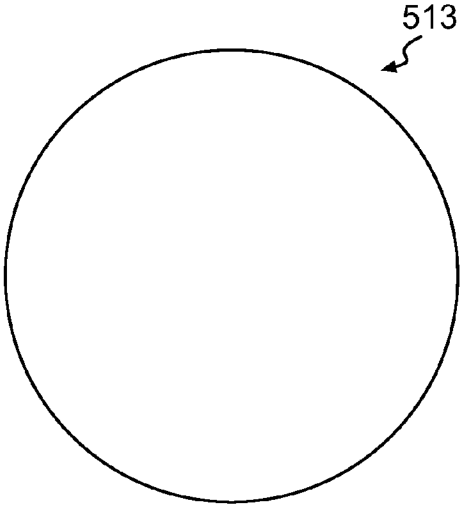


FIG. 103B

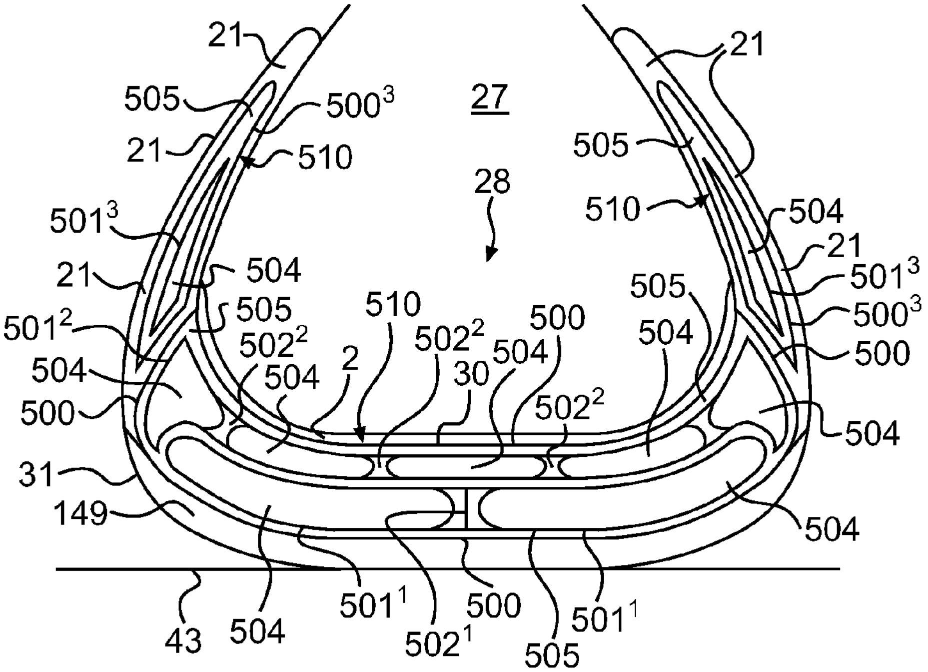


FIG. 104

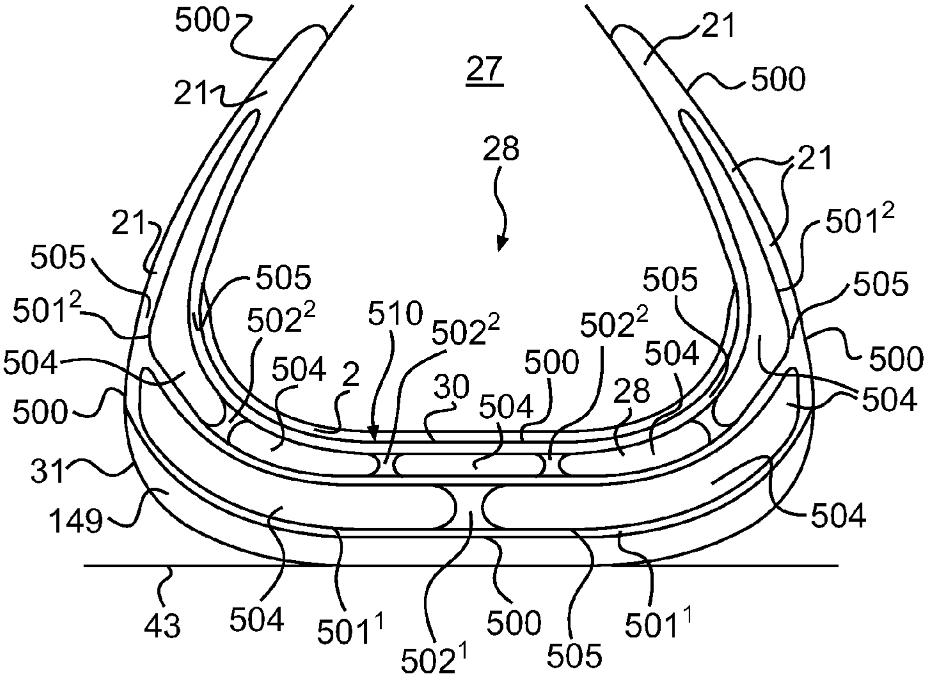


FIG. 105

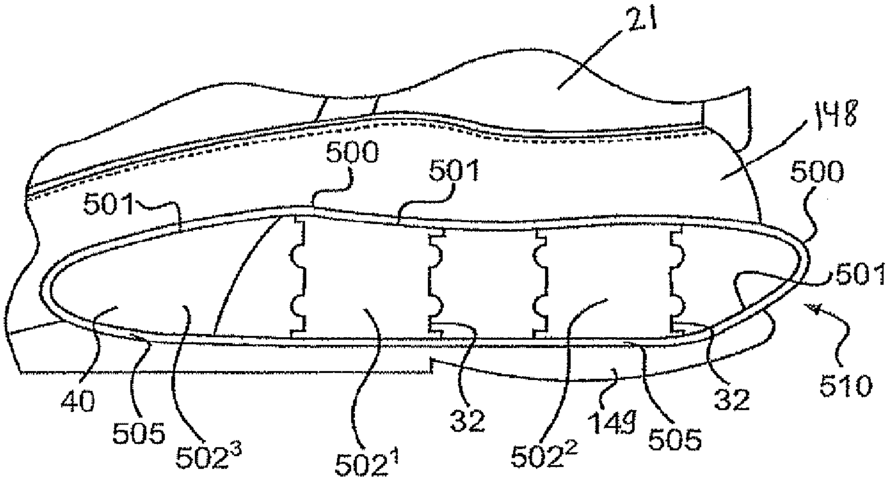


FIG. 106A

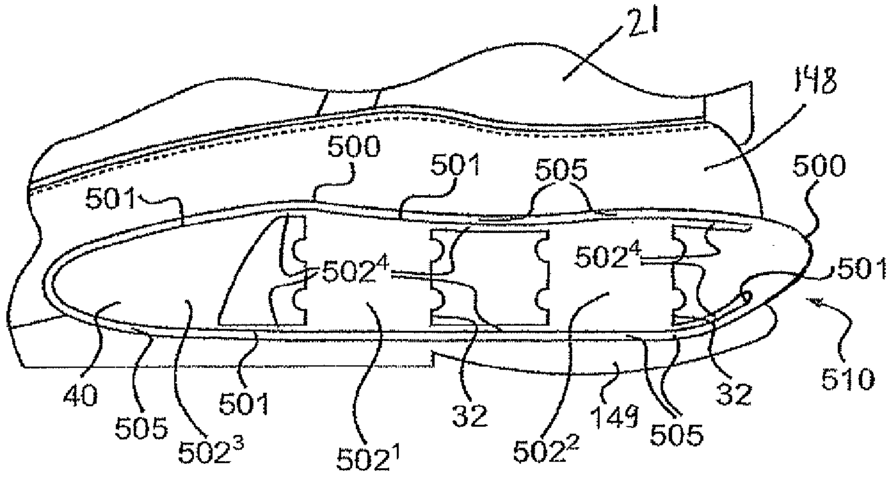


FIG. 106B

FIG. 107A

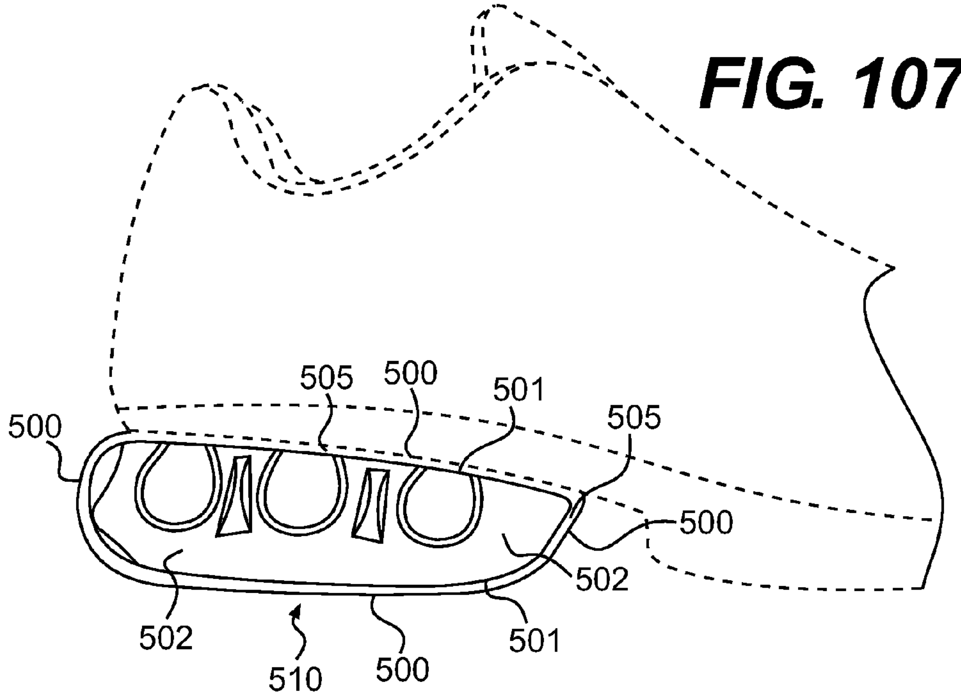
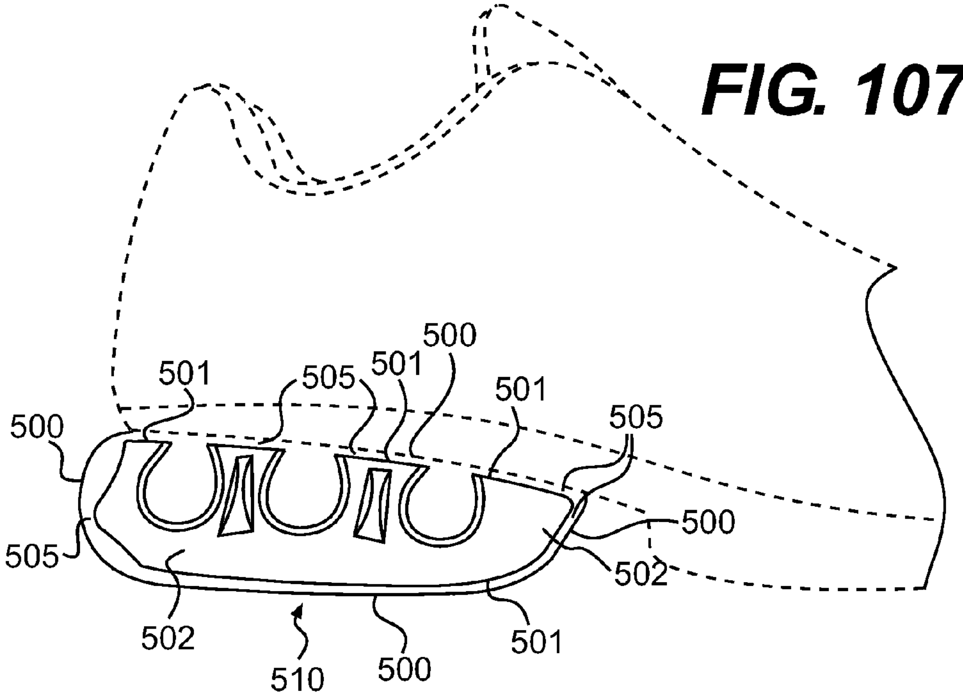


FIG. 107B



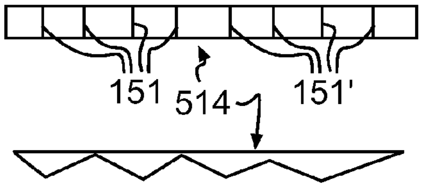


FIG. 107D

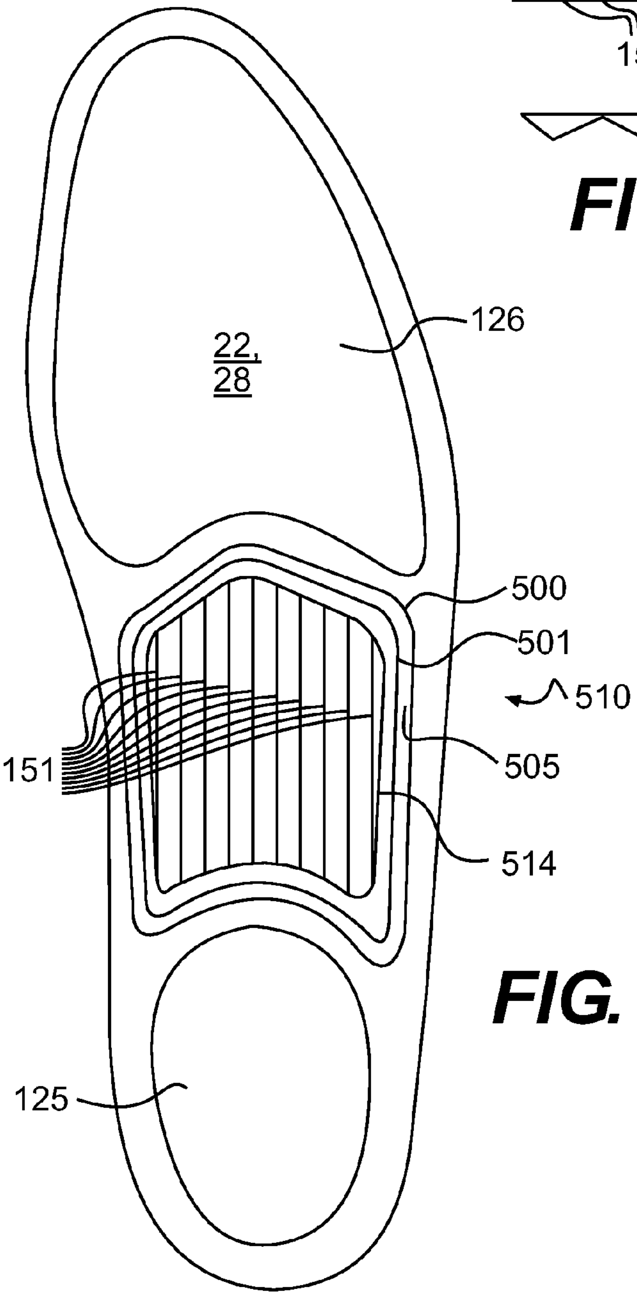


FIG. 107C

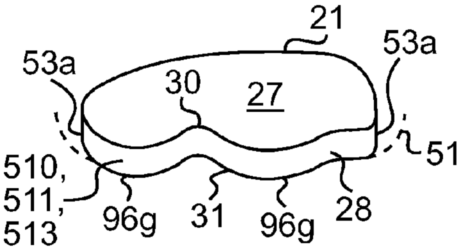


FIG. 108A
PRIOR ART

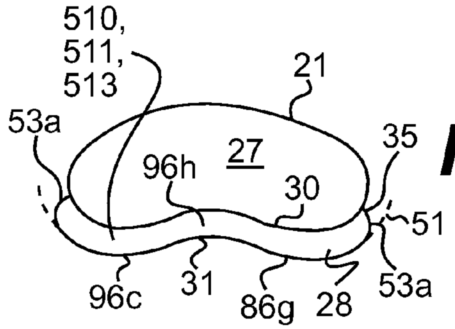


FIG. 108B
PRIOR ART

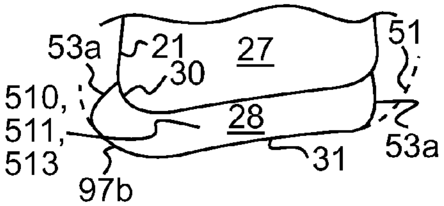


FIG. 108C
PRIOR ART

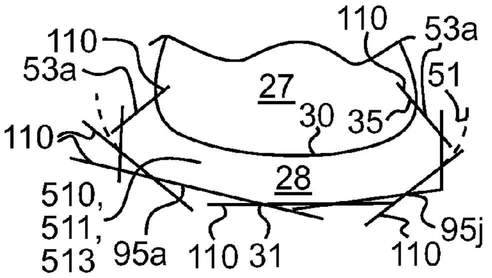
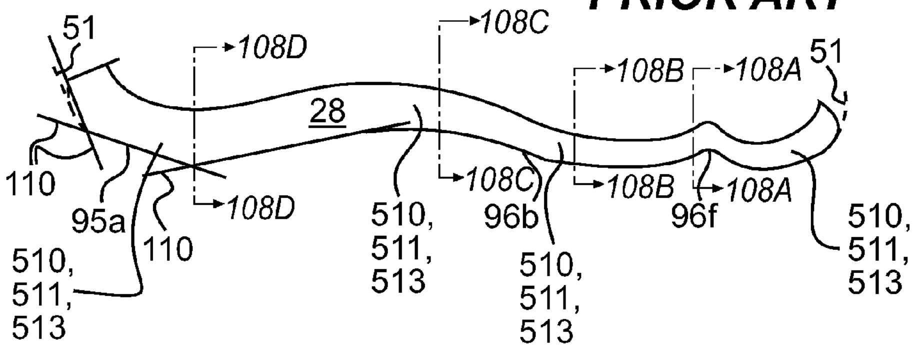


FIG. 108D
PRIOR ART

FIG. 108E
PRIOR ART



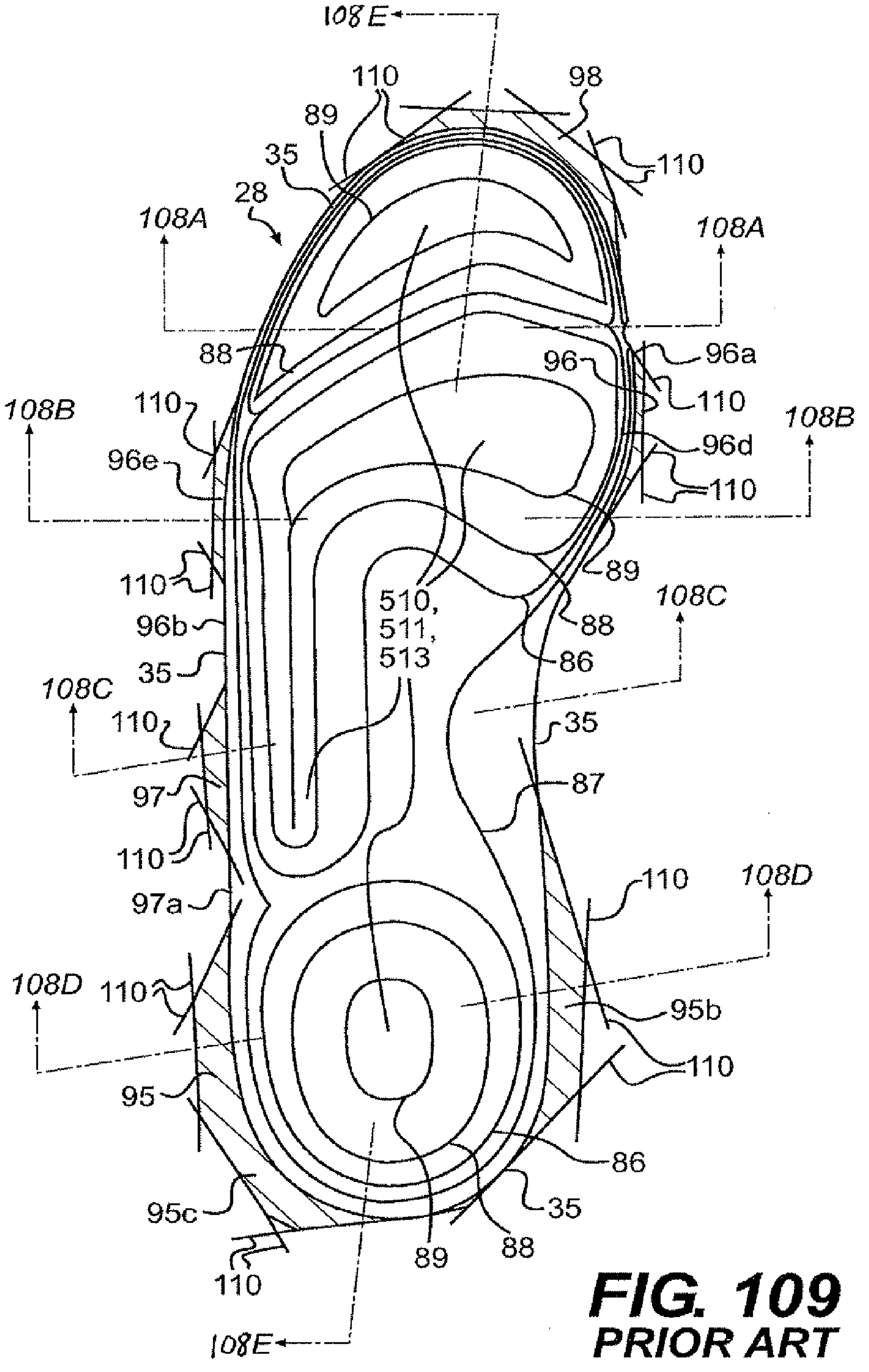


**FIG. 109**
**PRIOR ART**

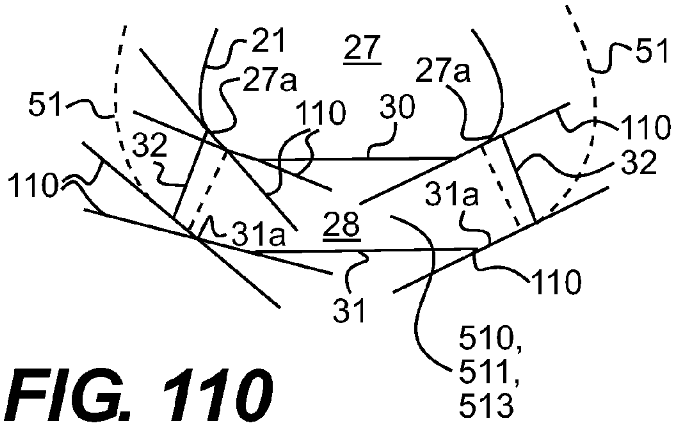


FIG. 110
PRIOR ART

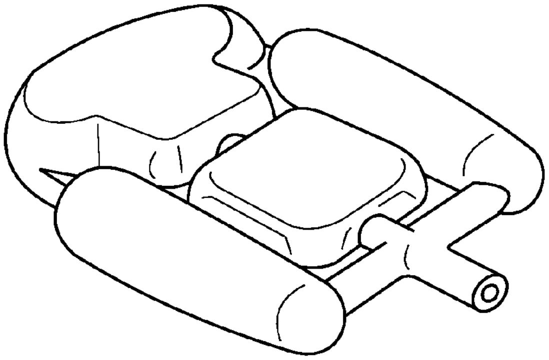


FIG. 111
PRIOR ART

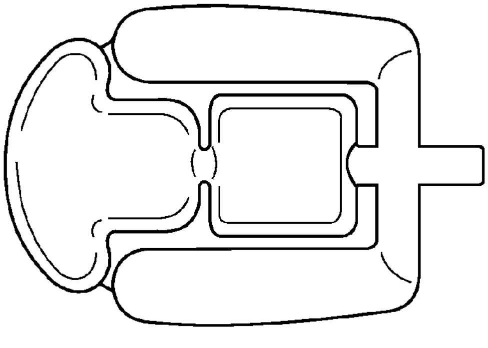


FIG. 112
PRIOR ART

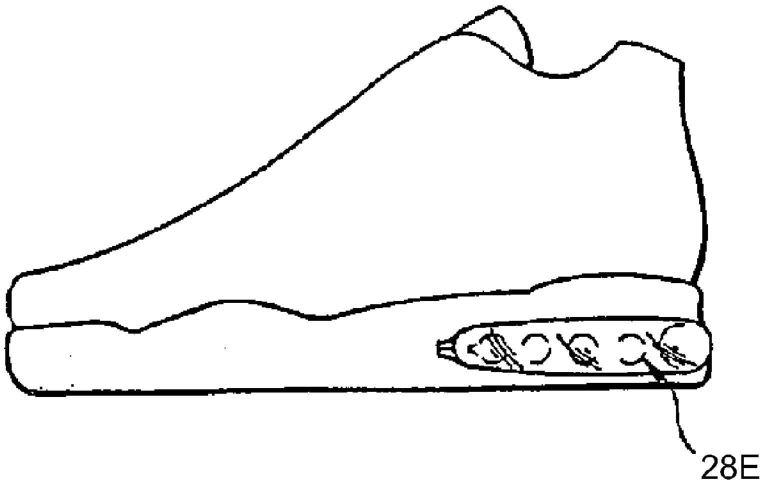


FIG. 113
PRIOR ART

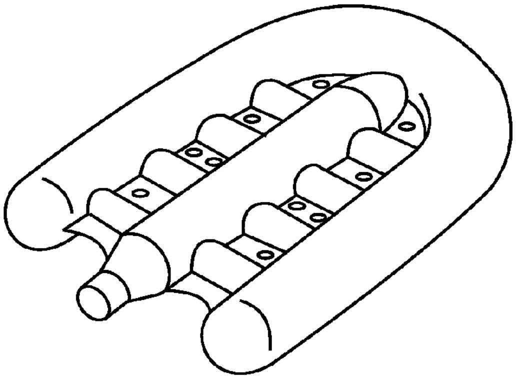
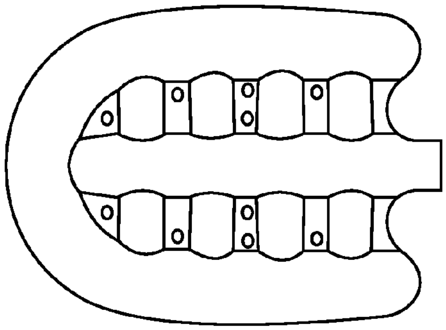


FIG. 114
PRIOR ART

FIG. 115
PRIOR ART



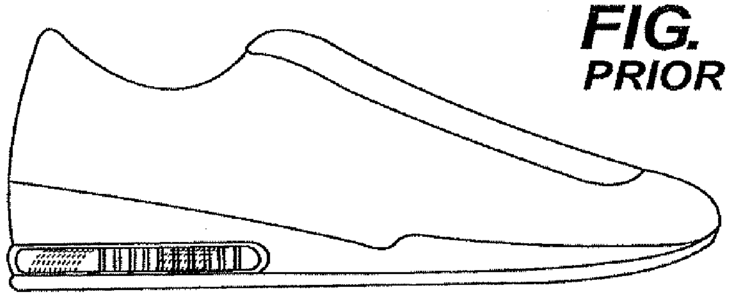


FIG. 116
PRIOR ART

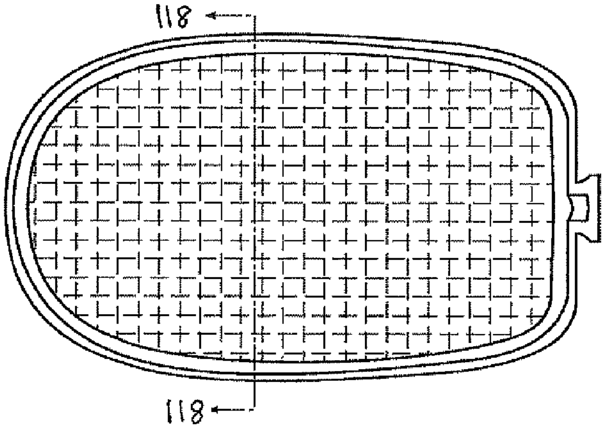
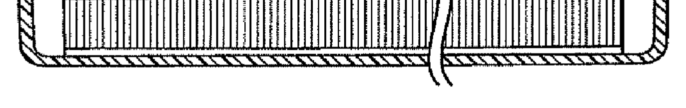


FIG. 117
PRIOR ART

FIG. 118
PRIOR ART



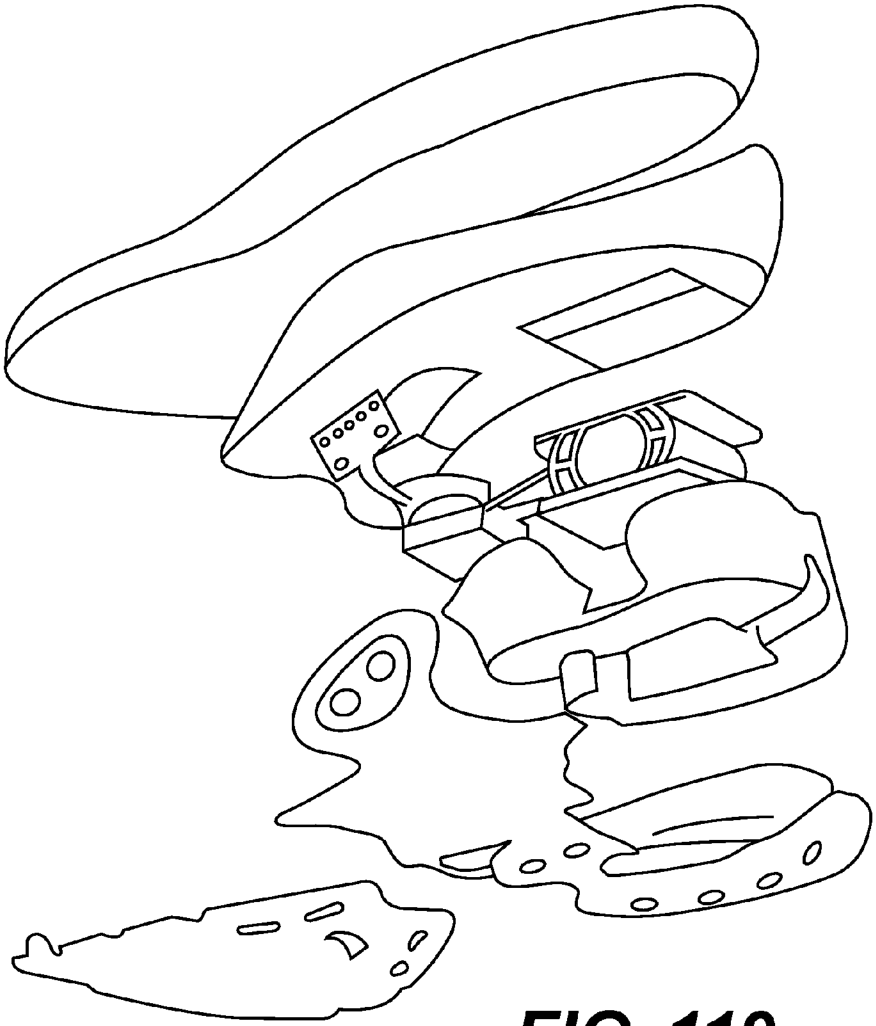


FIG. 119
PRIOR ART

# DEVICES WITH AN INTERNAL FLEXIBILITY SLIT, INCLUDING FOR FOOTWEAR

## CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of the following Provisional Patent Applications by the present inventor: Ser. Nos. 60/629,384 filed Nov. 22, 2004; 60/629,385 filed Nov. 22, 2004; 60/629,523 filed Nov. 22, 2004; 60/633,664 filed Dec. 6, 2004; 60/634,781 filed Dec. 9, 2004; 60/634,782 filed Dec. 9, 2004; 60/672,407 filed Apr. 18, 2005; 60/677,538 filed May 4, 2005; 60/679,182 filed May 9, 2005; and 60/700,179 filed Jul. 18, 2005.

## BACKGROUND OF THE INVENTION

### 1. Field of the Invention

The invention relates to all forms of footwear, including street and athletic, as well as any other products benefiting from increased flexibility, better resistance to shock and shear forces, and stable support. More particularly, the invention incorporates devices as a unitary integral component with at least one internal (or mostly internal) sipe, including slits or channels or grooves and any other shape, including geometrically regular or non-regular, such as anthropomorphic shapes, into a large variety of products including footwear using materials known in the art or their current or future equivalent. Still more particularly, the unitary internal sipe component provides improved flexibility to products utilizing them, as well as improved cushioning to absorb shock and/or shear forces, while also improving stability of support, and therefore the siped devices can be used in any existing product that provides or utilizes cushioning. These products include footwear and orthotics; athletic, occupational and medical equipment and apparel; padding or cushioning, such as for equipment and furniture; balls; tires; and any other structural or support elements in a mechanical, architectural or any other device. Still more particularly, the integral component with at least one sipe can include a media such as a lubricant or glue of any useful characteristic such as viscosity or any material, including a magnetorheological fluid.

The invention further relates to at least one chamber or compartment or bladder surrounded, partially or completely, by at least one internal (or mostly internal) sipe for use in any footwear soles or uppers, or orthotic soles or uppers, and for other flexibility, cushioning, and support uses in athletic equipment like helmets and apparel including protective padding and guards, as well as medical protective equipment and apparel, and other uses, such as protective flooring, improved furniture cushioning, balls and tires for wheels, and many other uses.

The internal sipe integral component invention further can be usefully combined with the applicant's prior footwear inventions described in this application, including removable midsole structures and orthotics and chambers with controlled variable pressure, including control by computer.

### 2. Brief Description of the Prior Art

Existing devices are generally much less flexible than would be optimal, especially products for human (or animal) users, whose non-skeletal anatomical structures like bare foot soles generally remain flexible even under significant pressure, whereas the products interfacing directly with them are often much more rigid.

Taking footwear soles as one example, cushioning elements like gas bladders or chambers or compartments are

typically fixed directly in other midsole foam plastic material to form a structure that is much more rigid than the sole of the human wearer's bare foot. As a result, the support and cushioning of the bare foot are seriously degraded when shod in existing footwear, since the relatively rigid shoe sole drastically alters by obstructing the way in which the bare foot would otherwise interact with the ground underneath a wearer. The natural interface is interrupted.

The use of external sipes—that is, sipes in the form of slits or channels that are open to an outside surface, particularly a ground-contracting surface—to provide flexibility in footwear soles has been fully described by the applicant in prior applications, including the examples shown in FIGS. **55**A-**55**C, **56**, **57**, and **73**A-**73**D. Such external sipes principally provide flexibility to the footwear sole by providing the capability of the opposing surfaces of the sipe to separate easily from each other. External sipes are structurally unlike natural anatomical structures (since to be effective, they must be much deeper than surface skin texture like finger prints, the closest anatomical analogy), however, and tend to introduce significant instability by creating excessive shoe sole edge weakness adjacent the sipes, while also collecting debris in the sipes, both seriously reducing their performance. In addition, the optimal pattern and depth of such sipes is difficult to ascertain directly and tends to be a trial and error process guided by guessing, rather than the much easier procedure of following the design of the anatomical structure with which it is intended to interface to create natural flexibility.

The use of a integral component with internal sipes in footwear soles like those described in this application overcome the problems of external sipes noted above and are naturally more optimal as well, since they more closely parallel structurally the anatomical structures of the wearer's bare foot sole. As one example, simply enveloping the outer surface of existing cushioning devices like gas bladders or foamed plastic EVA or PU with a new outer layer of material that is unattached (or at least partially unattached) thereby creates an internal sipe between the inner surface of the new compartment and the outer surface of the existing bladder/midsole component, allowing the two surfaces to move relative to each other rather than being fixed to each other. Especially in the common form of a slit structure seen in many example embodiments, the flexibility of the internal sipe is provided by this relative motion between opposing surfaces that in many the example embodiments are fully in contact with each other, again in contract to the separating surfaces of external sipes; such surface contact is, of course, exclusive of any internal sipe media, which can be used as an additional enhancement, in contrast to the flexibility-obstructing debris often clogging external sipes. As a result, the footwear sole in which at least one integral internal sipe component is incorporated becomes much more flexible, much more like the wearer's bare foot sole itself, so that foot sole can interact with the ground naturally. The resulting footwear sole with internal sipes has improved, natural flexibility, improved cushioning from shock and shear forces, and better, more natural stable support.

A limited use of internal sipes has also been described by the applicant in prior applications, including the examples shown in FIGS. **12**A-**12**D, **60**A-**60**E, and **70**-**71**, which are generally unglued portions coinciding with lamination layer boundaries, such as between bottomsole and midsole layers. This approach requires completely new and somewhat difficult approaches in the assembly of the footwear sole during manufacture, as well as significantly greater potential for problems of layer separation (especially bottom sole) since the inherent reduction in gluing surfaces makes the remaining gluing surfaces critical and under increased load; significantly increased positional accuracy in the application of glue is required. Also, the use of lubricating media (and the potential control thereof, including by microprocessor) is also more difficult, since the sipe is formed by existing parts and is not discretely enclosed with the new outer layer to contain the media, as it is in the new invention described in this application.

In contrast, the new invention of this application is a discrete device in the form of an integral component that can easily be inserted as a single simple step into the footwear sole during the manufacturing process or, alternatively, inserted in one single simple step by a wearer (into the upper portion of a midsole insert, for example, much like inserting an insole into an shoe), for whom the new extra layer provides buffering protection for the wearer from direct, potentially abrasive contact with a cushioning component (forming a portion of the inner, foot sole-contacting surface of the shoe sole, for example).

In addition, the new invention allows easier and more effective containment of a lubricating media (including media with special capabilities, like magnetorheological fluid) within the integral internal sipe, so that the relative motion between inner surfaces of the sipe can be controlled by that media (and, alternatively, by direct computer control); it avoids the need for the use of closed-cell midsole materials or a special impermeable layer applied to the footwear sole material to prevent the sipe media from leaking away.

Accordingly, it is a general object of one or more embodiments of the invention to elaborate upon the application of the use of a device in the form of an integral component with one or more internal sipes to improve the flexibility, cushioning, and stability of footwear and other products.

It is still another object of one or more embodiments of the invention to provide footwear having an integral component with at least one internal (or mostly internal) sipes, including slits or channels or grooves and any other shape, including geometrically regular or non-regular, such as anthropomorphic shapes, to improve flexibility, cushioning and stability. It is still another object of one or more embodiments of the invention to include an integral device with one or more internal sipes that include a media such as a lubricant or glue of any useful characteristic such as viscosity or any material, including a magnetorheological fluid.

It is another object of one or more embodiments of the invention to create a shoe sole with flexibility, support and cushioning that is provided by siped chambers or compartments or bladders in the footwear sole or upper or orthotics. The compartments or chambers or bladders are surrounded, partially or completely, by at least one internal (or mostly internal) sipe for use in any footwear soles or uppers, or orthotic soles or uppers, and for other flexibility, cushioning, and stability uses in athletic equipment like helmets and apparel including protective padding and guards, as well as medical protective equipment and apparel, and other uses, such as protective flooring, improved furniture cushioning, balls and tires for wheels, and many other uses.

It is another object of one or more embodiments of the invention to create footwear, orthotic or other products with at least one outer chamber; at least one inner chamber inside the outer chamber; the outer chamber and the inner chamber being separated at least in part by an internal sipe; at least a portion of an inner surface of the outer chamber forming at least a portion of an inner surface of the internal sipe; and the internal sipe providing increased flexibility, cushioning, and stability for the footwear, orthotic or other product.

A further object of one or more embodiments of the invention is to combine the integral component with at least one internal sipe with the applicant's prior footwear inventions described in this application, including removable midsole structures and orthotics and chambers with controlled variable pressure, including control by computer.

These and other objects of the invention will become apparent from the summary and detailed description of the invention, which follow, taken with the accompanying drawings.

## SUMMARY OF THE INVENTION

In one aspect the present invention attempts, as closely as possible, to replicate the naturally effective structures of the bare foot that provide flexibility, cushioning, and stable support. More specifically, the invention relates to a device for a footwear sole or upper or both, or an orthotic or orthotic upper or both, or other, non-footwear devices, including a unitary internal sipe component, said internal sipe providing increased flexibility for said device. More specifically, the invention relates to an integral component with at least one sipe with a media such as a lubricant or glue of any useful characteristic such as viscosity or any material, including a magnetorheological fluid.

Even more specifically, the invention relates to footwear or orthotics or other products with at least one compartment or chamber or bladder surrounded, partially or completely, by at least one internal (or mostly internal) sipe for use in any footwear soles or uppers, or orthotic soles or uppers, and for other flexibility, cushioning, and stability uses. Even more specifically, the invention relates to footwear, orthotic or other products with at least one outer chamber; at least one inner chamber inside the outer chamber; the outer chamber and the inner chamber being separated at least in part by an internal sipe; at least a portion of an inner surface of the outer chamber forming at least a portion of an inner surface of the internal sipe; and the internal sipe providing increased flexibility, cushioning, and stability for the footwear, orthotic or other product.

These and other features of the invention will become apparent from the detailed description of the invention that follows.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1-82** are prior art from the applicant's earlier applications and are FIGS. 1-82 in the applicant's PCT Application No. PCT/US01/13096, published by WIPO as WO 01/80678 A2 on 1 Nov. 2001. FIGS. **83-107** are new with this application. FIGS. **108-119** are prior art.

FIG. **1** is a perspective view of a prior art conventional athletic shoe to which the present invention is applicable.

FIG. **2** illustrates in a close-up frontal plane cross-section of the heel at the ankle joint the typical shoe known in the art that does not deform as a result of body weight when tilted sideways on the bottom edge.

FIG. **3** shows, in the same close-up cross-section as FIG. **2**, a naturally rounded shoe sole design also tilted sideways.

FIG. **4** shows a rear view of a barefoot heel tilted laterally 20 degrees.

FIG. **5**A shows, in a frontal plane cross-section at the ankle joint area of the heel, tension stabilized sides applied to a naturally rounded shoe sole.

FIG. **5**B shows a close-up of a second embodiment of tension stabilized sides.

FIG. **6** shows, in a frontal plane cross-section, the FIG. **5** design when tilted to its edge but undeformed by load.

FIG. **7** shows, in frontal plane cross-section at the ankle joint area of the heel, the FIG. **5** design when tilted to its edge and naturally deformed by body weight.

FIG. **8** is a sequential series of frontal plane cross-sections of the barefoot heel at the ankle joint area.

FIG. **8**A is an unloaded and upright barefoot heel.

FIG. **8**B is a heel moderately loaded by: full body weight and upright.

FIG. **8**C is a heavily loaded heel at peak landing force while running and upright.

FIG. **8**D is heavily loaded heel shown tilted out laterally by about 20 degrees, the maximum tilt for the heel.

FIGS. **9**A-**9**D show a sequential series of frontal plane cross-sections of a shoe sole design of the heel at the ankle joint area that corresponds exactly to the FIG. **8** series described above.

FIG. **10** shows two perspective views and a close-up view of a part of a shoe sole with a structure like the fibrous connective tissue of the groups of fat cells of the human heel.

FIG. **10**A shows a quartered section of a shoe sole with a structure comprising elements corresponding to the calcaneus with fat pad chambers below it.

FIG. **10**B shows a horizontal plane close-up of the inner structures of an individual chamber of a shoe sole.

FIG. **10**C shows a horizontal section of a shoe sole with a structure corresponding to the whorl arrangement off fat pads underneath the calcaneus.

FIGS. **11**A-**11**B are frontal plane cross-sectional views showing different variations of removable midsole inserts in accordance with the present invention.

FIG. **11**C shows a shoe sole with the removable midsole insert removed.

FIG. **11**D is an exploded view of an embodiment of a removable midsole insert in accordance with the present invention.

FIG. **11**E is a cross-sectional view showing a snap-fit arrangement for releasably securing the removable midsole insert.

FIG. **11**F is a cross-sectional view of an embodiment that employs interlocking geometries for releasably securing the removable midsole insert of the present invention.

FIG. **11**G is a frontal plane cross-section of a forefoot section removable midsole formed with an asymmetric side height.

FIGS. **11**H-**11**J show other frontal plane sections of the removable midsole insert along the lines in FIG. **11**L.

FIG. **11**K shows a sagittal plane section of the shoe sole of FIGS. **11**G-**11**I and **11**L.

FIG. **11**L shows a horizontal plane top view of the shoe sole of FIGS. **11**G-**11**K.

FIG. **11**M-**11**O are frontal plane cross-sectional views showing three variations of mid sole sections with one or more pressure controlled encapsulated midsole sections and a control system such as a microprocessor.

FIG. **11**P is an exploded view of an embodiment of a removable midsole with pressure controlled encapsulated midsole sections and a control system such as a microprocessor.

FIGS. **11**Q and **11**R are frontal plane cross-sectional views showing two variations of the removable midsole insert with a thin outer sole layer.

FIG. **11**S shows the interface between the bottomsole and the secondary bottomsole.

FIG. **11**T is a schematic representation of suitable pressure sensing circuitry for use in the present invention.

FIG. **11**U is a schematic representation of a control system that may be employed in the present invention.

FIG. **11**V shows an embodiment of the present invention that employs mechanical fasteners to releasably secure the removable midsole insert in place.

FIGS. **12**A-**12**C show a series of conventional shoe sole cross-sections in the frontal plane at the heel utilizing both sagittal plane and horizontal plane sipes, and in which some or all of the sipes do not originate from any outer shoe sole surface, but rather are entirely internal

FIG. **12**D shows a similar approach as is shown in FIGS. **12**A-**12**C applied to the fully rounded design.

FIGS. **13**A-**13**B show, in frontal plane cross-section at the heel area, shoe sole structures similar to those shown in FIGS. **5**A-B, but in more detail and with the bottom sole extending relatively farther up the side of the midsole.

FIG. **14** shows, in frontal plane cross-section at the heel portion of a shoe, a shoe sole with naturally rounded sides based on a theoretically ideal stability plane.

FIG. **15** shows, in frontal plane cross-section, the most general case of a fully rounded shoe sole that follows the natural contour of the bottom of the foot as well as its sides, also as based on the theoretically ideal stability plane.

FIGS. **16**A-**16**C show, in frontal plane cross-section at the heel, a quadrant-sided shoe sole, based on a theoretically ideal stability plane.

FIG. **17** shows a frontal plane cross-section at the heel portion of a shoe with naturally rounded sides like those of FIG. **14**, wherein a portion of the shoe sole thickness is increased beyond the theoretically ideal stability plane.

FIG. **18** is a view similar to FIG. **17**, but of a shoe with fully rounded sides wherein the sole thickness increases with increasing distance from the center line of the ground-contacting portion of the sole.

FIG. **19** is a view similar to FIG. **18** where the fully rounded sole thickness variations are continually increasing on each side.

FIG. **20** is a view similar to FIGS. **17**-**19** wherein the sole thickness varies in diverse sequences.

FIG. **21** is a frontal plane cross-section showing a density variation in the midsole.

FIG. **22** is a view similar to FIG. **21** wherein the firmest density material is at the outermost edge of the midsole.

FIG. **23** is a view similar to FIGS. **21** and **22** showing still another density variation that is asymmetrical.

FIG. **24** shows a variation in the thickness of the sole for the quadrant-sided shoe sole embodiment of FIGS. **16**A-**16**C that is greater than a theoretically ideal stability plane.

FIG. **25** shows a quadrant-sided embodiment as in FIG. **24** wherein the density of the sole varies.

FIG. **26** shows a bottom sole tread design that provides a similar density variation to that shown in FIG. **23**.

FIGS. **27**A-**27**C show embodiments similar to those shown in FIGS. **14**-**16**, but wherein a portion of the shoe sole thickness is decreased to less than the theoretically ideal stability plane.

FIGS. **28**A-**28**F show embodiments of the invention with shoe sole sides having thicknesses both greater and lesser than the theoretically ideal stability plane.

FIG. **29** is a frontal plane cross-section showing a shoe sole of uniform thickness that conforms to the natural shape of the human foot.

FIGS. **30**A-**30**D show a load-bearing flat component of a shoe sole and a naturally rounded side component as well as a preferred horizontal periphery of the flat load-bearing portion of the shoe sole.

FIGS. **31**A-**31**B are diagrammatic sketches showing a rounded side sole design according to the invention with variable heel lift.

FIG. **32** is a side view of a stable rounded shoe sole according to the invention.

FIG. **33**A is a cross-sectional view of the forefoot portion of a shoe sole taken along line **33**A of FIGS. **32** and **33**D.

FIG. **33**B is a cross-sectional view taken along line **33**B of FIGS. **32** and **33**D.

FIG. **33**C is a cross-sectional view of the heel portion taken along line **33**C in FIGS. **32** and **33**D. FIG. **33**D is a top view of the shoe sole shown in FIG. **32**

FIGS. **34**A-**34**D are frontal plane cross-sectional views of a shoe sole according to the invention showing a theoretically ideal stability plane and truncations of the sole side contoured to reduce shoe bulk.

FIGS. **35**A-**35**C show a contoured sole design according to the invention when applied to various tread and cleat patterns.

FIG. **36** is a diagrammatic frontal plane cross-sectional view of static forces acting on the ankle joint and its position relative to a shoe sole according to the invention during normal and extreme inversion and eversion motion.

FIG. **37** is a diagrammatic frontal plane view of a plurality of moment curves of the center of gravity for various degrees of inversion for a shoe sole according to the invention contrasted with comparable motions of conventional shoes.

FIGS. **38**A-**38**F show a design with naturally rounded sides extended to other structural contours underneath the load-bearing foot such as the main longitudinal arch.

FIGS. **39**A-**39**E illustrate a fully contoured shoe sole design extended to the bottom of the entire non-load bearing foot.

FIG. **40** shows a fully contoured shoe sole design abbreviated along the sides to only essential structural support and propulsion elements.

FIGS. **41**A-**41**B illustrate a street shoe with a correctly contoured sole according to the invention and side edges perpendicular to the ground.

FIGS. **42**A-**42**D show several embodiments wherein the bottom sole includes most or all of the special rounding of the designs and retains a flat upper surface.

FIG. **43** is a rear view of a heel of a foot for explaining the use of a stationary sprain simulation test.

FIG. **44** is a rear view of a conventional athletic shoe unstably rotating about an edge of its sole when the shoe sole is tilted to the outside.

FIGS. **45**A-**45**C illustrate functionally the principles of natural deformation as applied to the shoe soles of the invention.

FIG. **46** shows variations in the relative density of the shoe sole including the shoe insole to maximize an ability of the sole to deform naturally.

FIG. **47** shows a shoe having naturally rounded sides bent inwardly from a conventional design so then when worn the shoe approximates a custom fit.

FIGS. **48**A-**48**J show a shoe sole having a fully contoured design but having sides which are abbreviated to the essential structural stability and propulsion elements and are combined and integrated into discontinuous structural elements underneath the foot that simulate those of the foot.

FIG. **49** shows the theoretically ideal stability plane concept applied to a negative heel shoe sole that is less thick in the heel area than in the rest of the shoe sole, such as a shoe sole comprising a forefoot lift.

FIG. **49**A is a frontal plane cross-sectional view of the forefoot portion taken along line **49**A of FIG. **49**D.

FIG. **49**B is a frontal plane cross-sectional view taken along line **49**B of FIG. **49**D.

FIG. **49**C is a frontal plane cross-sectional view of the heel along line **49**C of FIG. **49**D.

FIG. **49**D is a top view of the shoe sole with a thicker forefoot section shown with cross-hatching.

FIGS. **50**A-**50**E show a plurality of side sagittal plane cross-sectional views of examples of negative heel sole thickness variations (forefoot lift) to which the general approach shown in FIGS. **49**A-**49**D can be applied.

FIG. **51** shows the use of the theoretically ideal stability plane concept applied to a flat shoe sole with no heel lift by maintaining the same thickness throughout and providing the shoe sole with rounded stability sides abbreviated to only essential structural support elements.

FIG. **51**A is a frontal plane cross-sectional view of the forefoot portion taken along line **51**A of FIG. **51**D.

FIG. **51**B is a frontal plane cross-sectional view taken along line **51**B of FIG. **51**D.

FIG. **51**C is a frontal plane cross-sectional view taken along the heel along line **51**C in FIG. **51**D.

FIG. **51**D is a top view of the shoe sole with sides that are abbreviated to essential structural support elements shown hatched. FIG. **51**E is a sagittal plane cross-section of the shoe sole of FIG. **51**D.

FIG. **52** shows, in frontal plane cross-section at the heel, the use of a high-density midsole material on the naturally rounded sides and a low-density midsole material everywhere else to reduce side width.

FIG. **53** shows the footprints of the natural barefoot sole and shoe sole.

FIG. **53**A shows the foot upright with its sole flat on the ground.

FIG. **53**B shows the foot tilted out 20 degrees to about its normal limit.

FIG. **53**C shows a conventional shoe sole of the same size when tilted out 20 degrees to the same position as FIG. **53**B. The right foot and shoe are shown.

FIG. **54** shows footprints like those shown in FIGS. **53**A and **53**B of a right bare foot upright and tilted out 20 degrees, but showing also their actual relative positions to each other as a high arched foot rolls outward from upright to tilted out 20 degrees.

FIG. **55** shows a shoe sole with a lateral stability sipe in the form of a vertical slit.

FIG. **55**A is a top view of a conventional shoe sole with a corresponding outline of the wearer's footprint superimposed on it to identify the position of the lateral stability sipe relative to the wearer's foot.

FIG. **55**B is a frontal plane cross-section of the shoe sole with lateral stability sipe.

FIG. **55**C is a top view like FIG. **55**A, but showing the print of the shoe sole with a lateral stability sipe when it is tilted outward 20 degrees.

FIG. **56** shows a medial stability sipe, analogous to the lateral sipe, providing increased pronation stability. The head of the first metatarsal and the first phalange are included with the heel to form a medial support section.

FIG. **57** shows footprints like FIG. **54**, of a right bare foot upright and tilted out 20 degrees, showing the actual relative positions to each other as a low arched foot rolls outward from upright to tilted out 20 degrees.

FIGS. **58**A-D show the use of flexible and relatively inelastic fiber in the form of strands, woven or unwoven (such as pressed sheets), embedded in midsole and bottom sole material.

FIGS. **59**A-F show the use of flexible inelastic fiber or fiber strands, woven or unwoven (such as pressed sheets) to make an embedded capsule shell that surrounds the cushioning compartment **161** containing a pressure-transmitting medium like gas, gel, or liquid.

FIGS. **60**A-D show the use of embedded flexible inelastic fiber or fiber strands, woven or unwoven, in various embodiments similar those shown in FIGS. **58**A-D.

FIG. **60**E shows a frontal plane cross-section of a fibrous capsule shell **191** that directly envelops the surface of the encapsulated midsole section **188**.

FIG. **61**A compares the footprint made by a conventional shoe with the relative positions of the wearer's right foot sole in the maximum supination position **37***a* and the maximum pronation position **37***b*.

FIG. **61**B shows an overhead perspective of the actual bone structures of the foot that are indicated in FIG. **63**C.

FIG. **62** compares a footprint made by a convention shoe with the relative position of the wearer's right foot sole in the maximum supination position.

FIG. **63** shows an electronic image of the relative forces present at the different areas of the bare foot sole when at the maximum supination position shown as **37***a* in FIG. **61**A; the forces were measured during a standing simulation of the most common ankle spraining position.

FIG. **64** shows on the right side an upper shoe sole surface of the rounded side that is complementary to the shape of the wearer's foot sole; on the left side FIG. **64** shows an upper surface between complementary and parallel to the flat ground and a lower surface of the rounded shoe sole side that is not in contact with the ground.

FIG. **65** indicates the angular measurements of the rounded shoe sole sides from zero degrees to 180 degrees.

FIGS. **66**A-**66**F show a shoe sole without rounded stability sides.

FIGS. **67**A-**67**E and **68** also show a shoe sole without rounded stability sides.

FIGS. **69**A-**69**D show additional variations of the naturally rounded sides of the present invention.

FIG. **70** shows a bottomsole structure with forefoot, heel, and base of the fifth metatarsal support areas.

FIG. **71** shows a similar structure to FIG. **70**, but with only the section under the forefoot unglued or not firmly attached.

FIG. **72**A shows a shoe sole combining additional stability corrections **96***a*, **96***b*, and **98***a'*, supporting the first and fifth metatarsal heads and distal phalange heads.

FIG. **72**B shows a shoe sole with symmetrical stability additions **96***a* and **96***b*.

FIGS. **73**A-**73**D show in close-up sections of the shoe sole including various new forms of sipes, including both slits and channels.

FIG. **74** shows, in FIGS. **74**A-**74**E, a plurality of side sagittal plane cross-sectional views showing examples of variations in heel lift thickness similar to those shown in FIGS. **50**A-E for the forefoot lift.

FIG. **75** shows, in FIGS. **75**A-**75**C, a method, known from the prior art, for assembling the midsole shoe sole structure of the present invention.

FIG. **76** shows a frontal plane cross-section of a shoe sole structure wherein one or more components are manufactured by the method of the present invention.

FIG. **77** also shows a frontal plane cross-section of a shoe sole structure wherein one or more components are manufactured by the method of the present invention.

FIG. **78** illustrates, in FIGS. **78**A-**78**E, the design and manufacturing methods of the present invention using a series of frontal plane cross-sections of shoe soles.

FIG. **79** shows a method of establishing the radial shoe sole thickness using a line perpendicular to a line tangent to a point on the upper or lower surface of the shoe sole.

FIG. **80** shows a circle radius method of establishing the shoe sole thickness.

FIG. **81** is a diagram of another method of measuring shoe sole thickness.

FIG. **82** illustrates an embodiment wherein the stability sides are determined geometrically as a section of a ring.

FIGS. **83**-**107** are new.

FIGS. **83**A-**86**A show a frontal or sagittal plane cross section view of an example of a device **510** such as a flexible insert with a siped compartment or chamber or bladder.

FIGS. **83**B-**88**B show a top view in a horizontal plane of a device **510** example of FIGS. **83**A, **84**A, **85**A, **86**A, **87**A and **88**A.

FIGS. **87**A-**88**A show a frontal or sagittal plane cross section view of an example of a device **510** such as a flexible insert with two siped compartments or chambers or bladders or combination.

FIG. **89** shows, in a frontal plane cross section in the heel area, a shoe and shoe sole including a single siped compartment **510**.

FIG. **90** shows a similar embodiment and view to that shown in FIG. **89**, including also an attachment **503** between **500** and **501**.

FIG. **91** shows a similar embodiment and view to that shown in FIG. **89**, including also an inner compartment/chamber **501** with a number of inner compartment structural elements **502**.

FIG. **91**A shows a similar embodiment and view to that shown in FIG. **91**, including also the openings **521**, **522** in the inner and outer compartments/chambers **501**, **500** and the attachment **503** of FIG. **86**A therein.

FIG. **92** shows a similar embodiment and view to that shown in FIG. **89**, including also more than one siped compartment **510**.

FIGS. **93** and **94** show a similar embodiment and view to that shown in FIG. **89**, including also more than one inner compartments **501** in an outer compartment **500**.

FIGS. **95** and **96** show similar embodiments and views to that shown in FIG. **89**, but wherein the outer compartment/chamber/bladder **500** forms substantially all of the midsole portion of the footwear sole (exclusive of the outer sole).

FIG. **97** shows a similar embodiment and view to that shown in FIG. **89**, but also including the features of FIG. **11**N, with the siped compartment/chamber/bladder **510** applied to it.

FIG. **98** shows a somewhat similar embodiment and view to that shown in FIG. **92**, but including an electromagnetic shock absorption system in each chamber, which are without sipes.

FIG. **99**A shows a similar embodiment and view to that shown in FIG. **97**, but including an electromagnetic shock absorption system. FIG. **99**B is a close-up view of an embodiment like FIG. **89**, but showing magnetorheological fluid **508** located within an internal sipe **505**.

FIG. **100**A shows, in a frontal or sagittal plane cross section, a flexible insert or component **511** including a single compartment/chamber **161**/**188** or bladder with an associated internal sipe **505** component. FIG. **100**B shows a top horizontal plane view of flexible insert or component **511** of FIG. **100**A.

FIG. **101**A shows, in frontal or sagittal plane cross section, a flexible insert or component **513** forming a unitary internal sipe. FIG. **101**B is a top horizontal plane view of flexible insert or component **513** of FIG. **101**A.

FIG. **102**A shows, in frontal or sagittal plane cross section, the FIG. **101**A embodiment of a unitary internal sipe **513** position as a separate component in a footwear sole. FIG. **102**B is like FIG. **101**B and thus shows a top horizontal plane view of flexible insert or component **513** of FIG. **102**A.

FIG. **103**A shows, in frontal or sagittal plane cross section, the unitary internal sipe **513** in an embodiment including three separate internal flexibility sipes **505**. FIG. **103**B is like FIG. **101**B and thus shows a to horizontal plane view of flexible insert or component **513** of FIG. **103**A.

FIG. **104** shows, in frontal plane cross section in the heel area, a flexible insert or component **510** used in the footwear upper **21**.

FIG. **105** shows, in frontal plane cross section in the heel area, a flexible insert or component **510** used both in the footwear upper **21** and in the sole **22** or **28**.

FIGS. **106**A and **106**B, as well as FIGS. **107**A and **107**B, show a heel section of a footwear sole or orthotic with an example of a flexible insert or component **510** using specific examples of the structural elements **502**.

FIG. **107**C shows an example in a horizontal plane cross-section of a footwear sole **22** of a device or flexible insert or component **510** in which the inner compartment **501** includes a flexible shank **514** located in the media **504** in the general area of the instep of the shoe sole between the heel area and the forefoot area. FIG. **107**D shows two different examples of versions of the flexible shank **514** in frontal plane cross-sections.

FIGS. **108**A-**108**E and **110** show prior art frontal plane cross section examples of shoe soles **22** or **28** or midsole insert or orthotics **145** with several planar sides to approximate curvature from the applicant's WIPO publication no. WO 02/09547, which can be combined with the flexible insert or components **510**, **511**, or **513**;

FIG. **109** shows a similar top view example of the same shoe sole as is shown in FIGS. **108**A-**108**E.

FIGS. **111**-**117** show perspective views of prior art examples of gas bladders of Nike Air™ (FIGS. **111**-**115**), which are FIGS. 12-16 of U.S. Pat. No. 6,846,534 and Zoom Air™ (FIGS. **116**-**117**), which are FIGS. 1-2 of published U.S. Patent Application 2005/0039346 A1.

FIG. **118** is a cross-sectional view along line **118**-**118** of FIG. **117** and is a prior art example of a gas bladder as shown in FIG. 3 of published U.S. Patent Application 2005/0039346 A1.

FIG. **119** shows perspective views of prior art Adidas 1™ shoe sole electronic/electromechanical cushioning system.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

All reference numerals used in the figures contained herein are defined as follows:

| Ref. No. | Element Description |
|---|---|
| 2 | insole |
| 3 | attachment point of upper midsole and shoe upper |
| 4 | attachment point of bottom sole and shoe upper |
| 5 | attachment point of bottom sole and upper midsole |
| 6 | attachment point of bottom sole and lower midsole |
| 8 | lower surface interface of removable midsole section |
| 9 | interface line between encapsulated section and midsole sections |
| 11 | lateral stability sipe |
| 12 | medial stability sipe |
| 13 | interface between insole and shoe upper |
| 14 | medial origin of the lateral stability sipe |
| 16 | hatched area of decreased area of footprint due to pronation |
| 17 | footprint outline when tilted |
| 18 | inner footprint outline of low arched foot |
| 19 | hatched area of increased area of footprint due to pronation |
| 20 | athletic shoe |
| 21 | shoe upper |
| 21a | inner or secondary shoe upper |
| 22 | conventional shoe sole |
| 23 | bottom outside edge of the shoe sole |
| 23a | lever arm |
| 26 | stabilizing quadrants |
| 27 | human foot |
| 28 | rounded shoe sole |
| 28a | rounded stability sides |
| 28b | load bearing shoe sole |
| 29 | outer surface of the foot |
| 30 | inner surface of the shoe sole |
| 30a | side or inner edge of the shoe sole stability side |
| 30b | inner shoe sole surface portion which contacts the wearer's foot |
| 31 | outer surface of the shoe sole |
| 31a | outer edge of rounded stability sides |
| 31b | outer surface portion of shoe sole parallel to 30b |
| 32 | outside and top edge of the stability side |
| 33 | inner edge of the naturally rounded stability side |
| 34 | perpendicular sides of the load-bearing shoe sole |
| 35 | peripheral extent of the upper surface of sole |
| 36 | shoe sole outline |
| 37 | foot outline |
| 37a | maximum supination position |
| 37b | maximum pronation position |
| 38 | heel lift or wedge |
| 39 | combined midsole and bottom sole |
| 40 | forefoot lift or wedge |
| 43 | ground |
| 45 | density edge |
| 51 | theoretically ideal stability plane |
| 51' | half of the theoretically ideal stability plane |
| 53a | upper side surface |
| 60 | tread portion |
| 61 | cleated portion |
| 62 | alternative tread construction |
| 63 | surface which the cleat bases are affixed |
| 70 | curve of range of side to side motion |
| 71 | center of gravity |
| 74 | shoe sole stability equilibrium point |
| 80 | conventional wide heel flare curve |
| 82 | narrow rectangle the width of heel curve |
| 85 | areas of shoe sole that are in contact with the ground under load |
| 86-89 | rounded line |
| 92 | head of first metatarsal |
| 93 | head of fifth distal phalange |
| 94 | head of fifth metatarsal |
| 95 | base and lateral tuberosity of the calcaneus |
| 95c | base of the calcaneus |
| 95d | lateral tuberosity of the calcaneus |
| 96a | stability correction supporting fifth metatarsal and distal phalange heads |
| 96b | stability correction supporting first metatarsal and distal phalange heads |
| 96c | head of the fifth metatarsal |
| 96d | head of the first metatarsal |
| 97 | base of the fifth metatarsal |
| 97' | fifth metatarsal support area |
| 98 | head of the first distal phalange |
| 98a | stability correction supporting first distal phalange |
| 98a' | stability correction supporting fifth distal phalange |
| 100 | straight line replacing indentation at the base of the fifth metatarsal |
| 104 | pressure sensing device |
| 108 | lateral tuberosity of the calcaneus |
| 109 | base of the calcaneus |
| 111-113 | flexibility axis |
| 115 | center of rotation of radius r + r' |
| 119 | center of shoe sole support section |

-continued

| Ref. No. | Element Description |
|---|---|
| 120 | pressure sensing circuitry |
| 121 | main longitudinal arch (long arch) |
| 122 | flexibility axis |
| 123 | flexible connecting top layer of sipes |
| 124 | flexibility axis |
| 125 | base of the calcaneus (heel) |
| 125' | heel support area |
| 126 | metatarsal heads (forefoot) |
| 126' | forefoot support area |
| 129 | honeycombed portion |
| 141 | snap-fit |
| 142 | mechanical fasteners/Velcro ™ |
| 143 | interlocking geometries |
| 145 | removable midsole insert |
| 146 | location of slight crimp |
| 147 | upper midsole (upper areas of shoe midsole) |
| 148 | midsole |
| 149 | bottom or outer sole |
| 149a | secondary bottom or outer sole |
| 150 | compression force |
| 151 | channel sipes |
| 155a | tension force along the top surface of the shoe sole |
| 155b | mirror image of tension force 155a |
| 158 | subcalcaneal fat pad |
| 159 | calcaneus |
| 160 | bottom sole of the foot |
| 161 | cushioning compartment |
| 162 | natural crease or upward taper |
| 163 | crease or taper in the human foot |
| 164 | chambers of matrix of elastic fibrous connective tissue |
| 165 | lower surface of the upper midsole |
| 166 | upper surface of the bottom sole |
| 167 | outer surface of the support structures of the foot |
| 168 | upper surface of the foot's bottom sole |
| 169 | shank |
| 170 | flexible filler material |
| 180 | mini-chambers |
| 181 | internal deformation slits (sipes) in the sagittal plane |
| 182 | internal deformation slits (sipes) in the horizontal plane |
| 184 | encapsulating midsole section |
| 185 | midsole sides |
| 187 | upper midsole section |
| 188 | bladder or encapsulated central section |
| 189 | central wall |
| 191 | fibrous capsule shell |
| 192 | subdivided cushioning compartments |
| 195 | heel element |
| 200 | pressures sensing system |
| 201 | horizontal line through the lowermost point of upper surface of the shoe sole |
| 205 | variable capacitor |
| 206 | fluid duct |
| 210 | fluid valve |
| 220 | pressure sensing circuitry |
| 223 | frequency-to-voltage converter (FVC) |
| 224 | oscillator |
| 225 | analog-to-digital (AID) converter |
| 227 | multiplexer |
| 228 | data lines |
| 229 | control lines |
| 270 | shoe sole last |
| 290 | lower surface of shoe sole last |
| 300 | encapsulated midsole section control system |
| 301 | programmable microcomputer |
| 302 | control lines |
| 303 | cushion adjustment control |
| 304 | illuminator |
| 310 | digital-to-analog (D/A) converter |

FIG. **1** shows a perspective view of a shoe, such as a typical athletic shoe **20** according to the prior art, wherein the athletic shoe **20** includes a shoe upper **21** and a conventional shoe sole **22**.

FIG. **2** illustrates, in a close-up, a cross-section of a typical shoe of existing art (undeformed by body weight) on the ground **43** when tilted on the bottom outside edge of the shoe sole **23**, an inherent stability problem remains in existing shoe designs, even when the abnormal torque producing rigid heel counter and other motion devices are removed. The problem is that the remaining shoe upper **21** (shown in the thickened and darkened line), while providing no lever arm extension, since it is flexible instead of rigid, nonetheless creates unnatural destabilizing torque on the conventional shoe sole **22**. The torque is due to the tension force along the top surface of the shoe sole **155***a* caused by a compression force **150** (a composite of the force of gravity on the body and a sideways motion force) to the side by the human foot **27**, due simply to the shoe **20** being tilted to the side, for example. The resulting destabilizing force acts to pull the shoe sole **22** in rotation around a lever arm **23***a* that is the width of the shoe sole **22** at the edge **23**. Roughly speaking, the force of the foot on the shoe upper **21** pulls the shoe **20** over on its side when the shoe **20** is tilted sideways. The compression force **150** also creates a tension force **155***b*, which is the mirror image of tension force **155***a*. FIG. **3** shows, in a close-up cross-section, a naturally rounded shoe sole **28** (also shown undeformed by body weight) when tilted on the bottom outside edge **23** having the same inherent stability problem remaining in the naturally rounded shoe sole **28** design, though to a reduced degree. The problem is less since the direction of the force vector **150** along the lower surface of the shoe upper **21** is parallel to the ground **43** at the outside edge **32** edge, instead of angled toward the ground **43** as in a conventional design like that shown in FIG. **2**, so the resulting torque produced by a lever arm **23***a* created by the bottom outside edge **23** would be less, and the rounded shoe sole **28** provides direct structural support when tilted, unlike conventional designs.

FIG. **4** shows (in a rear view) that, in contrast, the bare human foot **27** is naturally stable because, when deformed by body weight and tilted to its natural lateral limit of about 20°, it does not create any destabilizing torque due to tension force. Even though tension paralleling that on the shoe upper **21** is created on the outer surface of the foot **29**, of both the bottom and sides of the bare foot **27** by the compression force of weight-bearing, no destabilizing torque is created because the lower surface under tension (i.e., the foot's bottom sole, shown in the darkened line) is resting directly in contact with the ground **43**. Consequently, there is no artificially created unnatural lever arm **23***a* against which to pull. The weight of the body firmly anchors the outer surface **29** of the sole underneath the foot **27** so that even considerable pressure against the outer surface **29** of the side of the foot **27** results in no destabilizing motion. When the foot **27** is tilted, the supporting structures of the foot **27**, like the calcaneus **159**, slide against the side of the strong but flexible outer surface of the foot **29** and create very substantial pressure on that outer surface **29** at the sides of the foot **27**. But that pressure is precisely resisted and balanced by tension along the outer surface **29** of the foot **27**, resulting in a stable equilibrium.

FIG. **5** shows, in cross-section of the upright heel deformed by body weight, the principle of the tension-stabilized sides of the bare foot **27** applied to the naturally rounded shoe sole design. The same principle can be applied to conventional shoes, but is not shown. The key change from the existing art of shoes is that the sides of the shoe upper **21** (shown as darkened lines) must wrap around the outside edges **32** of the rounded shoe sole **28**, instead of attaching underneath the foot **27** to the inner surface of the shoe sole **30**, as is done conventionally. The shoe upper sides can overlap and be attached to either the inner surface of the shoe sole **30** (shown on the left) or outer surface of the shoe sole **31** (shown on the right) of the bottom sole **149**, since those sides are not particularly load-bearing, as shown. Alternatively, the bottom sole **149**, optimally thin and tapering as shown, can extend upward around the outside edges **32** of the rounded shoe sole **28** to overlap and attach to the shoe upper sides (shown FIG. **5**B). Their optimal position coincides with the theoretically ideal stability plane, so that the tension force on the shoe sides is transmitted directly all the way down to the outer surface **31** of the shoe sole **28**, which anchors it on the ground **43** with virtually no intervening artificial lever arm **23***a*. For shoes with only one sole layer, the attachment of the shoe upper sides should be at or near the outer surface **31** of the rounded shoe sole **28**.

The design shown in FIG. **5** is based on a fundamentally different conception that the shoe upper **21** is integrated into the shoe sole **28**, instead of attached on top of it, and the shoe sole **28** is treated as a natural extension of the foot sole, not attached to it separately.

The fabric (or other flexible material, like leather) of the shoe upper **21** would preferably be non-stretch or relatively so, so as not to be deformed excessively by the tension placed upon its sides when compressed as the foot and shoe tilt. The fabric can be reinforced in areas of particularly high tension, like the essential structural support and propulsion elements as shown and described in FIG. **11**L (i.e., the base and lateral tuberosity of the calcaneus, the base of the fifth metatarsal, the heads of the metatarsals, and the first distal phalange). The reinforcement can take many forms, such as that of corners of the jib sail of a racing sailboat or more simply straps. As closely as possible, the reinforcement should have the same performance characteristics as the heavily callused skin of the sole of an habitually bare foot **27**. Preferably, the relative density of the rounded shoe sole **28** is as described in FIG. **46** of the present application with the softest sole density nearest the foot sole, a progression through less soft sole density through the sole **28**; to the firmest and least flexible at the outermost shoe sole layer. This arrangement allows the conforming sides of the shoe sole **28** to avoid providing a rigid destabilizing lever arm **23***a*.

The change from existing art to provide the tension-stabilized sides shown in FIG. **5** is that the shoe upper **21** is directly integrated functionally with the shoe sole **28**, instead of simply being attached on top of it. The advantage of the tension-stabilized sides design is that it provides natural stability as close to that of the bare foot **27** as possible, and does so economically, with the minimum shoe sole side width possible.

The result is a shoe sole **28** that is naturally stabilized in the same way the bare foot **27** is stabilized, as seen in FIG. **6**, which shows a close-up cross-section of a naturally rounded shoe sole **28** (undeformed by body weight) when tilted to the edge. The same destabilizing force against the side of the shoe shown in FIG. **2** is now stably resisted by offsetting tension in the surface of the shoe upper **21** extended down the side of the shoe sole **28** so that it is anchored by the weight of the body when the shoe and foot **27** are tilted.

In order to avoid creating unnatural torque on the shoe sole **28**, the shoe uppers **21** may be joined or bonded only to the bottom sole **149**, not the midsole **148**, so that pressure shown on the side of the shoe upper **21** produces side tension only and not the destabilizing torque from pulling similar to that described in FIG. **2**. However, to avoid unnatural torque, the upper areas of the shoe midsole **147**, which form a sharp corner, should be composed of relatively soft midsole material. In this case, bonding the shoe uppers **21** to the midsole **148** would not create very much destabilizing torque. The bottom sole **149** is preferably thin, at least on the stability sides, so that its attachment overlap with the shoe upper sides coincides, as closely as possible, to the theoretically ideal stability plane so that force is transmitted by the outer shoe sole surface **31** to the ground **43**.

In summary, the FIG. **5** design is for a shoe construction including a shoe upper **21** that is composed of material that is flexible and relatively inelastic at least where the shoe upper **21** contacts the areas of the structural bone elements of the human foot **27**, a shoe sole **28** that has relatively flexible sides and at least a portion of the sides of the shoe upper **21** are attached directly to the bottom sole **149**, while enveloping the outside the other sole portions of the shoe sole **28**. This construction can either be applied to conventional shoe sole structures or to the applicant's prior shoe sole inventions, such as the naturally rounded shoe sole **28** conforming to the theoretically ideal stability plane.

FIG. **7** shows, in cross-section at the heel, the tension-stabilized sides concept applied to naturally rounded shoe sole **28** when the shoe and foot are tilted out fully and are naturally deformed by body weight. Although, constant shoe sole thickness is shown undeformed, FIG. **7** shows that the shape and stability function of the shoe sole **28** and shoe uppers **21** mirror almost exactly that of the human foot **27**.

FIGS. **8**A-**8**D show the natural cushioning of the human foot **27** in cross-sections at the heel. FIG. **8**A shows the bare heel upright and unloaded, with little pressure on the sub calcaneal fat pad **158**, which is evenly distributed between the calcaneus **159**, which is the heel bone, and the bottom sole of the foot **160**.

FIG. **8**B shows the bare heel upright but under the moderate pressure of full body weight. The compression of the calcaneus **159** against the subcalcaneal fat pad **158** produces evenly balanced pressure within the subcalcaneal fat pad **158** because it is contained and surrounded by a relatively unstretchable fibrous capsule, the bottom sole of the foot **160**. Underneath the foot, where the bottom sole of the foot **160** is in direct contact with the ground **43**, the pressure caused by the calcaneus **159** on the compressed sub calcaneal fat pad **158** is transmitted directly to the ground **43**. Simultaneously, substantial tension is created on the sides of the bottom sole of the foot **160** because of the surrounding relatively tough fibrous capsule. That combination of bottom pressure and side tension is the foot's natural shock absorption system for support structures like the calcaneus **159** and the other bones of the foot **27** that come in contact with the ground **43**.

Of equal functional importance is the outer surface of the support structures of the foot **167** like the calcaneus **159** and other bones that make firm contact with the upper surface of the foot's bottom sole **168**, with relatively little uncompressed fat pad intervening. In effect, the support structures of the foot land on the ground **43** and are firmly supported; they are not suspended on top of springy material in a buoyant manner analogous to a water bed or pneumatic tire, as in some existing proprietary shoe sole cushioning systems. This simultaneously firm, yet cushioned, support provided by the foot sole must have a significantly beneficial impact on energy efficiency, also called energy return, different from some conventional shoe sole designs which provide shock absorption cushioning during the landing and support phases of locomotion at the expense of firm support during the take-off phase.

The incredible and unique feature of the foot's natural system is that once the calcaneus **159** is in fairly direct contact with the bottom sole **160** and therefore providing firm support and stability, increased pressure produces a more rigid fibrous capsule that protects the calcaneus **159** and produces greater tension at the sides to absorb shock. So, in a sense, even when the foot's suspension system would seem in a conventional way to have bottomed out under normal body weight pressure, it continues to react with a mechanism to protect and cushion the foot **27** even under much more extreme pressure.

This is seen in FIG. **8**C, which shows the human heel under the heavy pressure of roughly three times body weight force of landing during routine running. This can be easily verified when one stands barefoot on a hard floor. The heel feels very firmly supported and yet can be lifted and virtually slammed onto the floor with little increase in the feeling of firmness; the heel simply becomes harder as the pressure increases.

In addition, it should be noted that this system allows the relatively narrow base of the calcaneus **159** to pivot from side to side freely in normal pronation/supination motion without any obstructing torsion on it, despite the significantly greater width of a compressed foot sole providing protection and cushioning. This is important in maintaining natural alignment of joints above the ankle joint such as the knee, hip, and back, particularly in the horizontal plane, so that the entire body is properly adjusted to absorb shock correctly. In contrast, existing shoe sole designs., which are generally relatively wide to provide stability, produce unnatural frontal plane torsion on the calcaneus **159**, restricting its natural motion and causing misalignment of the joints operating above it resulting in the overuse injuries unusually frequent with such shoes. Instead of flexible sides that harden under tension caused by pressure like that of the foot **27**, some existing shoe sole designs are forced by lack of other alternatives to use relatively rigid sides in an attempt to provide sufficient stability to offset the otherwise uncontrollable buoyancy and lack of firm support of air or gel cushions.

FIG. **8**D shows the foot **27** deformed under full body weight and tilted laterally to roughly the 20° limit of normal movement range. Again it is clear that the natural system provides both firm lateral support and stability by providing relatively direct contact with the ground **43** while at the same time providing a cushioning mechanism through side tension and subcalcaneal fat pad pressure.

FIGS. **9**A-**9**D show, also in cross-sections at the heel, a naturally rounded shoe sole design that parallels as closely as possible the overall natural cushioning and stability system of the bare foot **27** described in FIG. **8**, including a cushioning compartment **161** under support structures of the foot **27** containing a pressure-transmitting medium like gas, gel, or liquid, like the subcalcaneal fat pad **158** under the calcaneus **159** and other bones of the foot **27**. Consequently, FIGS. **9**A-D directly correspond to FIGS. **8**A-D. The optimal pressure-transmitting medium is that which most closely approximates the fat pads of the foot **27**. Silicone gel is probably the optimal material currently available, but future improvements are probable. Since it transmits pressure indirectly, in that it compresses in volume under pressure, gas is significantly less optimal. The gas, gel, or liquid, or any other effective material can be further encapsulated with a separate encapsulation, in addition to the sides of the rounded shoe sole **28**, to control leakage and maintain uniformity, as is conventional, and can be subdivided into any practical number of encapsulated areas within a cushioning compartment **161**, again as is conventional. The relative thickness of the cushioning compartment **161** can vary, as can the bottom sole **149** and the upper midsole **147** and can be consistent or different in various areas of the shoe sole **28**. The optimal relative sizes should be those that approximate most closely those of the average human foot **27**, which suggests both a smaller upper and lower soles and a larger cushioning compartment **161** than shown in FIG. **9**. The cushioning compartments or pads **161** can be placed anywhere from directly underneath the foot **27**, like an insole, to directly above the bottom sole **149**. Optimally, the amount of compression created by a given load in any cushioning compartment **161** should be tuned to approximate, as closely as possible, the compression under the corresponding fat pad of the foot **27**.

The function of the subcalcaneal fat pad **158** is not met satisfactorily with existing proprietary cushioning systems, even those featuring gas, gel or liquid as a pressure transmitting medium. In contrast to those artificial systems, the design shown in FIG. **9** conforms to the natural rounded shape of the foot **27** and to the natural method of transmitting bottom pressure into side tension in the flexible but relatively non-stretching sides of the shoe sole **28**.

Some existing cushioning systems do not bottom out under moderate loads and rarely, if ever, do so under extreme loads. Rather, the upper surface of the cushioning device remains suspended above the lower surface. In contrast, the design in FIG. **9** provides firm support to foot support structures by providing for actual contact between the lower surface of the upper midsole **165** and the upper surface of the bottom sole **166** when fully loaded under moderate body weight pressure, as indicated in FIG. **9**B, or under maximum normal peak landing force during running, as indicated in FIG. **9**C, just as the human foot **27** does in FIGS. **8**B and **8**C. The greater the downward force transmitted through the foot **27** to the shoe, the greater the compression pressure in the cushioning compartment **161** and the greater the resulting tension on the shoe sole sides.

FIG. **9**D shows the same shoe sole design when fully loaded and tilted to the natural 20° lateral limit, like FIG. **8**D. FIG. **9**D shows that an added stability benefit of the natural cushioning system for shoe soles is the effective thickness of the shoe sole **28** reduced by compression on the side so that the potential destabilizing lever arm **23***a* represented by the shoe sole thickness is also reduced, thereby, increasing foot and ankle stability. Another benefit of the FIG. **9** design is that the upper midsole **147** shoe surface can move in any horizontal direction, either sideways or front to back in order to absorb shearing forces. The shearing motion is controlled by tension in the sides. Note that the right side of FIGS. **9**A-D is modified to provide a natural crease or upward taper **162** which allows complete side compression without binding or bunching between the upper and lower shoe sole components **147**, **148**, and **149**. The shoe sole crease **162** parallels exactly a similar crease or taper in the human foot **163**. Further, **201** represents a horizontal line through the lowermost point of the inner surface of the shoe sole.

Another possible variation of joining shoe upper **21** to shoe bottom sole **149** is on the right (lateral) side of FIGS. **9**A-D which makes use of the fact that it is optimal for the tension absorbing shoe sole sides, whether shoe upper **21** or bottom sole **149**, to coincide with the theoretically ideal stability plane along the side of the shoe sole **28** beyond that point reached when the shoe is tilted to the foot's natural limit, so that no destabilizing shoe sole lever arm **23***a* is created when the shoe is tilted fully as in FIG. **9**D. The joint may be moved up slightly so that the fabric side does not come in contact with the ground **43** or it may be covered with a coating to provide both traction and fabric protection.

It should be noted that the FIG. **9** design provides a structural basis for the shoe sole **28** to conform easily to the natural shape of the human foot **27** and to parallel the natural deformation flattening of the foot **27** during load-bearing motion on the ground **43**. This is true even if the shoe sole **28** is made conventionally with a flat sole, as long as rigid structures such as heel counters and motion control devices are not used. Though not optimal, such a conventional flat shoe made like FIG. **9** would provide the essential features of the invention resulting in significantly improved cushioning and stability.

The FIG. **9** design could also be applied to intermediate-shaped shoe soles that neither conform to the flat ground **43** or the naturally rounded foot **27**. In addition, the FIG. **9** design can be applied to the applicant's other designs, such as those described in FIGS. **14-28** of the present application.

In summary, the FIG. **9** design shows a shoe sole construction for a shoe, including a shoe sole **28** with a cushioning compartment or compartments **161** under the structural elements of the human foot **27**, including at least the heel; the cushioning compartment or compartments **161** contain a pressure-transmitting medium like liquid, gas, or gel; a portion of the upper surface of the shoe sole compartment **161** firmly contacting the lower surface of said compartment **161** during normal load-bearing; and pressure from the load-bearing being transmitted progressively, at least in part, to the relatively inelastic sides, top, and bottom of the shoe sole compartment or compartments **161** producing tension.

While the FIG. **9** design copies in a simplified way the macro structure of the foot **27**, FIGS. **10** A-C focus more on the exact detail of shoe sole **28** modeled after the natural structures of the foot **27** including the micro level. FIGS. **10**A and **10**C are perspective views of cross-sections of a part of a rounded shoe sole **28** with a structure like the human heel wherein elements of the shoe sole structure are similar to chambers of a matrix of elastic fibrous connective tissue **164** which hold closely packed fat cells in the foot **27**. The chambers **164** in the foot **27** are structured as whorls radiating out from the calcaneus **159**. These fibrous-tissue strands are firmly attached to the under surface of the calcaneus and extend to the subcutaneous tissues. They are usually in the form of the letter "U", with the open end of the "U" pointing toward the calcaneus **159**.

As the most natural embodiment, an approximation of this specific chamber structure would appear to be optimal as an accurate model for the structure of the shoe sole cushioning compartments **161**. The description of the structure of calcaneal padding provided by Erich Blechschmidt in Foot and Ankle, March, 1982, (translated from the original 1933 article in German) is so detailed and comprehensive that copying the same structure as a model in shoe sole design is not difficult technically, once the crucial connection is made that such copying of this natural system is necessary to overcome inherent weaknesses in the design of existing shoes. Other arrangements and orientations of the whorls are possible but would probably be less optimal.

Pursuing this nearly exact design analogy, the lower surface of the upper midsole **165** would correspond to the outer surface **167** of the calcaneus **159** and would be the origin of the U-shaped whorl chambers **164** noted above.

FIG. **10**B shows a close-up of the interior structure of the large chambers of a rounded shoe sole **28** as shown in FIGS. **10**A and **10**C, with mini-chambers **180** similar to mini-chambers in the foot **27**. It is clear from the fine interior structure and compression characteristics of the mini-chambers **180** in the foot that those directly under the calcaneus **159** become very hard quite easily due to the high local pressure on them and the limited degree of their elasticity so that they are able to provide very firm support to the calcaneus **159** and/or other bones of the foot sole. By virtue of their being fairly inelastic, the compression forces on those chambers are dissipated to other areas of the network of fat pads under any given support structure of the foot **27**, like the calcaneus **159**. Consequently, if a cushioning compartment **161**, such as the compartment **161** under the heel shown in FIG. **9**, is subdivided into smaller chambers, like those shown in FIG. **10**, then actual contact between the lower surface of the upper midsole **165** and the upper surface of the bottom sole **166** would no longer be required to provide firm support so long as the compartment **161** and the pressure-transmitting medium contained in them have material characteristics similar to those of the foot **27** described above. The use of gas may not be satisfactory in this approach as its compressibility may not allow adequate firmness.

In summary, the FIG. **10** design shows a shoe construction including a shoe sole **28** with compartments **161** under the structural elements of the human foot **27**, including at least the heel; the compartments **161** containing a pressure-transmitting medium like liquid, gas or gel; the compartments **161** having a whorled structure like that of the fat pads of the human foot sole; and load-bearing pressure being transmitted progressively at least in part to the relatively inelastic sides, top, and bottom of the shoe sole compartments **161**, producing tension therein. The elasticity of the material of the compartments **161** and the pressure-transmitting medium are such that normal weight-bearing loads produce sufficient tension within the structure of the compartments **161** to provide adequate structural rigidity to allow firm natural support to the foot structural elements, like that provided by the fat pads of the bare foot **27**. That shoe sole construction can have shoe sole compartments **161** that are subdivided into mini-chambers like those of the fat pads of the foot sole.

Since the bare foot **27** that is never shod is protected by very hard calluses (called a "Seri boot") which the shod foot lacks, it seems reasonable to infer that the natural protection and shock absorption system of the shod foot **27** is adversely affected by its unnaturally undeveloped fibrous capsules (surrounding the sub calcaneal and other fat pads under foot bone support structures). A solution would be to produce a shoe intended for use without socks (i.e., with smooth surfaces above the foot bottom sole) that uses insoles that coincide with the foot bottom sole, including its sides. The upper surface of those insoles, which would be in contact with the bottom sole of the foot **27** (and its sides), would be coarse enough to stimulate the production of natural barefoot calluses. The insoles would be removable and available in different uniform grades of coarseness, as is sandpaper, so that the user can progress from finer grades to coarser grades as his foot soles toughen with use.

Similarly, socks could be produced to serve the same function, with the area of the sock that corresponds to the foot bottom sole (and sides of the bottom sole) made of a material coarse enough to stimulate the production of calluses on the bottom sole of the foot **27**, with different grades of coarseness available, from fine to coarse, corresponding to feet from soft to naturally tough. Using a tube sock design with uniform coarseness, rather than conventional sock design assumed above, would allow the user to rotate the sock on his foot to eliminate any "hot spot" irritation points that might develop. Also, since the toes are most prone to blistering and the heel is most important in shock absorption, the toe area of the sock could be relatively less abrasive than the heel area.

The invention shown in FIGS. **11**A-**11**C is a removable midsole insert **145**. Alternatively, the removable midsole insert **145** can be attached permanently to adjoining portions of the rounded shoe sole **28** after initial insertion using glue or other common forms of attachment. The rounded shoe sole **28** has an inner surface **30** and a outer surface **31** with at least a part of both surfaces being concavely rounded relative to an intended wearer's foot location inside the shoe, as viewed in a frontal plane cross-section from inside the shoe when in an unloaded, upright condition. Preferably, all or part of the removable midsole insert **145** can be removable through any practical number of insertion/removal cycles. The removable midsole insert **145** can also, optionally, include a concavely rounded side, as shown in FIG. **11**A, a concavely rounded underneath portion or be conventionally formed, with other portions of the shoe sole **28** including concave rounding on the side or underneath portion or portions. All or part of the preferred insole **2** can also be removable or can be integrated into the upper portion of the removable midsole insert **145**.

The removable portion or portions of the midsole insert **145** can include all or part of the heel lift of the rounded shoe sole **28**, or all or part of the heel lift **38** can be incorporated into the bottom sole **149** permanently, either using bottom sole material, midsole material or other suitable material. Heel lift **38** is typically formed from cushioning material such as the midsole materials described herein and may be integrated with the upper midsole **147** or midsole **148** or any portion thereof, including the removable midsole insert **145**.

The removable portion of the midsole insert **145** can extend the entire length of the shoe sole **28**, as shown in FIGS. **11**K and **11**L, or only a part of the length, such as a heel area as shown in cross-section in FIG. **11** G, a midtarsal area as shown in cross-section in FIG. **11**H, a forefoot area as shown in cross-section in FIGS. **11**I and **11**J, or some portion or combination of those areas. The removable portion and/or midsole insert **145** may be fabricated in any suitable, conventional manner employed for the fabrication of shoe midsoles or other similar structures.

The midsole insert **145**, as well as other midsole portions of the shoe sole **28** such as the midsole **148** and the upper midsole **147**, can be fabricated from any suitable material such as elastomeric foam materials. Examples of current art for elastomeric foam materials include polyether urethane, polyester urethane, polyurethane foams, ethylene vinyl acetate, ethylene vinyl acetate/polyethylene copolymer, polyester elastomers such as Hytrel™, fluoroelastomers, chlorinated polyethylene, chlorosulfonated polyethylene, acrylonitrile rubber, ethylene vinyl acetate/polypropylene copolymers, polyethylene, polypropylene, neoprene, natural rubber, Dacron™ polyester, polyvinyl chloride, thermoplastic rubbers, nitrile rubber, butyl rubber, sulfide rubber, polyvinyl acetate, methyl rubber, buna N, buna S, polystyrene, ethylene propylene polymers, polybutadiene, butadiene styrene rubber, and silicone rubbers. The most preferred elastomeric foam materials in the current art of shoe sole midsole materials are polyurethanes, ethylene vinyl acetate, ethylene vinyl acetate/polyethylene copolymers, ethylene vinyl acetate/polypropylene copolymers, neoprene, and polyester elastomers. Suitable materials are selected on the basis of durability, flexibility, and resiliency for cushioning the foot among other properties.

As shown in FIG. **11**D, the midsole insert **145** itself can incorporate cushioning or structural compartments **161** or components. FIG. **11**D shows cushioning compartments or chambers **161** encapsulated in part of mid sole insert **145**, as well as bottom sole **149**, as viewed in a frontal plane cross-section. FIG. **11**D is a perspective view to indicate the placement of disks or capsules of cushioning material. The disks or capsules of cushioning material may be made from any of the midsole materials mentioned above, and preferably include a flexible, resilient midsole material such as ethyl vinyl acetate (EVA), that may be softer or firmer than other sole material or may be provided with special shock absorption, energy efficiency, wear, or stability characteristics. The disks or capsules may include a gas, gel, liquid or any other suitable cushioning material. The cushioning material may optionally be encapsulated itself using a film made of a suitable material such as polyurethane film. Other similar materials may also be employed. The encapsulation can be used to form the cushioning material into an insertable capsule in a conventional manner. The example shown in FIG. **11**D shows such cushioning disks **161** located in the heel area and the lateral and medial forefoot areas, proximate to the heads of the first and fifth metatarsal bones of a wearer's foot. The cushioning material, for example disks or compartments **161**, may form part of the upper surface of the upper portion of the midsole insert **145** as shown in FIG. **11**D. A cushioning compartment or disk **161** can generally be placed anywhere in the removable midsole insert **145** or in only a part of the midsole insert **145**. A part of the cushioning compartment or disk **161** can extend into the outer sole **149** or other sole portions, or, alternatively, one or more compartments or disks **161** may constitute all or substantially all of the midsole insert **145**. As shown in FIG. **11**L, cushioning disks or compartments may also be suitably located at other essential support elements like the base of the fifth metatarsal **97**, the head of the first distal phalange **98**, or the base and lateral tuberosity of the calcaneus **95**, among other suitable conventional locations. In addition, structural components like a shank **169** can also be incorporated partially or completely in a midsole insert **145**, such as in the medial midtarsal area, as shown in FIG. **11**D, under the main longitudinal arch of a wearer's foot, and/or under the base of the wearer's fifth metatarsal bone, or other suitable alternative locations.

In one embodiment, the FIG. **11**D invention can be made of all mass-produced standard size components, rather than custom fit, but can be individually tailored for the right and left shoe with variations in the firmness of the material in compartments **161** for special applications such as sports shoes, golf shoes or other shoes which may require differences between firmness of the left and right shoe sole.

One of the advantages provided by the removable midsole insert **145** of the present invention is that it allows replacement of foamed plastic portions of the midsole which degrade quickly with wear, losing their designed level of resilience, with new midsole material as necessary over the life of the shoe to, thereby, maintain substantially optimal shock absorption and energy return characteristics of the rounded shoe sole **28**. The removable midsole insert **145** can also be transferred from one pair of shoes composed generally of shoe uppers and bottom sole like FIG. **11**C to another pair like FIG. **11**C, providing cost savings. Besides using the removable midsole insert **145** to replace worn components with new components, the removable midsole insert **145** can provide another advantage of allowing the use of different cushioning or support characteristics in a single shoe or pair of shoes made like FIG. **11**C, such as firmer or softer portions of the midsole, or thicker or thinner portions of the midsole, or entire midsoles that are firmer, softer, thicker or thinner, either as separate layers or as an integral part of mid sole insert **145**. In this manner, a single pair of shoes can be customized to provide the desired cushioning or support characteristics for a particular activity or different levels of activity such as running, training or racing. FIG. **11**D shows an example of such removable midsole inserts **145** in the form of disks or capsules **161**, but midsole or insole layers or the entire midsole insert **145** can be removed and replaced temporarily or permanently.

Such removable midsole inserts **145** can be made to include density or firmness variations like those shown in FIGS. **21**-**23**, and **25**. The midsole density or firmness variations can differ between a right foot shoe and a left foot shoe, such as FIG. **21**'s left shoe and FIG. **22**'s right shoe, showing equivalent portions.

Such replacement removable midsole inserts **145** can be made to include thickness variations, including those shown in FIG. **17**-**20**, **24**, **27** or **28**. Combinations of density or firmness variations and thickness variations shown above can also be made in the removable midsole inserts **145**.

Replacement removable midsole inserts **145** may be held in position at least in part by enveloping sides of the shoe upper **21** and/or bottom sole **149**. Alternatively, a portion of the midsole material may be fixed in the shoe sole **28** and extend up the sides to provide support for holding removable midsole inserts **145** in place. If the associated rounded shoe sole **28** has one or more of the abbreviated sides shown in FIG. **11**L, then the removable midsole insert can also be held in position against relative motion in the sagittal plane by indentations formed between one or more concavely rounded sides which match the contour of one or more of the adjacent abbreviations. Combinations of these various embodiments may also be employed.

The removable midsole insert **145** has a lower surface interface **8** with the upper surface of the bottom sole **166**. The interface **8** would typically remain unglued, to facilitate repeated removal of the midsole inserts **145**, or could be affixed by a weak glue, like that used with self-stick removable paper notes, that does not permanently fix the position of the midsole insert **145** in place.

The interface **8** can also be bounded by non-slip or controlled slippage surfaces. The two surfaces which form the interface **8** can have interlocking complementary geometry as shown, for example, in FIGS. **11**E-**11**F, such as mating protrusions and indentations, or the removable midsole insert **145** may be held in place by other conventional temporary attachments, such as Velcro™ strips **142** shown in FIG. **11**V. Conversely, providing no means to restrain slippage between the surfaces of interface **8** may, in some cases, provide additional injury protection. Thus, controlled facilitation of slippage at the interface **8** may be desirable in some instances and can be utilized within the scope of the invention.

The removable midsole insert **145** of the present invention may be inserted and removed in the same manner as conventional removable insoles or conventional midsoles, that is, generally in the same manner as the wearer inserts his foot **27** into the shoe. Insertion of the removable midsole insert **145** may, in some cases, requiring loosening of the shoelaces or other mechanisms for securing the shoe to a wearer's foot **27**. For example, the midsole insert **145** may be inserted into the interior cavity of the shoe upper and affixed to or abutted against, the top side of the shoe sole. In a particularly preferred embodiment, a bottom sole **149** is first inserted into the interior cavity of the shoe upper **21** as indicated by the arrow in FIG. **75**A. The bottom sole **149** is inserted into the cavity so that any rounded stability sides **28***a* are inserted into and protrude out of corresponding openings in the shoe upper **21**. The bottom sole **149** is then attached to the shoe upper **21**, preferably by a stitch that weaves around the outer perimeter of the openings thereby connecting the shoe upper **21** to the bottom sole **149**. In addition, an adhesive can be applied to the surface of the shoe upper **21**, which will contact the bottom sole **149** before the bottom sole **149** is inserted into the shoe upper **21**.

Once the bottom sole **149** is attached, the removable midsole insert **145'** may then be inserted into the interior cavity of the shoe upper **21** and affixed to the upper surface of the bottom sole **166**, as shown in FIG. **75**C. The midsole insert **145** can be releasably secured in place by any suitable method, including mechanical fasteners **142** shown in FIG. **11**V, adhesives, snap-fit arrangements **141**, reclosable compartments, interlocking geometries **143** and other similar structures. Additionally, the removable midsole insert **145** preferably includes protrusions placed in an abutting relationship with the bottom sole **149** so that the protrusions occupy corresponding recesses in the bottom sole **149**. Alternatively, the removable midsole insert **145** may be glued to affix the midsole insert **145** in place on the bottom sole **149**. In such an embodiment, an adhesive can be used on the interface **8** of the midsole insert **145** to secure it to the bottom sole **149**.

Replacement removable midsole inserts **145** with concavely rounded sides that provide support for only a narrow range of sideways motion or with higher concavely rounded sides that provide for a very wide range of sideways motion can be used to adapt the same shoe for different sports, like running or basketball, for which lesser or greater protection against ankle sprains may be considered necessary, as shown in FIG. **11**G. Different removable midsole inserts **145** may also be employed on the left or right side, respectively. Replacement removable midsole inserts **145** with higher curved sides that provide for an extra range of motion for sports tend to encourage pronation-prone wearers on the medial side or on the lateral side for sports which tend to encourage supination-prone wearers are other potentially beneficial embodiments.

Individual removable midsole inserts **145** can be custom-made for a specific class of wearer or can be selected by the individual from mass-produced standard sizes with standard variations in the height of the concavely rounded sides, for example.

FIGS. **11**M-**11**P show shoe soles with one or more encapsulated midsole sections or chambers such as bladders **188** for containing fluid such as a gas, liquid, gel or other suitable materials with a duct, a flow regulator, a sensor, and a control system such as a microcomputer. The existing art is described by U.S. Pat. No. 5,813,142 by Demon, issued Sep. 29, 1998, and by the references cited therein.

FIGS. **11**M-**11**P also include the applicant's concavely rounded sides as described elsewhere in this application, such as FIGS. **11**A-**11**L (and/or concavely rounded underneath portions). In addition, FIGS. **11**M-**11**P show ducts that communicate between encapsulated midsole sections or chambers/bladders **188** or within portions of the encapsulated midsole sections or bladders **188**. Other suitable conventional embodiments can also be used in combination with the applicant's concavely rounded portions. Also, FIGS. **11**N-**11**P show removable midsole inserts **145**. FIG. **11**M shows a non-removable midsole in combination with the pressure-controlled bladder or encapsulated section **188** of the invention. The bladders or sections **188** can be any size relative to the midsole encapsulating them, including replacing the encapsulating midsole substantially or entirely.

Also, included in the applicant's invention is the use of a piezo-electric effect controlled by a microprocessor control system to affect the hardness or firmness of the material contained in the encapsulated midsole section, bladder, or other midsole portion **188**. For example, a disk-shaped midsole or other suitable cushioning compartment **161** may be controlled by electric current flow instead of fluid flow with common electrical components replacing those described below which are used for conducting and controlling fluid flow under pressure.

FIG. **11**M shows a shoe sole embodiment with the applicant's concavely rounded sides invention described in earlier figures, including both concavely rounded sole inner and outer surfaces **30**, **31**, with a bladder or an encapsulated midsole section **188** in both the medial and lateral sides and in the middle or underneath portion between the sides. An embodiment with a bladder or encapsulated midsole section **188** located in only a single side and the middle portion is also possible as is an embodiment with a bladder or encapsulated midsole section **188** located in both the medial and lateral sides without one in the middle portion. Each of the bladders **188** is connected to an adjacent bladder(s) **188** by a fluid duct **206** passing through a fluid valve **210**, located in midsole insert **145**, although the location could be anywhere in a single or multi-layer rounded shoe sole **28**. FIG. **11**M is based on the left side of FIG. **13**A. In a piezo-electric embodiment using midsole sections **188**, the fluid duct between sections would be replaced by a suitable wired or wireless connection. A combination of one or more bladders **188** with one or more encapsulated midsole sections **188** is also possible.

One advantage of the applicant's invention, as shown in the applicant's FIG. **1**M, is to provide better lateral or side-to-side stability through the use of rounded sides, to compensate for excessive pronation or supination, or both, when standing or during locomotion. The FIG. **11**M embodiment also shows a fluid containment system that is fully enclosed and uses other bladders **188** as reservoirs to provide a unique advantage. The advantage of the FIG. **11**M embodiment is to provide a structural means by which to change the hardness or firmness of each of the shoe sole sides and of the middle or underneath sole portion, relative to the hardness or firmness of one or both of the other sides or sole portion, as seen for example in a frontal plane, as shown. Similar structure can also be used to vary hardness or firmness as viewed in a sagittal plane.

Although FIG. **11**M shows communication between each bladder or midsole section **188** within a frontal plane cross-section (or sagittal plane cross-section), which is a highly effective embodiment, communication might also be between only two adjacent or non-adjacent bladders or midsole sections **188** due to cost, weight, or other design considerations.

Pressures sensing system **200** also includes pressure sensing circuitry **220**, shown in FIG. **11**T, which converts the change in pressure detected by variable capacitor **205** into digital data. Each variable capacitor **205** forms part of a conventional frequency-to-voltage converter (FVC) **223** which outputs a voltage proportional to the capacitance of variable capacitor **205**. Oscillator **224** is electrically connected to each FVC **223** and provides an adjustable reference oscillator. The voltage produced by each of the five FVC's **223** is provided as an input to multiplexer **227** which cycles through the five channels sequentially connecting the voltage from each FVC **223** to analog-to-digital (AID) converter **225** which converts the analog voltages into digital data for transmission to control system **300** via data lines **228**, connecting each in turn to control system **300** via data lines **228**. Control lines **229** allow control system **300** to control the multiplexer **227** to selectively receive data from each pressure sensing device in any desirable order. These components and this circuitry are well known to those skilled in the art and any suitable component or circuitry might be used to perform the same function.

Fluid pressure system **200** may selectively reduce the impact of the user's foot in each of the five zones.

Control system **300**, which includes a programmable microcomputer **301** having conventional RAM and ROM, receives information from pressure sensing system **200** indicative of the relative pressure sensed by each pressure sensing device **104**. Control system **300** receives digital data from pressure sensing circuitry **220** proportional to the relative pressure sensed by pressure sensing devices **104**. Control system **300** is also in communication with fluid valves **210** to vary the opening of fluid valves **210** and thus control the flow air. As the fluid valves of this embodiment are solenoids (and thus electrically controlled), control system **300** is in electrical communication with fluid valves **210**.

As shown in FIG. **11** U, programmable microcomputer **301** of control system **300** selects (via on of five control lines **302**) one of the five digital-to-analog (D/A) converters **310** to receive data from microcomputer **301** to control fluid valves **210**. The selected D/A converter **310** receives the data and produces an analog voltage proportional to the digital data received. The output of each D/A converter **310** remains constant until changed by microcomputer **301** (which can be accomplished using conventional data latches not shown). The output of each D/A converter **310** is supplied to each of the respective fluid valves **210** to selectively control the size of the opening of fluid valves **210**.

Control system **300** also includes a cushion adjustment control **303** that allows the user to control the level of cushioning response from the shoe. A knob on the shoe is adjusted by the user to provide adjustments in cushioning ranging from no additional cushioning (fluid valves **210** never open) to a maximum cushioning. This is accomplished by scaling the data to be transmitted to the D/A converters (which controls the opening of fluid valves **210**) by the amount of desired cushioning as received by control system **300** from cushion adjustment control **303**. However, any suitable conventional means of adjusting the cushioning could be used.

An illuminator **304**, such as a conventional light emitting diode (LED), is also mounted to the circuit board that houses the electronics of control system **300** to provide the user with an indication of the operation of the apparatus.

Each fluid bladder or midsole section **188** may be provided with an associated pressure-sensing device that measures the pressure exerted by the user's foot **27** on the fluid bladder or midsole section **188**. As the pressure increases above a threshold, a control system opens (perhaps only partially) a flow regulator to allow fluid to escape from the fluid bladder or section **188**. Thus, the release of fluid from the fluid bladder or section **188** may be employed to reduce the impact of the user's foot **27** on the ground **43**. Point pressure under a single bladder **188**, for example, can be reduced by a controlled fluid outflow to any other single bladder or any combination of the other bladders.

Preferably, the sole **28** of the shoe is divided into zones which roughly correspond to the essential structural support and propulsion elements of the intended wearer's foot **27**, including the base and lateral tuberosity of the calcaneus **95**, the heads of the metatarsals **96***c*, **96***d* (particularly the first and fifth), the base of the fifth metatarsal **97**, the main longitudinal arch (optional), and the head of the first distal phalange **98**. The zones under each individual element can be merged with adjacent zones, such as a lateral metatarsal head zone shown at **96***c* and a medial metatarsal head zone shown at **96***d*.

The pressure sensing system preferably measures the relative change in pressure in each of the zones. The fluid pressure system, thereby, reduces the impact experienced by the user's foot **27** by regulating the escape of a fluid from a fluid bladder or midsole section **188** located in each zone of the sole **28**. The control system **300** receives pressure data from the pressure sensing system and controls the fluid pressure system in accordance with predetermined criteria, which can be implemented via electronic circuitry, software or other conventional means.

The pressure sensing system may include a pressure sensing device **104** disposed in the sole **28** of the shoe at each zone. In a preferred embodiment, the pressure sensing device **104** is a pressure sensitive variable capacitor which may be formed by a pair of parallel flexible conductive plates disposed on each side of a compressible dielectric. The dielectric can be made from any suitable material such as rubber or another suitable elastomer. The outside of each of the flexible conductive plates is preferably covered by a flexible sheath (such as rubber) for added protection. Since the capacitance of a parallel plate capacitor is inversely proportional to the distance between the plates, compressing the dielectric by applying increasing pressure results in an increase in the capacitance of the pressure sensitive variable capacitor. When the pressure is released, the dielectric expands substantially to its original thickness so that the pressure sensitive variable capacitor returns substantially to its original capacitance. Consequently, the dielectric must have a relatively high compression limit and a high degree of elasticity to provide ideal function under variable loading.

The pressure sensing system also includes pressure-sensing circuitry **120** which converts the change in pressure detected by the variable capacitor into digital data. Each variable capacitor forms part of a conventional frequency-to-voltage converter (FVC) which outputs a voltage proportional to the capacitance of a variable capacitor. An adjustable reference oscillator may be electrically connected to each FVC. The voltage produced by each of the FVC's is provided as an input to a multiplexer which cycles through the channels sequentially connecting the voltage from each FVC to an analog-to-digital (A/D) converter to convert the analog voltages into digital data for transmission to control system **300** via data lines, each of which is connected to control system **300**. The control system **300** can control the multiplexer to selectively receive data from each pressure-sensing device in any desirable order. These components and circuitry are well known to those skilled in the art and any suitable component or circuitry might be used to perform the same function.

The fluid pressure system selectively reduces the impact of the user's foot **27** in each of the zones. Associated with each pressure-sensing device **104** in each zone, and embedded in the shoe sole **28**, is at least one bladder or midsole section **188** that forms part of the fluid pressure system. A fluid duct **206** is connected at its first end to its respective bladder or section **188** and is connected at its other end to a fluid reservoir. In this embodiment, fluid duct **206** connects bladder or midsole section **188** with ambient air, which acts as a fluid reservoir, or, in a different embodiment, with another bladder **188** also acting as a fluid reservoir. A flow regulator, which in this embodiment is a fluid valve **210**, is disposed in fluid duct **206** to regulate the flow of fluid through fluid duct **206**. Fluid valve **210** is adjustable over a range of openings (i.e., variable metering) to control the flow of fluid exiting bladder or section **188** and may be any suitable conventional valve such as a solenoid valve as in this embodiment.

Control system **300**, which preferably includes a programmable microcomputer having conventional RAM and/or ROM, receives information from the pressure sensing system indicative of the relative pressure sensed by each pressure sensing device **104**. Control system **300** receives digital data from pressure sensing circuitry **120** proportional to the relative pressure sensed by pressure sensing devices **104**. Control system **300** is also in communication with fluid valves **210** to vary the opening of fluid valves **210** and thus control the flow of fluid. As the fluid valves of this embodiment are solenoids (and thus electrically controlled), control system **300** is in electrical communication with fluid valves **210**. An analog electronic control system **300** with other components being analog is also possible.

The preferred programmable microcomputer of control system **300** selects (via a control line) one of the digital-to-analog (D/A) converters to receive data from the microcomputer in order to control fluid valves **210**. The selected D/A converter receives the data and produces an analog voltage proportional to the digital data received. The output of each D/A converter remains constant until changed by the microcomputer that can be accomplished using conventional data latches. The output of each D/A converter is supplied to each of the respective fluid valves **210** to selectively control the size of the opening of fluid valves **210**.

Control system **300** also can include a cushioning adjustment control to allow the user to control the level of cushioning response from the shoe. A control device on the shoe can be adjusted by the user to provide adjustments in cushioning ranging from no additional cushioning (fluid valves **210** never open) to maximum cushioning (fluid valves **210** open wide). This is accomplished by scaling the data to be transmitted to the D/A converters (which controls the opening of fluid valves **210**) by the amount of desired cushioning as received by control system **300** from the cushioning adjustment control. However, any suitable conventional means of adjusting the cushioning could be used.

An illuminator, such as a conventional light emitting diode (LED), can be mounted to the circuit board that houses the electronics of control system **300** to provide the user with an indication of the state of operation of the apparatus.

The operation of this embodiment of the present invention is most useful for applications in which the user is either walking or running for an extended period of time during which weight is distributed among the zones of the foot in a cyclical pattern. The system begins by performing an initialization process, which is used to set up pressure thresholds for each zone. During initialization, fluid valves **210** are fully closed while the bladders or sections **188** are in their uncompressed state (e.g., before the user puts on the shoes). In this configuration, no fluid, including a gas, like air, can escape the bladders or sections **188** regardless of the amount of pressure applied to the bladders or sections **188** by the user's foot **27**. As the user begins to walk or run with the shoes on, control system **300** receives and stores measurements of the change in pressure of each zone from the pressure sensing system. During this period, fluid valves **210** are kept closed.

Next, control system **300** computes a threshold pressure for each zone based on the measured pressures for a given number of strides. In this embodiment, the system counts a predetermined number of strides, i.e., ten strides (by counting the number of pressure changes), but another system might simply store data for a given period of time (e.g., twenty seconds). The number of strides is preprogrammed into the microcomputer but might be inputted by the user in other embodiments. Control system **300** then examines the stored pressure data and calculates a threshold pressure for each zone. The calculated threshold pressure, in this embodiment, will be less than the average peak pressure measured and is in part determined by the ability of the associated bladder or section **188** to reduce the force of the impact as explained in more detail below.

After initialization, control system **300** will continue to monitor data from the pressure sensing system and compare the pressure data from each zone with the pressure threshold of that zone. When control system **300** detects a measured pressure that is greater than the pressure threshold for that zone, control system **300** opens the fluid valve **210** (in the manner as discussed above) associated with that pressure zone to allow fluid to escape from the bladder or section **188** into the fluid reservoir at a controlled rate. In this embodiment, air escapes from bladder or section **188** through fluid duct **206** (and fluid valve **210** disposed therein) into ambient air. The release of fluid from the bladder or section **188** allows the bladder or section **188** to deform and thereby lessens the "push back" of the bladder. The user experiences a "softening" or enhanced cushioning of the sole **28** of the shoe in that zone, which reduces the impact on the user's foot **27** in that zone.

The size of the opening of fluid valve **210** should be such as to allow fluid to escape the bladder or section **188** in a controlled manner. The fluid should not escape from bladder or section **188** so quickly that the bladder or section **188** becomes fully deflated (and can therefore supply no additional cushioning) before the peak of the pressure exerted by the user. However, the fluid must be allowed to escape from the bladder or section **188** at a high enough rate to provide the desired cushioning. Factors which will bear on the size of the opening of the flow regulator include the viscosity of the fluid, the size of the fluid bladder, the pressure exerted by fluid in the fluid reservoir, the peak pressure exerted, and the length of time such pressure is maintained.

As the user's foot **27** leaves the traveling surface, a fluid like air is forced back into the bladder or section **188** by a reduction in the internal air pressure of the bladder or section **188** (i.e., a vacuum is created) as the bladder or section **188** returns to its non-compressed size and shape. After control system **300** receives pressure data from the pressure sensing system indicating that no pressure (or minimal pressure) is being applied to the zones over a predetermined length of time (long enough to indicate that the shoe is not in contact with the ground **43** and that the bladders or sections **188** have returned to their non-compressed size and shape), control system **300** again closes all fluid valves **210** in preparation for the next impact of the user's foot **27** with the ground **43**.

Pressure sensing circuitry **120** and control system **300** are mounted to the shoe and are powered by a conventional battery supply. As pressure sensing device **104** and the fluid system are generally located in the sole of the shoe, the described electrical connections are preferably embedded in the shoe upper **21** and the shoe sole **28**.

The FIG. **11**M embodiment can also be modified to omit the applicant's concavely rounded sides and can be combined with the various features of anyone or more of the other figures included in this application, as can the features of FIGS. **11**N-**11**P. Pressure sensing devices **104** are also shown in FIG. **11**M. A control system **300**, such as a microprocessor as described above, forms part of the embodiment shown in FIG. **11**M (and FIGS. **11**N-**11**O), but does not appear in the frontal plane cross-section shown.

FIG. **11**N shows the application of the FIG. **11**M concept as described above and implemented in combination with a removable midsole insert **145**. One significant advantage of this embodiment, besides improved lateral stability, is that the potentially most expensive component of the shoe sole, the removable insert, can be moved to other pairs of shoe upper **21**/bottom soles **149**, whether new or having a different style or function. Separate removable insoles can also be useful in this case, especially in changing from athletic shoes to dress shoes, for function and/or style.

FIG. **11**N shows a simplified embodiment employing only two bladders or encapsulated sections **188**, each of which extends from a concavely rounded side to the central portion. FIG. **11**N is based on the right side of FIG. **13**A.

The FIG. **11**O embodiment is similar to the FIG. **11**N embodiment, except that only one bladder or encapsulated section **188** is shown, separated centrally by a wall **189** containing a fluid valve communicating between the two separate chambers of the section or bladder **188**. The angle of the separating central wall **189** provides a gradual transition from the pressure of the left chamber to the pressure of the right chamber but is not required. Other structures may be present within or outside the section or bladder **188** for support or other purposes, as is known in the art.

FIG. **11**P is a perspective view of the applicant's invention, including the control system **300**, such as a microprocessor and pressure-sensing circuitry **120**, which can be located anywhere in the removable midsole insert **145** in order for the entire unit to be removable as a single piece. Placement in the shank proximate the main longitudinal arch of the wearer's foot **27** is shown in this figure, or alternatively, the removable midsole insert **145** may be located elsewhere in the shoe, potentially with a wired or wireless connection and potentially separate means of attachment. The heel bladder **188** shown in FIG. **11**P is similar to that shown in FIG. **11**O with both lateral and medial chambers. Like FIG. **11**M, FIGS. **11**N-**11**P operate in the manner known in the art as described above, except as otherwise shown or described herein by the applicant, with the applicant's depicted embodiments being preferred but not required.

The removable midsole insert **145** of the various embodiments shown in FIGS. **11**A-**11**P can include its own integral upper or bootie, such as of elastic incorporating stretchable fabric, and its own outer sole for protection of the midsole and for traction so that the midsole insert **145** can be worn, preferably indoors, without the shoe upper **21** and outer sole **149**. Such a removable midsole insert **145** can still be inserted into the FIG. **11**C upper and sole as described above for outdoor or other rigorous use. An embodiment of a removable midsole insert **145** with an integral upper or bootie is described below.

As shown in FIGS. **11**Q and **11**R, the removable midsole insert **145** can include its own integral inner or secondary shoe upper **21***a*, such as a bootie or slipper incorporating stretchable fabric, i.e., elastic or Spandex™, non-stretchable fabric or both, with typical attachment means such as laces, straps, Velcro™ or zippers, or it can simply be a slip-on structure, like a slipper, loafer or pull-on boot.

FIGS. **11**Q and **11**R also show the removable midsole insert **145** with its own thin outer sole **149***a* made from rubber or other suitable, typical material for wear protection of the midsole and for traction so that the removable midsole insert **145** can be worn indoors, for example, without the shoe upper **21** and outer sole **149**. However, it can also be inserted into, for example, the FIG. **11**C shoe upper **21** and shoe sole **28** for heavier use, such as walking outdoors or engaging in athletics. Separate components or an entire outer sole **149** can also be affixed directly to the removable midsole insert **145** with a sufficiently durable secondary shoe upper **21***a* using conventional means for affixing it, such as the interface **8** interlocking geometrically with the upper surface of the bottom sole **166** or secondary bottom sole **149***a*, as shown in FIGS. **11**E and **11**F, in conjunction with straps, or with straps alone, roughly in the manner of sandals. Similarly, all or part of the shoe upper **21** can be affixed through conventional means to the secondary shoe upper **21***a*, independently of the bottom sole **149** or in combination with it.

FIGS. **11**Q-**11**S show an embodiment of an inner shoe in accordance with the present invention. FIG. **11**Q shows, in frontal plane cross-section, first, an embodiment with a very thin coat of traction material such as latex rubber forming a secondary bottom sole **149***a* providing traction to prevent slipping and protecting underneath portion of the removable midsole insert **145** from wear and, second, a lowtop slipper inner shoe upper **21***a*. Such a latex rubber coat can be applied in a continuous manner over part or all of the outer surface of the secondary bottom sole **149***a* or it can be applied in a regular pattern, like dots or circles, as is typical to provide better grip for gloves, or can even be applied in a random pattern.

FIG. **11**R shows, in frontal plane cross-section, another embodiment with a secondary bottom sole **149***a* of a rubber material that might be as thin as 1 millimeter, for example. The rubber material protects just that part of the removable midsole insert **145** which makes contact with the ground **43** when the intended wearer's foot is upright protecting the midsole part which would wear most quickly due to a high level of ground contact. Other suitable outsole material can be used. The secondary bottom sole **149***a* can extend part or all the way up either or both of the rounded shoe sole lateral and medial sides.

FIG. **11**R also shows a lowtop slipper inner secondary shoe upper **21***a* which can envelop all or a portion of the midsole sides, including joining with the secondary bottom sole **149***a*, such as overlapping it on the inside between the removable midsole insert **145** and the secondary bottom sole **149***a*. FIG. **11**Q shows the secondary shoe upper **21***a* connecting to the insole **2**. The secondary shoe upper **21***a* can also envelop the insole.

FIG. **11**S shows, in close-up cross-section, the interface surface **8** between the bottom sole **149** and the secondary bottom sole **149***a* of the removable midsole insert **145**. Direct contact, as shown of the rubber or rubber-like materials or bottom sole **149** and secondary bottom sole **149***a*, provides an excellent means inside the shoe sole to prevent internal slipping due to shear forces at the interface **8**, thereby increasing the stability of the shoe sole. Therefore, removal of typical materials other than those of bottom sole **149** and secondary bottom sole **149***a*, such as, for example, board last material, increases stability. This can be accomplished by outright removal of a board last after the upper to which it is attached has been assembled on a last or assembling without a lasting board. Alternatively, by using a board last with holes or sections removed, direct contact can occur at the bottom sole **149** and secondary bottom sole **149***a*. Such holes or sections can be random or regular, including simply a very loose weave fabric, or can coincide with some or all of the essential support and propulsion elements of the foot **27** described earlier, such as the pattern shown in FIG. **70**.

In an advantageous embodiment, most or all of a stability enhancing portion of the removable midsole **145**, such as special shaping or increased density inserts, is located in the upper portion of the removable midsole insert **145** where it is accessible through the opening of the secondary shoe upper **21***a* for alteration so that it can be modified to better compensate for instability based on testing and usage of the intended wearer.

In another advantageous embodiment, only this uppermost portion is the removable midsole insert **145** while the lower portion of the midsole is fixed in a conventional manner in the shoe sole **28**. Such an embodiment can still be constructed using the embodiments described above, including FIGS. **11**A-**11**S, especially including FIGS. **11**Q-**11**R, and the compartments with computer control mechanisms, particularly as shown in FIG. **11**P. The uppermost removable midsole insert **145** might include the relatively expensive computer microprocessor and associated memory, for example, which might communicate with the remaining portions of the compartment pressure controlling system using a wireless communication system.

The embodiments shown in FIGS. **11**M-**11**S can also include the capability to function sufficiently rapidly to sense an unstable shoe sole condition such as, for example, that initiating a slip, trip or fall and to react to promote a stable or more stable shoe sole condition to attempt to prevent a fall or at least attempt to reduce associated injuries, for example, by rapidly reducing high point pressure in one zone of the shoe sole so that pressures in all zones are quickly equalized to restore the stability of the shoe sole.

The removable midsole insert **145**, for example as shown in FIGS. **11**A-**11**S, can also be used in combination with, or to implement, one or more features of any of the applicant's prior inventions shown in the other figures in this application. Such use can also include a combination of features shown in any other figures of the present application. For example, the removable midsole insert **145** of the present invention may replace all or any portion or portions of the various midsoles, insoles, and bottom soles which are shown in the figures of the present application and may be combined with the various other features described in reference to any of these figures in any of these forms.

The removable midsole insert **145** shown in FIGS. **11**A-**11**S can be integrated into or may replace any conventional midsole, insert or portion thereof. If the removable midsole is used to replace a conventional mass-market or "over the counter" shoe sole insert, for example, then any of the features of the conventional insert can be provided by an equivalent feature, including structural support or cushioning or otherwise, in the removable midsole insert **145**.

In summary, the FIGS. **11**A-**11**S relate generally to the provision of a removable midsole insert for a shoe sole which is formed at least in part by midsole material and may be removable from the shoe. The removable midsole insert can be used in combination with or to replace anyone or more features of the applicant's prior inventions as shown in the figures of this application. Such use of the removable midsole insert can also include a combination of features shown in any other figures of the present application. For example, the removable midsole insert of the present invention may replace all or any portion or portions of the various midsoles, insoles, and bottom soles which are shown in the figures of the present application and may be combined with or used to implement one or more of the various other features described in reference to any of these figures in any of these forms.

FIGS. **12**A-C show a series of conventional shoe sole cross-sections in the frontal plane at the heel utilizing both sagittal plane sipes **181** and horizontal plane sipes **182**, and in which some or all of the sipes do not originate from any outer shoe sole surface **31**, but rather are entirely internal. Relative motion between internal surfaces is, thereby, made possible to facilitate the natural deformation of the shoe sole **28**.

FIG. **12**A shows a group of three midsole sections or lamination layers. Preferably, the central section **188** is not glued to the other surfaces in contact with it. Instead, those surfaces are internal deformation sipes in the sagittal plane **181** and in the horizontal plane **182**, which encapsulate the central section **188**, either completely or partially. The relative motion between midsole section layers at the deformation sipes **181** and **182** can be enhanced with lubricating agents, either wet like silicone or dry like polytetrafluoroethylene, of any degree of viscosity. Shoe sole materials can be closed cell if necessary to contain the lubricating agent or a non-porous surface coating or layer of lubricant can be applied. The deformation sipes **181**, **182** can be enlarged to channels or any other practical geometric shape as sipes defined in the broadest possible terms.

The use of roughened surfaces or other conventional methods of increasing the coefficient of friction between midsole section layers can diminish the relative motion. If even greater control of the relative motion of the central layer **188** is desired, as few as one or many more points can be glued together anywhere on the internal deformation sipes **181** and **182**, making them discontinuous, and the glue can be any degree of elastic or inelastic.

In FIG. **12**A, the outside structure of the sagittal plane deformation sipes **181** is the shoe upper **21**, which is typically flexible and relatively elastic fabric or leather. In the absence of any connective outer material like the shoe upper **21** shown in FIG. **12**A, just the outer edges of the horizontal plane deformation sipes **182** can be glued together.

FIG. **12**B shows another conventional shoe sole in frontal plane cross-section at the heel with a combination similar to FIG. **12**A of both horizontal and sagittal plane deformation sipes **181**, **182** that encapsulate a central section **188**. Like FIG. **12**A, the FIG. **12**B structure allows the relative motion of the central section **188** with its encapsulating midsole section **184**, which encompasses its sides as well as the top surface, and bottom sole **149**, both of which are attached at the interface **8**.

This FIG. **12**B approach is analogous to the applicant's fully rounded shoe sole **28** invention with an encapsulated midsole compartment **161** of a pressure-transmitting medium like gas, gel or liquid and which is preferably silicone. In this conventional shoe sole case, however, the pressure-transmitting medium is a more conventional section of a typical shoe cushioning material like PV or EVA, which also provides cushioning.

FIG. **12**C is another conventional shoe sole shown in frontal plane cross-section at the heel with a combination similar to FIGS. **12**A and **12**B of both horizontal and sagittal plane deformation sipes **181**, **182**. However, instead of encapsulating a central section **188**, in FIG. **12**C an upper midsole section **187** is partially encapsulated by an encapsulating midsole section **184** and surrounded by deformation sipes **181**, **182** so that it acts much like the central section **188**, but is more stable and more closely analogous to the actual structure of the human foot **27**.

The upper midsole section **187** would be analogous to the integrated mass of fatty pads, which are U shaped and attached to the calcaneus **159** or heel bone. Similarly, the shape of the deformation sipes **181**, **182** is U-shaped in FIG. **12**C and the upper section **187** is attached to the heel by the shoe upper **21**, so it should function in a similar fashion to the aggregate action of the fatty pads. The major benefit of the FIG. **12**C invention is that the approach is so much simpler and therefore easier and faster to implement than the highly complicated anthropomorphic design shown in FIG. **10** above. The midsole sides **185** shown in FIG. **12**C are like the side portion of the encapsulating midsole section **184** in FIG. **12**B.

FIG. **12**D shows, in a frontal plane cross-section at the heel, a similar approach applied to the applicant's fully rounded design. FIG. **12**D shows a design including two different embodiments of a partially encapsulated central section **188** and a variation of the attachment for attaching the shoe upper **21** to the bottom sole **149**. The left side of FIG. **12**D shows a variation of the encapsulation of a central section **188** shown in FIG. **12**B, but the encapsulation is only partial, with a center upper section of the central section **188** either attached to or continuous with the encapsulating midsole section **184**. The right side of FIG. **12**D shows a structure of deformation sipes **181**, **182** like that of FIG. **12**C, with the upper midsole section **187** provided with the capability of moving relative to both the bottom sole **149** and the side of the midsole **148**. The FIG. **12**D structure varies from that of FIG. **12**C also in that the deformation sipe **181** in roughly the sagittal plane is partial only and does not extend to the inner surface **30** of the midsole **148**, as it does FIG. **12**C.

FIGS. **13**A and **13**B show, in frontal plane cross-section at the heel area, shoe sole structures like FIGS. **5**A and B, but in more detail and with the bottom sole **149** extending relatively farther up the side of the midsole **148**.

The right side of FIGS. **13**A and **13**B show the preferred embodiment, which is a relatively thin and tapering portion of the bottom sole **149** extending up most of the midsole **148** and is attached to the midsole and to the shoe upper **21**, which is also attached preferably first to the upper midsole **147** where both meet at the attachment point of upper midsole and shoe upper **3** and attached to the bottom sole where both meet at the attachment point of bottom sole and shoe upper **4**. The bottom sole **149** is also attached to the upper midsole **147** where they join at the attachment point of bottom sale and upper midsole **5** and to the midsole **148** at the attachment point of bottom sole and lower midsole **6**.

The left side of FIGS. **13**A and **13**B shows a more conventional attachment arrangement where the shoe sale **28** is attached to a fully lasted shoe upper **21**. The bottom sale **149** is attached to the midsole **148** where their surfaces coincide at the attachment point of bottom sole and lower midsole **6**, the upper midsole **147** at the attachment point of bottom sale and upper midsole **5**, and the shoe upper **21** at the attachment point of bottom sole and shoe upper **4**.

FIG. **13**A shows a shoe sole with another variation of an encapsulated midsole section **188**. The encapsulated midsole section **188** is shown bounded by the bottom sole **149** at line **8** and by the rest of the midsole **147** and **148** at line **9**. FIG. **13**A shows more detail than prior figures, including an insole **2** (also called a sock liner), which is rounded to the shape of the wearer's foot sole, just like the rest of the shoe sole **28**. In this manner, the foot sole is supported throughout its entire range of sideways motion, from maximum supination to maximum pronation.

The insole **2** overlaps the shoe upper **21** at interface **13**. This approach ensures that the load-bearing surface of the wearer's foot sole does not come in contact with any seams, which could cause abrasions. Although only the heel section is shown in this figure, the same insole structure would preferably be used elsewhere, particularly the forefoot. Preferably, the insole **2** would coincide with the entire load-bearing surface of the wearer's foot sole, including the front surface of the toes, to provide support for front-to-back motion as well as sideways motion.

The FIG. **13** design provides firm flexibility by encapsulating fully or partially, roughly the central section **188** of the relatively thick heel of the shoe sole **28** or other areas of the sole, such as any or all of the essential support elements of the foot including the lateral tuberosity of the calcaneus **108**; base of the calcaneus **109**; base of the fifth metatarsal **97**; the heads of the metatarsals **92**, **94**; and the first distal phalange **98**. The outer surfaces of that encapsulated section or sections **188** are allowed to move relatively freely by not gluing the encapsulated midsole section **188** to the surrounding shoe sole **28**.

Firmness in the FIG. **13** design is provided by the high pressure created under multiples of body weight loads during locomotion within the encapsulated section or sections **188**, making it relatively hard under extreme pressure, roughly like the heel of the foot **27**. Unlike conventional shoe soles **22**, which are relatively inflexible and thereby create local point pressures, particularly at the bottom outside edge of the shoe sole **23**, the FIG. **13** design tends to distribute pressure evenly throughout the encapsulated section **188**, so that the natural biomechanics of the wearer's foot sole are maintained and shearing forces are more effectively dealt with.

In the FIG. **13**A design, firm flexibility is provided by encapsulating roughly the middle section of the relatively thick heel of the shoe sole **28** or other areas of the sole **28**, while allowing the outer surfaces of that section to move relatively freely by not conventionally gluing the encapsulated section **188** to the surrounding shoe sole **28**. Firmness is provided by the high pressure created under body weight loads within the encapsulated section **188**, making it relatively hard under extreme pressure, roughly like the heel of the foot **27**, because it is surrounded by flexible but relatively inelastic materials, particularly the bottom sole **149**, and connecting to the shoe upper **21**, which also can be constructed by flexible and relatively inelastic material. The same U-shaped structure is, thus, formed on a macro level by the shoe sole **28** that is constructed on a micro level in the human foot sole, as described definitively by Erich Blechschmidt in Foot and Ankle, March, 1982.

In summary, the FIG. **13**A design shows a shoe sole construction for a shoe, comprising a shoe sole **28** with at least one compartment defined by interfaces **8**, **9** under the structural elements of the human foot **27**; the compartment containing a pressure-transmitting medium composed of an central section **188** of midsole material that is not attached to the shoe sole **28** surrounding it; and pressure from normal load-bearing that is transmitted progressively at least in part to the relatively inelastic sides, top, and bottom of said shoe sole compartment producing tension. The FIG. **13**A design can be combined with the designs shown in FIGS. **58**-**60** so that the compartment is surrounded by a reinforcing layer of relatively flexible and inelastic fiber.

FIGS. **13**A and **13**B show constant shoe sole thickness in frontal plane cross-sections, but that thickness can vary somewhat (up to roughly 25% in some cases). FIG. **13**B shows a design just like FIG. **13**A except that the encapsulated section is reduced to only the load-bearing boundary layer between the midsole **148** and the bottom sole **149**. In simple terms, then, most or all of the upper surface of the bottom sole **166** and the lower surface of the midsole **148** are not attached, or at least not firmly attached, where they coincide at interface **8**. The bottom sole and the midsole are firmly attached only along the non-load-bearing sides of the midsole **148**. This approach is simple and easy. The load-bearing boundary layer at interface **8** is like the internal horizontal sipe **182** described in FIG. **12** above. The sipe at interface **8** can be a channel filled with flexible material or it can simply be a thinner chamber.

The boundary area at interface **8** can be unglued, so that relative motion between the two surfaces is controlled only by their structural attachment together at the sides. In addition, the boundary area can be lubricated to facilitate relative motion between surfaces or lubricated by a viscous liquid that restricts motion or the boundary area at interface **8** can be glued with semi-elastic or semi-adhesive glue that controls relative motion but still permits some motion. The semi-elastic or semi-adhesive glue would then serve a shock absorption function as well.

In summary, the FIG. **13**B design shows a shoe construction for a shoe including a shoe upper **21** and a shoe sole **28** that has a bottom portion with sides that are relatively flexible and inelastic. This design also includes at least a portion of the bottom sole sides that is firmly attached directly to the shoe upper **21** and a shoe upper **21** that is composed of material that is flexible and relatively inelastic, at least where the shoe upper **21** is attached to the bottom sole **149**. The attached portions envelop the other sole portions of the shoe sole **28**; and the shoe sole **28** has at least one horizontal boundary area at interface **8** serving as a sipe that is contained internally within the shoe sole **28**. The FIG. **13**B design can be combined with FIGS. **58**-**60** to include a shoe sole bottom portion composed of material reinforced with at least one fiber layer that is relatively flexible and inelastic and that is oriented in the horizontal plane.

FIGS. **14**, **15**, and **16** show frontal plane cross-sectional views taken at about the ankle joint of sole **28** according to the applicant's prior inventions based on the theoretically ideal stability plane to show the heel section of the shoe. FIGS. **17** through **26** show the same view of the applicant's enhancement of that invention. In the figures, a foot **27** is positioned in a naturally rounded shoe having an upper **21** and a rounded shoe sole **28**. The shoe sole **28** normally contacts the ground **43** at about the lower central heel portion thereof, as shown in FIG. **17**. The concept of the theoretically ideal stability plane defines the plane **51** in terms of a locus of points determined by the thickness (s) of the shoe sole **28**.

FIG. **14** shows, in a rear cross-sectional view, the inner surface of the shoe sole **30** conforming to the natural rounded shape of the foot **27** and the thickness (s) of the shoe sole **28** remaining constant in the frontal plane, so that the outer surface of the shoe sole **31** coincides with the theoretically ideal stability plane.

FIG. **15** shows a fully rounded shoe sole design that follows the natural rounded shape of the bottom as well as the sides of the foot **27**, while retaining a constant shoe sole thickness (s) in the frontal plane. The fully rounded shoe sole **28** assumes that the resulting slightly rounded bottom when unloaded will deform under load and flatten just as the human foot bottom is slightly rounded unloaded but flattens under load. Therefore, the shoe sole material must be of such composition as to allow the natural deformation following that of the foot **27**. The design applies to the heel and to the rest of the shoe sole **28** as well. By providing the closest match to the natural shape of the foot **27**, the fully rounded design allows the foot **27** to function as naturally as possible. Under load, the design of FIG. **15** would deform by flattening to look essentially like the design shown in FIG. **14**. Seen in this light, the naturally rounded side design in FIG. **14** is a more conservative design that is a special case of the more general fully rounded design in FIG. **15**, which is the closest to the natural form of the foot **27**. The amount of deformation flattening used in the FIG. **14** design, which obviously varies under different loads, is not an essential element of the applicant's invention.

FIGS. **14** and **15** both show in frontal plane cross-sections the theoretically ideal stability plane which is also theoretically ideal for efficient natural motion of all kinds, including running, jogging or walking. FIG. **15** shows the most general case, the fully rounded design that conforms to the natural shape of the unloaded foot **27**. For any given individual, the theoretically ideal stability plane **51** is determined, first, by the desired shoe sole thickness (s) in a frontal plane cross-section, and, second, by the natural shape of the individual's outer foot surface **29**.

For the special case shown in FIG. **14**, the theoretically ideal stability plane for any particular individual (or size average of individuals) is determined, first, by the given frontal plane cross-section shoe sole thickness (s); second, by the natural shape of the individual's foot **27**; and, third, by the frontal plane cross section width of the individual's load-bearing footprint, which is defined as the inner surface of the shoe sole **30** that is in physical contact with and supports the human foot sole.

The theoretically ideal stability plane for the special case is composed conceptually of two parts. Shown in FIG. **14**, the first part is a outer surface portion **31***b* of equal length and parallel to inner surface portion **30***b* at a constant distance equal to shoe sole thickness (s). This corresponds to a conventional shoe sole **22** directly underneath the human foot **27**, and also corresponds to the flattened portion of the bottom of the load-bearing shoe sole **28***b*. The second part is the naturally rounded stability side outer edge **31***a* located at each side of the outer surface portion **31***b*. Each point on the rounded side outer edge **31***a* is located at a distance, which is exactly the shoe sole thickness (s) from the closest point on the rounded side inner edge **30***a*.

In summary, the theoretically ideal stability plane is used to determine a geometrically precise lower surface rounding of the shoe sole **28** based on an upper surface rounding that conforms to the contour of the foot **27**.

It can be stated unequivocally that any shoe sole contour even having a similar shape that exceeds the theoretically ideal stability plane will restrict natural foot motion, while any rounding less than that plane will degrade natural stability in direct proportion to the amount of the deviation. The theoretical ideal was taken to be that which is closest to natural.

FIG. **16** illustrates in frontal plane cross-section another variation of a shoe sole **28** that uses stabilizing quadrants **26** at the outer edge of a shoe sole **28**. The stabilizing quadrants **26** would be abbreviated as viewed in a horizontal plane in actual embodiments.

FIG. **17** illustrates the shoe sole side thickness increasing beyond the theoretically ideal stability plane to increase stability somewhat beyond its natural level. The unavoidable trade-off which results is that natural motion would be restricted somewhat and the weight of the shoe sole **28** would increase somewhat.

FIG. **17** shows a situation wherein the thickness of the combined midsole and bottomsole **39** at each of the opposed sides is thicker at the outer edge of the sides **31***a* by a thickness which gradually varies continuously from a thickness (s) through a thickness (S+S**1**) to a thickness (S+S**2**). These designs recognize that lifetime use of existing shoes, the design of which has an inherent problem that continually disrupts natural human biomechanics, has produced, thereby, actual structural changes in a human foot **27** and ankle to an extent that must be compensated for. Specifically, one of the most common of the abnormal effects of the inherent existing problem is a weakening of the long arch of the foot **27**, increasing pronation. These designs, therefore, provide greater than natural stability and should be particularly useful to individuals, generally with low arches, prone to pronate excessively, and could be used only on the medial side. Similarly, individuals with high arches and a tendency to over supinate and who are vulnerable to lateral ankle sprains would also benefit, and the design could be used only on the lateral side. A shoe for the general population that compensates for both weaknesses in the same shoe would incorporate the enhanced stability of the design compensation on both sides. FIG. **17**, like FIGS. **14** and **15**, shows an embodiment which allows the shoe sole **28** to deform naturally, closely paralleling the natural deformation of the bare foot **27** under load. In addition, shoe sole material must be of such composition as to allow natural deformation similar to that of the foot **27**.

This design retains the concept of contouring the shape of the shoe sole **28** to the shape of the human foot **27**. The difference is that the shoe sole thickness in the frontal plane is allowed to vary rather than remain uniformly constant. More specifically, FIGS. **17**, **18**, **19**, **20**, and **24** show, in frontal plane cross-sections at the heel, that the shoe sole thickness can increase beyond the theoretically ideal stability plane **51**, in order to provide greater than natural stability. Such variations (and the following variations) can be consistent through all frontal plane cross-sections, so that there are proportionately equal increases to the theoretically ideal stability plane **51** from the front of the shoe sole **28** to the back. Alternatively, the thickness can vary, preferably continuously, from one frontal plane to the next.

The exact amount of the increase in shoe sole thickness beyond the theoretically ideal stability plane is to be determined empirically. Ideally, right and left shoe soles could be for each individual based on a biomechanical analysis of the extent of his or her foot and ankle dysfunction in order to provide an optimal individual correction. If epidemiological studies indicate general corrective patterns for specific categories of individuals or the population as a whole, then mass-produced shoes with soles incorporating rounded sides having a thickness exceeding the theoretically ideal stability plane would be possible. It is expected that any such mass-produced shoes for the general population would have thicknesses exceeding the theoretically ideal stability plane by an amount up to 5 or 10 percent, while more specific groups or individuals with more severe dysfunction could have an empirically demonstrated need for greater thicknesses on the order of up to 25 percent more than the theoretically ideal stability plane. The optimal rounded sides for the increased thickness may also be determined empirically.

FIG. **18** shows a variation of the enhanced fully rounded design wherein the shoe sole **28** begins to thicken beyond the theoretically ideal stability plane **51** that is somewhat offset to the sides.

FIG. **19** shows a thickness variation which is symmetrical as in the case of FIGS. **17** and **18**, but wherein the shoe sole begins to thicken beyond the theoretically ideal stability plane **51** directly underneath the foot heel **27** on about a center line of the shoe sole. In fact, in this case the thickness of the shoe sole is the same as the theoretically ideal stability plane only at that beginning point underneath the upright foot. For the embodiment wherein the shoe sole thickness varies, the theoretically ideal stability plane is determined by the least thickness in the shoe sole's direct load-bearing portion meaning that portion with direct tread contact on the ground. The outer edge or periphery of the shoe sole is obviously excluded, since the thickness there always decreases to zero. Note that the capability of the design to deform naturally may make some portions of the shoe sole load-bearing when they are actually under a load, especially walking or running, even though they may not be when the shoe sole is not under a load.

FIG. **20** shows that the thickness can also increase and then decrease. Other thickness variation sequences are also possible. The variation in rounded side thickness can be either symmetrical on both sides or asymmetrical, particularly with the medial side being thicker to provide more stability than the lateral side, although many other asymmetrical variations are possible. Also, the pattern of the right foot can vary from that of the left foot.

FIGS. **21**, **22**, **23**, and **25** show that similar variations in the density of the shoe midsole **148** (other portions of the shoe sole area not shown) can provide similar, but reduced, effects to the variations in shoe sole thickness described previously in FIGS. **17**-**20**. The major advantage of this approach is that the structural theoretically ideal stability plane is retained, so that naturally optimal stability and efficient motion are retained to the maximum extent possible.

The forms of dual and tri-density midsoles **148** shown in the figures are extremely common in the current art of athletic shoes **20**, and any number of densities are theoretically possible, although an angled alternation of just two densities like that shown in FIG. **21** provides continually changing composite density. However, multi-densities in the midsole **148** are not preferred since only a uniform density provides a neutral shoe sole design that does not interfere with natural foot and ankle biomechanics in the way that multi-density shoe soles do by providing different amounts of support to different parts of the foot **27**. In these figures, the density of the sole material designated by the legend ($d^1$) is firmer than (d), while ($d^2$) is the firmest of the three representative densities shown. In FIG. **21**, a dual density sole is shown, with (d) being the less firm density. Shoe soles using a combination both of sole thicknesses greater than the theoretically ideal stability plane and of midsole density variations like those just described are also possible.

FIG. **26** shows a bottom sole tread design that provides about the same overall shoe sole density variation as that provided in FIG. **23** by midsole density variation. The less supporting tread there is under any particular portion of the shoe sole **28**, the less effective overall shoe sole density there is since the midsole above that portion will deform more easily than if it were fully supported.

FIG. **27** shows embodiments like those in FIGS. **17** through **26** but wherein a portion of the shoe sole thickness is decreased to less than the theoretically ideal stability plane **51**. It is anticipated that some individuals with foot and ankle biomechanics that have been degraded by existing shoes may benefit from such embodiments which would provide less than natural stability but greater freedom of motion and less shoe sole weight and bulk. In particular, it is anticipated that individuals with overly rigid feet, those with restricted range of motion, and those tending to over-supinate may benefit from the FIG. **14** embodiments. Even more particularly, it is expected that the invention will benefit individuals with significant bilateral foot function asymmetry, namely, a tendency toward pronation on one foot and supination on the other foot. Consequently, it is anticipated that this embodiment would be used only on the shoe sole of the supinating foot, and on the inside portion only, possibly only a portion thereof. It is expected that the range less than the theoretically ideal stability plane would be a maximum of about five to ten percent, though a maximum of up to twenty-five percent may be beneficial to some individuals.

FIG. **27**A shows an embodiment like FIGS. **17** and **20**, but with naturally rounded sides less than the theoretically ideal stability plane. FIG. **27**B shows an embodiment like the fully rounded design in FIGS. **18** and **19**, but with a shoe sole thickness decreasing with increasing distance from the center portion of the sole **28**. FIG. **27**C shows an embodiment like the quadrant-sided design of FIG. **24** but with the quadrant sides reduced from the theoretically ideal stability plane in a manner whereby the thickness decreases with increasing distance from the center portion of the shoe sole **28**. The lesser-sided design of FIG. **27** would also apply to the FIGS. **21-23**, and **25** density variation approach and to the FIG. **26** approach using tread design to approximate density variation.

FIG. **28**A-**28**C show, in cross-sections, that with the quadrant-sided design of FIGS. **16**, **24**, **25**, and **27**C, it is possible to have shoe sole sides that are both greater and lesser than the theoretically ideal stability plane in the same shoe. The radius of an intermediate shoe sole thickness, taken at (**S2**) at the base of the fifth metatarsal in FIG. **28**B, is maintained constant throughout the quadrant sides of the shoe sole **28**, including both the heel, as shown in FIG. **28**C, and the forefoot, as shown in FIG. **28**A, so that the side thickness is less than the theoretically ideal stability plane at the heel and more at the forefoot. Though possible, this is not a preferred approach.

The same approach can be applied to the naturally rounded sides or fully rounded designs described in FIGS. **14**, **15**, **17-23** and **26**, but it is also not preferred. In addition, as shown in FIGS. **28**D-**28**F, it is possible to have shoe sole sides with thicknesses that are both greater and lesser than the theoretically ideal stability plane in the same shoe, like FIGS. **28**A-**28**C, but wherein the side thickness (or radius) is neither constant like FIGS. **28**A-**28**C nor varies directly with shoe sole thickness, but instead varies indirectly with shoe sole thickness. As shown in FIGS. **28**D-**28**F, the shoe sole side thickness varies from somewhat less than the shoe sole thickness at the heel to somewhat more at the forefoot. This approach, though possible, is again not preferred and can be applied to the quadrant-sided design, but it is not preferred there either.

FIG. **29** shows in a frontal plane cross-section at the heel (center of ankle joint) the general concept of a shoe sole **28** that conforms to the natural shape of the human foot **27** and that has a constant thickness (s) in frontal plane cross-sections. The outer surface of the foot **29** of the bottom and sides of the foot **27** should correspond exactly to the inner surface of the shoe sole **30**. The shoe sole thickness is defined as the shortest distance (s) between any point on the inner surface of the shoe sole **30** and the outer surface of the shoe sole **31**. In effect, the applicant's general concept is a shoe sole **28** that wraps around and conforms to the natural contours of the foot **27** as if the shoe sole **28** were made of a theoretical single flat sheet of shoe sole material of uniform thickness, wrapped around the foot **27** with no distortion or deformation of that sheet as it is bent to the foot's contours. To overcome real world deformation problems associated with such bending or wrapping around contours, actual construction of the shoe sole contours of uniform thickness will preferably involve the use of multiple sheet lamination or injection molding techniques.

FIGS. **30**A, **30**B, and **30**C illustrate in frontal plane cross-section use of naturally rounded stabilizing sides **28***a* at the outer edge of a shoe sole. This eliminates the unnatural sharp bottom outside edge **23**, especially of flared shoes, in favor of a naturally rounded shoe sole outer surface **31** as shown in FIG. **29**. The side or inner edge of the shoe sole stability side **30***a* is rounded like the natural form on the side or edge of the human foot **27**, as is the outer edge of the shoe sole stability side **31***a* to follow a theoretically ideal stability plane. The thickness (s) of the shoe sole **28** is maintained exactly constant, even if the shoe sole **28** is tilted to either side, forward or backward. Thus, the naturally rounded stability sides **28***a*, are defined as the same as the thickness (s) of the shoe sole **28** so that, in cross-section, the stable shoe sole **28** has at its outer edge naturally rounded stability sides **28***a* with an outer edge **31***a* representing a portion of a theoretically ideal stability plane and described by naturally rounded sides **28***a* equal to the thickness (s) of the sole **28**. The inner surface portion **30***b* of the sole **28** coincides with the shoe wearer's load-bearing footprint since in the case shown, the shape of the foot **27** is assumed to be load-bearing and, therefore, flat along the bottom A top edge **32** of the naturally rounded stability side **28***a* can be located at any point along the rounded side of the outer surface of the foot **29**, while the inner edge of the naturally rounded stability side **33** coincides with the perpendicular sides of the load-bearing shoe sole **34**. In practice, the shoe sole **28** is preferably integrally formed from the portions **28***b* and **28***a*. Thus, the theoretically ideal stability plane includes the rounded outer edge **31***a* merging into the outer surface portion **31***b* of the rounded shoe sole **28**.

Preferably, the peripheral extent of the shoe sole outline **36** of the load-bearing portion of the shoe sole **28***b* includes all of the support structures of the foot but extends no further than the outer edge of the foot sole **37** as defined by a load-bearing footprint, as shown in FIG. **30**D, which is a top view of the inner shoe sole surface portion **30***b*. FIG. **30**D thus illustrates a foot outline at numeral **37** and a recommended shoe sole outline **36** relative thereto. Thus, a horizontal plane outline of the top of the load-bearing portion of the shoe sole **28**, exclusive of rounded stability sides, should, preferably, coincide as nearly as practicable with the loadbearing portion of the foot outline **37** with which it comes into contact. Such a shoe sole outline **36**, as best seen in FIGS. **30**D and **33**D, should remain uniform throughout the entire thickness of the shoe sole **28** eliminating negative or positive sole flare so that the sides are exactly perpendicular to the horizontal plane as shown in FIG. **30**B. Preferably, the density of the shoe sole material is uniform.

As shown diagrammatically in FIG. **31**, preferably, as the heel lift or wedge **38** of thickness ($s^1$) increases the total thickness ($s+s^1$) of the combined midsole and outer sole **39** of thickness (s) in an anterior direction of the shoe, the naturally rounded stability sides **28***a* increase in thickness exactly the same amount according to the principles discussed in connection with FIG. **30**. Thus, the thickness of the inner edge of the naturally rounded stability side **33** is always equal to the constant thickness (s) of the load-bearing shoe sole **28***b* in the frontal plane cross-section.

As shown in FIG. **31**B, for a shoe that follows a more conventional horizontal plane outline, the shoe sole **28** can be improved significantly by the addition of a naturally rounded stability side **28***a* which correspondingly varies with the thickness of the shoe sole **28** and changes in the frontal plane according to the shoe heel lift **38**. Thus, as illustrated in FIG. **31**B, the thickness of the naturally rounded stability side **28***a* in the heel section is equal to the thickness ($s+s^1$) of the shoe sole **28** which is thicker than the combined midsole and outer sole **39** thickness (s) shown in FIG. **31**A by an amount equivalent to the heel lift **38** thickness ($s^1$). In the generalized case, the thickness (s) of the rounded stability side **28***a* is thus always equal to the thickness (s) of the shoe sole **28**.

FIG. **32** illustrates a side cross-sectional view of a shoe to which the invention has been applied and is also shown in a top plan view in FIG. **33**.

Thus, FIGS. **33**A, **33**B, and **33**C represent frontal plane cross-sections taken along the forefoot, at the base of the fifth metatarsal, and at the heel, thus, illustrating that the shoe sole thickness is constant within each frontal plane cross-section, even though, that thickness varies from front to back due to the heel lift **38** as shown in FIG. **32** and that the thickness of the naturally rounded stability sides **28***a* is equal to the shoe sole thickness in each FIG. **33**A-**33**C frontal plane cross-section. Moreover, as shown in FIG. **33**D, a horizontal plan view of the left shoe, the rounded stability side **28***a* of the shoe sole **28** follows the preferred principle in matching, as nearly as practical, the load-bearing foot outline **37** shown in FIG. **30**D.

FIG. **34** illustrates an embodiment of the invention which utilizes varying portions of the theoretically ideal stability plane **51** in the naturally rounded stability sides **28***a* in order to reduce the weight and bulk of the sole **28**, while accepting a sacrifice in some stability of the shoe. Thus, FIG. **34**A illustrates the preferred embodiment as described above in connection with FIG. **31** wherein the outer edge **31** a of the naturally rounded stability sides **28***a* follows a theoretically ideal stability plane **51**. As in FIGS. **29** and **30**, the rounded outer edges **31***a* and the outer surface portion **31***b* of the shoe sole **28** lie along the theoretically ideal stability plane **51**. As shown in FIG. **34**B, an engineering trade-off results in an abbreviation within the theoretically ideal stability plane **51** by forming a naturally rounded upper side surface **53***a* approximating the natural rounded shape of the foot **27** (or more geometrically regular; which is less preferred) at an angle relative to the upper plane of the shoe sole **28** so that only a smaller portion of the rounded side **28***a* defined by the constant thickness lying along the outer edge **31***a* is coplanar with the theoretically ideal stability plane **51**. FIGS. **34**C and **34**D show similar embodiments wherein each engineering trade-off shown results in progressively smaller portions of rounded side **28***a*, which lies along the theoretically ideal stability plane **51**. The portion of the outer edge **31***a* merges into the upper side surface **53***a* of the naturally rounded side **28***a*.

The embodiment of FIG. **34** may be desirable for portions of the shoe sole **28**, which are less frequently used so that the additional part of the side is used less frequently. For example, a shoe may typically roll out laterally, in an inversion mode, to about 20° on the order of 100 times for each single time it rolls out to 40°. For a basketball shoe, shown in FIG. **34**B, the extra stability is needed. Yet, the added shoe weight to cover that infrequently experienced range of motion is about equivalent to covering the more frequently encountered range. Since in a racing shoe this weight might not be desirable, an engineering trade-off of the type shown in FIG. **34**D is possible. A typical athletic/jogging shoe is shown in FIG. **34**C. The range of possible variations is limitless.

FIG. **35** shows the theoretically ideal stability plane **51** in defining embodiments of the shoe sole **28** having differing tread or cleat patterns. Thus, FIG. **35** illustrates that the invention is applicable to shoe soles **28** having conventional bottom treads. Accordingly, FIG. **35**A is similar to FIG. **34**B further including a tread portion **60**, while FIG. **35**B is also similar to FIG. **34**B wherein the sole includes a cleated portion **61**. The surface to which the cleat bases are affixed **63** should preferably be on the same plane and parallel the theoretically ideal stability plane **51**, since in soft ground that surface **63**, rather than the cleats, become loadbearing. The embodiment in FIG. **35**C is similar to FIG. **34**C showing still another alternative tread construction **62**. In each case, the load-bearing outer surface of the tread or cleat pattern **60**, **61** or **62** lies along the theoretically ideal stability plane **51**.

FIG. **36** illustrates in a curve of range of side to side motion **70** as inversion or eversion of the ankle center of gravity **71** from the shoe shown in frontal plane cross-section at the ankle. Thus, in a static case where the center of gravity **71** lies at approximately the mid-point of the shoe sole **28**, and assuming that the shoe inverts or everts from 0° to 20° to 40°, as shown in progressions in FIGS. **36**A, **36**B and **36**C, the locus of points of motion for the center of gravity **71** thus defines the curve **70** wherein the center of gravity **71** maintains a steady level motion with no vertical component through 40° of inversion or eversion. For the embodiment shown, the shoe sole stability equilibrium point, is at 28° (at point **74**) and in no case is there a pivoting edge to define a rotation point. The inherently superior side to side stability of the design provides pronation or eversion control, as well as lateral or inversion control. In marked contrast to conventional shoe sole designs, this design creates virtually no abnormal torque to resist natural inversion/eversion motion or to destabilize the ankle joint.

FIG. **37** thus compares the range of motion of the center of gravity **71** for the invention, as shown in curve **70**, in comparison to the conventional wide heel flare curve **80** and a narrow rectangle the width of a heel curve **82**. Since the shoe stability limit is 28° in the inverted mode, the shoe sole is stable at the 20° approximate bare foot inversion limit. That factor, and the broad base of support rather than the sharp bottom edge of the prior art, makes the rounded design stable even in the most extreme case as shown in FIGS. **36**A-**36**C and permits the inherent stability of the bare foot to dominate without interference, unlike existing designs, by providing constant, unvarying shoe sole thickness in successive frontal plane cross-sections. The stability superiority of the rounded side design is, thus, clear when observing how much flatter its center of gravity curve **70** is than in existing popular wide flare curve design **80**. The curve demonstrates that the rounded side design has significantly more efficient natural 7° inversion/eversion motion than the narrow rectangle design having the width of a human heel and is much more efficient than the conventional wide flare design. At the same time, the rounded side design is more stable in extremis than either conventional design because of the absence of destabilizing torque.

FIGS. **38**A-**38**D illustrate, in frontal plane cross-sections, the naturally rounded sides design extended to the other natural contours underneath the load-bearing foot **27**, such as the main longitudinal arch, the metatarsal (or forefoot) arch, and the ridge between the heads of the metatarsals (forefoot) and the heads of the distal phalanges (toes). As shown, the shoe sole thickness remains constant as the rounded inner and outer surfaces **30**, **31** of the shoe sole **28** follows that of the sides and bottom of the load-bearing foot **27**. FIG. **38**E shows a sagittal plane cross-section of the shoe sole **28** conforming to the rounded of the bottom of the load-bearing foot **27** with thickness varying according to the heel lift **38**. FIG. **38**F shows a horizontal plane top view of the left shoe that shows the areas **85** of the shoe sole **28** that correspond to the flattened portions of the foot sole that are in contact with the ground when load-bearing. Rounded lines **86** and **87** show approximately the relative height of the shoe sole contours above the flattened load-bearing areas **85** but within roughly the peripheral extent of the inner surface of sole **35** shown in FIG. **30**. A horizontal plane bottom view (not shown) of FIG. **38**F would be the exact reciprocal or converse of FIG. **38**F (i.e., peaks and valleys contours would be exactly reversed). FIGS. **39**A-**39**D show, in frontal plane cross-sections, the fully rounded shoe sole design extended to the bottom of the entire non-load-bearing foot **27**. FIG. **39**E shows a sagittal plane cross-section. The shoe sole contours underneath the foot **27** are the same as FIGS. **38**A-**38**E except that there are no flattened areas corresponding to the flattened areas of the load-bearing foot **27**. The exclusively rounded contours of the shoe sole follow those of the unloaded foot **27**. A heel lift **38** and a combined midsole and outer sole **39**, the same as that of FIG. **38**, are incorporated in this embodiment.

FIG. **40** shows the horizontal plane top view of the left shoe corresponding to the fully rounded design described in FIGS. **39**A-**39**E but abbreviated along the sides to only essential structural support and propulsion elements. Shoe sole material density can be increased in the unabbreviated essential elements to compensate for increased pressure loading there. The essential structural support elements are the base and lateral tuberosity of the calcaneus **95***c*, **95***d*, the heads of the metatarsals **96***c*, **96***d*, and the base of the fifth metatarsal **97**. They must be supported both underneath and to the outside for stability. The essential propulsion element is the head of first distal phalange **98**. The medial (inside) and lateral (outside) sides supporting the base of the calcaneus **95***c* are shown in FIG. **40** oriented roughly along either side of the horizontal plane subtalar ankle joint axis but can be located also more conventionally along the longitudinal axis of the shoe sole **28**. FIG. **40** shows that the naturally rounded stability sides need not be used except in the identified essential areas. Omitting the non-essential stability sides can make flexibility improvements and result in weight savings. Rounded lines **86** through **89** show approximately the relative height of the shoe sole contours within roughly the peripheral extent of the inner surface of shoe sole **35**. A horizontal plane bottom view of FIG. **40** would be the exact reciprocal or converse of FIG. **40** (i.e., peaks and valleys contours would be exactly reversed).

FIG. **41**A shows a development of street shoes with naturally rounded sole sides **28***a* incorporating features according to the present invention. FIG. **41**A develops a theoretically ideal stability plane **51**, as described above, for such a street shoe, wherein the thickness of the naturally rounded stability sides **28***a* equals the shoe sole thickness. The resulting street shoe with a correctly rounded shoe sole **28** is, thus, shown in frontal plane heel cross-section in FIG. **41**A, with side edges perpendicular to the ground, as is typical. FIG. **41**B shows a similar street shoe with a fully rounded design, including the bottom of the shoe sole **28**. Accordingly, the invention can be applied to an unconventional heel lift shoe, like a simple wedge, or to the most conventional design of a typical walking shoe with its heel separated from the forefoot by a hollow under the instep. The invention can be applied just at the shoe heel or to the entire shoe sole. With the invention, as so applied, the stability and natural motion of any existing shoe design, except for high heels or spike heels, can be significantly improved by the naturally rounded shoe sole design.

FIG. **42** shows a non-optimal but interim or low cost approach to shoe sole construction, whereby the midsole **148** and heel lift **38** are produced conventionally, or nearly so (at least leaving the midsole bottom surface flat, though the sides can be rounded), while the bottom or outer sole **149** includes most or all of the special contours of the design. Not only would that completely or mostly limit the special contours to the bottom sole **149**, which would be molded specially, it would also ease assembly, since two flat surfaces of the bottom of the midsole **148** and the top of the bottom sole **149** could be mated together with less difficulty than two rounded surfaces, as would be the case otherwise.

The advantage of this approach is seen in the naturally rounded design example illustrated in FIG. **42**A, which shows some contours on the relatively softer midsole sides, which are subject to less wear but benefit from greater traction for stability and ease of deformation, while the relatively harder rounded bottom sole **149** provides good wear for the load-bearing areas.

FIG. **42**B shows in a quadrant-sided design the concept applied to conventional street shoe heels that are usually separated from the forefoot by a hollow instep area under the main longitudinal arch.

FIG. **42**C shows in frontal plane cross-section the concept applied to the quadrant-sided or single plane design and indicating, in FIG. **42**D, the honeycombed portion **129** (shaded) of the bottom sole **149** (axis on the horizontal plane) which functions to reduce the density of the relatively hard bottom sole **149** to that of the midsole material to provide for relatively uniform shoe density.

Generally, insoles or sock liners should be considered structurally and functionally as part of the shoe sole **28**, as should any shoe material between foot **27** and ground **43**, like the bottom of the shoe upper **21** in a slip-lasted shoe or the board in a board-lasted shoe.

FIG. **43** shows in a realistic illustration a foot **27** in position for a new biomechanical test that is the basis for the discovery that ankle sprains are in fact unnatural for the bare foot. The test simulates a lateral ankle sprain, where the foot **27** on the ground **43** rolls or tilts to the outside, to the extreme end of its normal range of motion, which is usually about 20° at the outer surface of the foot **29**, as shown in a rear view of a bare (right) heel in FIG. **43**. Lateral (inversion) sprains are the most common ankle sprains accounting for about three-fourths of all ankle sprains.

The especially novel aspect of the testing approach is to perform the ankle spraining simulation while standing stationary. The absence of forward motion is the key to the dramatic success of the test because otherwise it is impossible to recreate for testing purposes the actual foot and ankle motion that occurs during a lateral ankle sprain and simultaneously to do it in a controlled manner while at normal running speed or even jogging slowly, or walking. Without the critical control achieved by slowing forward motion all the way down to zero, any test subject would end up with a sprained ankle

That is because actual running in the real world is dynamic and involves a repetitive force maximum of three times one's full body weight for each footstep, with sudden peaks up to roughly five or six times for quick stops, missteps, and direction changes, as might be experienced when spraining an ankle. In contrast, in the static simulation test, the forces are tightly controlled and moderate, ranging from no force at all up to whatever maximum amount that is comfortable.

The Stationary Sprain Simulation Test (SSST) consists simply of standing stationary with one foot bare and the other shod with any shoe. Each foot alternately is carefully tilted to the outside up to the extreme end of its range of motion, simulating a lateral ankle sprain. The SSST clearly identifies what can be no less than a fundamental problem in existing shoe designs. It demonstrates conclusively that nature's biomechanical system, the bare foot, is far superior in stability to man's artificial shoe design. Unfortunately, it also demonstrates that the shoe's severe instability overpowers the natural stability of the human foot and synthetically creates a combined biomechanical system that is artificially unstable. The shoe is the weak link. The test shows that the bare foot is inherently stable at the approximate 20° end of normal joint range because of the wide, steady foundation the bare heel provides the ankle joint, as seen in FIG. **43**. In fact, the area of physical contact of the bare heel with the ground **43** is not much less when tilted all the way out to 20° as when upright at 0°.

The SSST provides a natural yardstick to determine whether any given shoe allows the foot within it to function naturally. If a shoe cannot pass this simple test, it is positive proof that a particular shoe is interfering with natural foot and ankle biomechanics. The only question is the exact extent of the interference beyond that demonstrated by the SSST.

Conversely, the applicant's designs employ shoe soles thick enough to provide cushioning (thin-soled and heel-less moccasins do pass the test, but do not provide cushioning and only moderate protection) and naturally stable performance, like the bare foot, in the SSST.

FIG. **44** shows that, in complete contrast the foot equipped with a conventional athletic shoe **20** having an shoe upper **21**, though initially very stable while resting completely flat on the ground **43**, becomes immediately unstable when the conventional shoe sole **22** is tilted to the outside. The tilting motion lifts from contact with the ground **43** all of the shoe sole **22** except the artificially sharp bottom outside edge **23** of the bottom outside corner. The shoe sole instability increases the farther the foot is rolled laterally. Eventually, the instability induced by the shoe itself is so great that the normal load-bearing pressure of full body weight would actively force an ankle sprain, if not controlled. The abnormal tilting motion of the shoe does not stop at the bare foot's natural 20° limit, as can be seen from the 45° tilt of the shoe heel in FIG. **44**.

That continued outward rotation of the shoe past 20° causes the foot to slip within the shoe, shifting its position within the shoe to the outside edge, further increasing the shoe's structural instability. The slipping of the foot within the shoe is caused by the natural tendency of the foot to slide down the typically flat surface of the tilted shoe sole **22**; the more the tilt, the stronger the tendency. The heel is shown in FIG. **44** because of its primary importance in sprains due to its direct physical connection to the ankle ligaments that are torn in an ankle sprain and also because of the heel's predominant role within the foot in bearing body weight.

It is easy to see in the two figures, FIGS. **43** and **44**, how totally different the physical shape of the natural bare foot is compared to the shape of the artificial, conventional shoe sole. It is strikingly odd that the two objects, which apparently both have the same biomechanical function, have completely different physical shapes. Moreover, the shoe sole **22** clearly does not deform the same way the human foot sole does, primarily as a consequence of its dissimilar shape.

FIGS. **45**A-**45**C illustrate clearly the principle of natural deformation as it applies to the applicant's designs, even though, design diagrams like those preceding are normally shown in an ideal state, without any functional deformation, obviously to show their exact shape for proper construction. That natural structural shape, with its rounded sole design paralleling the foot, enables the shoe sole **28** to deform naturally like the foot **27**. The natural deformation feature creates such an important functional advantage it will be illustrated and discussed here fully. Note in the figures that even when the shoe sole shape is deformed, the constant shoe sole thickness, as viewed in the frontal plane, of the invention is maintained.

FIG. **45**A shows in the upright, unloaded condition, and therefore undeformed, the fully rounded shoe sole design indicated in FIG. **15** above. FIG. **45**A shows a fully rounded shoe sole design that follows the natural rounded shape of all of the foot sole, the bottom as well as the sides. The fully rounded shoe sole **28** assumes that the resulting slightly rounded bottom when unloaded will deform under load as shown in FIG. **45**B and flatten just as the human foot bottom is slightly rounded unloaded but flattens under load, like FIG. **14** above. Therefore, the shoe sole material must be of such composition as to allow the natural deformation following that of the foot **27**. The design applies particularly to the heel, but to the rest of the shoe sole **28** as well. By providing the closest possible match to the natural shape of the foot **27**, the fully rounded design allows the foot **27** to function as naturally as possible. Under load, the FIG. **45**A design would deform by flattening to look essentially like the design of FIG. **45**B.

FIGS. **45**A and **45**B show in frontal plane cross-sections the theoretically ideal stability plane **51** which is also theoretically ideal for efficient natural motion of all kinds, including running, jogging or walking. For any given individual, the theoretically ideal stability plane **51** is determined, first, by the desired shoe sole thickness (s) in a frontal plane cross-section, and, second, by the natural shape of the individual's foot **29**. For the case shown in FIG. **45**B, the theoretically ideal stability plane **51** for any particular individual (or size average of individuals) is determined, first, by the given frontal plane cross-section shoe sole thickness (s); second, by the natural shape of the individual's foot; and, third, by the frontal plane cross-sectional width of the individual's load-bearing footprint which is defined as the upper surface of the shoe sole **28** that is in physical contact with and supports the human foot sole.

FIG. **45**B shows the same fully rounded design when upright, under normal load (body weight) and therefore deformed naturally in a manner very closely paralleling the natural deformation under the same load of the foot **27**. An almost identical portion of the foot sole that is flattened in deformation is also flattened in deformation in the shoe sole **28**. FIG. **45**C shows the same design when tilted outward 20°

laterally, the normal bare foot limit; with virtually equal accuracy it shows the same design for the opposite foot tilted 20° inward, in fairly severe pronation. As shown, the deformation of the shoe sole **28** again very closely parallels that of the foot **27** even as it tilts. Just as the area of foot contact is almost as great when tilted 20°, the flattened area of the deformed shoe sole **28** is also nearly the same as when upright. Consequently, the bare foot is fully supported structurally and its natural stability is maintained undiminished, regardless of shoe tilt. In marked contrast, a conventional shoe **22**, shown in FIG. **2**, makes contact with the ground with only its relatively sharp bottom outside edge **23** when tilted and is therefore inherently unstable.

The capability to deform naturally is a design feature of the applicant's naturally rounded shoe sole designs, whether fully rounded or rounded only at the sides, though the fully rounded design is most optimal and is the most natural assuming the use of shoe sole material that allows natural deformation. It is an important feature because, by following the natural deformation of the human foot **27**, the naturally deforming shoe sole **28** can avoid interfering with the natural biomechanics of the foot and ankle.

FIG. **45**C also represents with reasonable accuracy a shoe sole design corresponding to FIG. **45**B, a naturally rounded shoe sole with a conventional built-in flattening deformation, as in FIG. **14** above, except that design would have a slight crimp at location **146**. Seen in this light, the naturally rounded side design in FIG. **45**B is a more conservative design that is a special case of the more generally fully rounded design in FIG. **45**A, which is the closest to the natural form of the foot **27**. The natural deformation of the applicant's shoe sole design follows that of the foot **27** very closely so that both provide a nearly equal flattened base to stabilize the foot **27**.

FIG. **46** shows the preferred relative density of the shoe sole **28**, including the insole **2** as a part, in order to maximize the shoe sole's ability to deform naturally following the natural deformation of the foot sole. Regardless of how many shoe sole layers (including insole **2**) or laminations of differing material densities and flexibility are used in total, the softest and most flexible material should be closest to the foot sole at the insole **2** or upper midsole **147**, with a progression through less soft material, such as a midsole **148** or heel lift **38**, to the firmest and least flexible material at the outermost shoe sole layer, the bottom sole **149**. This arrangement helps to avoid the unnatural side lever arm/torque problem mentioned in the several previous figures. That problem is most severe when the shoe sole is relatively hard and non-deforming uniformly throughout the shoe sole **28**, like most conventional street shoes, since hard material transmits the destabilizing torque most effectively by providing a rigid lever arm **23***a*.

The relative density shown in FIG. **46** also helps to allow the shoe sole **28** to duplicate the same kind of natural deformation exhibited by the bare foot sole in FIG. **43**, since the shoe sole layers closest to the foot **27**, and therefore with the most severe contours, have to deform the most in order to flatten like the bare foot and consequently need to be soft to do so easily. This shoe sole arrangement also replicates roughly the natural bare foot, which is covered with a very tough "Seri boot" outer surface (protecting a softer cushioning interior of fat pads), especially among primitive barefoot populations.

Finally, the use of natural relative density as indicated in FIG. **46** will allow more anthropomorphic embodiments of the applicant's designs (right and left sides of FIG. **46** show variations of different degrees) with sides going higher around the side contour of the foot **27** and thereby blending more naturally with the sides of the foot **27**. These conforming sides will not be effective as destabilizing lever arms **23***a* because the shoe sole material there would be soft and unresponsive in transmitting torque, since the lever arm **23***a* will bend.

As a point of clarification, the forgoing principle of preferred relative density refers to proximity to the foot **27** and is not inconsistent with the term "uniform density" used in conjunction with certain embodiments of applicant's invention. Uniform shoe sole density is preferred strictly in the sense of preserving even and natural support to the foot like the ground provides, so that a neutral starting point can be established, against which so-called improvements can be measured. The preferred uniform density is in marked contrast to the common practice in athletic shoes today, especially those beyond cheap or "bare bones" models, of increasing or decreasing the density of the shoe sole, particularly in the midsole, in various areas underneath the foot to provide extra support or special softness where believed necessary. The same effect is also created by areas either supported or unsupported by the tread pattern of the bottom sole. The most common example of this practice is the use of denser midsole material under the inside portion of the heel, to counteract excessive pronation.

FIG. **47** illustrates that the applicant's naturally rounded shoe sole sides can be made to provide a fit so close as to approximate a custom fit. By molding each mass-produced shoe size with sides that are bent in somewhat from the position **29** they would normally be able to conform to that standard size shoe last. The shoe soles so produced will very gently hold the sides of each individual foot exactly. Since the shoe sole **28** is designed as described in connection with FIG. **46** to deform easily and naturally like that of the bare foot, it will deform easily to provide this designed-in custom fit. The greater the; flexibility of the shoe sole sides, the greater the range of individual foot size variations can be custom fitted by a standard size. This approach applies to the fully rounded design described here in FIG. **45**A and in FIG. **15** above, which would be even more effective than the naturally rounded sides design shown in FIG. **47**.

Besides providing a better fit, the intentional under-sizing of the flexible shoe sole sides of FIG. **47** allows for a simplified design utilizing a geometric approximation of the actual contour of the human foot **27**. This geometric approximation is close enough to provide a virtual custom fit, when compensated for by the flexible under-sizing from standard shoe lasts described above.

FIG. **48** illustrates a fully rounded design, but abbreviated along the sides to only essential structural stability and propulsion elements as shown in FIG. **11**G-L above combined with freely articulating structural elements underneath the foot **27**. The unifying concept is that, on both the sides and underneath the main load-bearing portions of the shoe sole **28**, only the important structural (i.e., bone) elements of the foot **27** should be supported by the shoe sole **28**, if the natural flexibility of the foot **27** is to be paralleled accurately in shoe sole flexibility, so that the shoe sole **28** does not interfere with the foot's natural motion. In a sense, the shoe sole **28** should be composed of the same main structural elements as the foot **27** and they should articulate with each other just as do the main joints of the foot **27**.

FIG. **48**E shows the horizontal plane bottom view of the right shoe corresponding to the fully rounded design previously described, but abbreviated along the sides to only essential structural support and propulsion elements. Shoe sole material density can be increased in the unabbreviated essential elements to compensate for increased pressure loading there. The essential structural support elements are the base and lateral tuberosity of the calcaneus **95***c*, **95***d*, the heads of the metatarsals **96***c*, **96***d*, and the base of the fifth metatarsal **97** (and the adjoining cuboid in some individuals). They must be supported both underneath and to the outside edge of the foot for stability. The essential propulsion element is the head of the first distal phalange **98**. FIG. **48** shows that the naturally rounded stability sides need not be used except in the identified essential areas. Weight savings and flexibility improvements can be made by omitting the non-essential stability sides.

The design of the portion of the shoe sole **28** directly underneath the foot shown in FIG. **48** allows for unobstructed natural inversion/eversion motion of the calcaneus by providing maximum shoe sole flexibility particularly between area **125** at the base of the calcaneus (heel) and area **126** at the metatarsal heads (forefoot) along a flexibility axis **124**. An unnatural torsion occurs about that axis if flexibility is insufficient so that a conventional shoe sole **22** interferes with the inversion/eversion motion by restraining it. The object of the design is to allow the relatively more mobile (in inversion and eversion) calcaneus to articulate freely and independently from the relatively more fixed forefoot instead of the fixed or fused structure or lack of stable structure between the two in conventional designs. In a sense, freely articulating joints are created in the shoe sole **28** that parallel those of the foot **27**. The design is to remove nearly all of the shoe sole material between the heel and the forefoot except under one of the previously described essential structural support elements, the base of the fifth metatarsal **97**. An optional support for the main longitudinal arch **121** may also be retained for runners with substantial foot pronation, although it would not be necessary for many runners.

The forefoot can be subdivided (not shown) into its component essential structural support and propulsion elements, the individual heads of the metatarsal and the heads of the distal phalanges, so that each major articulating joint set of the foot is paralleled by a freely articulating shoe sole support propulsion element, an anthropomorphic design. Various aggregations of the subdivision are also possible.

The design in FIG. **48** features an enlarged structural support at the base of the fifth metatarsal **97** in order to include the cuboid, which can also come into contact with the ground under arch compression in some individuals. In addition, the design can provide general heel elements **195** for support in the heel area, as shown in FIG. **48**E' or alternatively can carefully orient the stability sides in the heel area to the exact positions of the lateral calcaneal tuberosity **108** and the main base of the calcaneus **109**, as in FIG. **48**E (showing heel area only of the right shoe). FIGS. **48**A-**48**D show frontal plane cross-sections of the left shoe and FIG. **48**E shows a bottom view of the right shoe, with flexibility axes **122**, **124**, **111**, **112**, and **113** indicated. FIG. **48**F shows a sagittal plane cross-section showing the structural elements joined by a very thin and relatively soft upper midsole layer **147**. FIGS. **48**G and **48**H show similar cross-sections with slightly different designs featuring durable fabric only (slip-lasted shoe) or a structurally sound arch design, respectively. FIG. **481** shows a side medial view of the shoe sole **28**.

FIG. **48**J shows a simple interim or low cost construction for the articulating heel support element **195** (showing the heel area only of the right shoe); while it is most critical and effective for the heel support element **95**, it can also be used with the other elements, such as the base of the fifth metatarsal **97** and the longitudinal arch **121**. The heel element **195** shown can be a single flexible layer or a lamination of layers. When cut from a flat sheet or molded in the general pattern shown, the outer edges can be easily bent to follow the contours of the foot **27**, particularly the sides. The shape shown allows a flat or slightly rounded heel element **195** to be attached to a highly rounded shoe upper **21** or very thin upper sole layer like that shown in FIG. **48**F. Thus, a very simple construction technique can yield a highly sophisticated shoe sole design. The size of the center of the shoe sole support section **119** can be small to conform to a fully or nearly fully rounded design or larger to conform to a rounded sides design, where there is a large flattened sole area under the heel. The flexibility is provided by the removed diagonal sections, the exact proportion of size and shape of which can vary.

FIG. **49** shows use of the theoretically ideal stability plane **51** concept to provide natural stability in negative heel shoe soles that are less thick in the heel area than in the rest of the shoe sole **28**; specifically, a negative heel version of the naturally rounded sides conforming to a load-bearing foot design shown in FIG. **14** above.

**49**A, **49**B, and **49**C represent frontal plane cross-sections taken along the forefoot, at the base of the fifth metatarsal, and at the heel, thus, illustrating that the shoe sole thickness is constant at each frontal plane cross-section, even though that thickness varies from front to back due to the forefoot lift **40** (shown hatched) causing a lower heel than forefoot, and that the thickness of the naturally rounded sides is equal to the shoe sole thickness in each FIG. **49**A-**49**C cross-section. Moreover, in FIG. **49**D, a horizontal plane overview or top view of the left shoe sole, it can be seen that the horizontal contour of the sole **28** follows the preferred principle in matching, as nearly as practical, the rough footprint of the load-bearing foot sole.

The abbreviation of essential structural support elements can also be applied to negative heel shoe soles **28** such as that shown in FIG. **49** and dramatically improves their flexibility. Negative heel shoe soles **28** such as are shown in FIG. **49** can also be modified by inclusion of aspects of the other embodiments disclosed herein.

FIG. **50** shows, in FIGS. **50**A-**50**D, possible sagittal plane shoe sole thickness variations for negative heel shoes. The hatched areas indicate the forefoot lift or wedge **40**. At each point along the shoe soles **28** seen in sagittal plane cross-sections, the thickness varies as shown in FIGS. **50**A-**50**D, while the thickness of the naturally rounded stability sides **28***a*, as measured in the frontal plane, equals and, therefore, varies directly with those sagittal plane thickness variations. FIG. **50**A shows the same embodiment as FIG. **49**.

FIG. **51** shows the application of the theoretically ideal stability plane concept in flat shoe soles **28** that have no heel lift to provide for natural stability, maintaining the same thickness throughout, with rounded stability sides abbreviated to only essential structural support elements to provide the shoe sole **28** with natural flexibility paralleling that of the human foot.

FIGS. **51**A, **51**B, and **51**C represent frontal plane cross-sections taken along the forefoot, at the base of the fifth metatarsal, and at the heel, thus, illustrating that the shoe sole thickness is constant at each frontal plane cross-section, while also constant in the sagittal plane from front to back, so that the heel and forefoot have the same shoe sole thickness, and that the thickness of the naturally rounded sides is equal to the shoe sole thickness in each FIG. **51**A-**51**C cross-section. Moreover, in FIG. **51**C, a horizontal plane overview or top view of the left shoe sole, it can be seen that the horizontal contour of the shoe sole follows the preferred principle in matching, as nearly as practical, the rough footprint of the load-bearing foot sole. FIG. **51**B, a sagittal plane cross-section, shows that shoe sole thickness is constant in that plane.

FIG. **51** shows the applicant's prior invention of rounded sides abbreviated to essential structural elements, as applied to a flat shoe sole **28**. FIG. **51** shows the horizontal plane top view of fully rounded shoe sole **28** of the left foot abbreviated along the sides to only essential structural support and propulsion elements (shown hatched). Shoe sole material density can be increased in the unabbreviated essential elements to compensate for increased pressure loading there. The essential structural support elements are the base and lateral tuberosity of the calcaneus **95**, the heads of the metatarsals **96***c* and **96***d*, and base of the fifth metatarsal **97**. They must be supported both underneath and to the outside for stability. The essential propulsion element is the head of the first distal phalange **98**.

The medial (inside) and lateral (outside) sides supporting the base and lateral tuberosity of the calcaneus **95** are shown in FIG. **51** oriented in a conventional way along the longitudinal axis of the shoe sole in order to provide direct structural support to the base and lateral tuberosity of the calcaneus, but they can be located also along either side of the horizontal plane subtalar ankle joint axis. FIG. **51** shows that the naturally rounded stability sides need not be used except in the identified essential areas. Weight savings and flexibility improvements can be made by omitting the non-essential stability sides. A horizontal plane bottom view (not shown) of FIG. **51** would be the exact reciprocal or converse of FIG. **51** with the peaks and valleys contours exactly reversed. Flat shoe soles such as FIG. **51** can also be modified by inclusion of aspects of the other embodiments disclosed herein.

Central section **188** and upper midsole section **187** in FIG. **12** must fulfill a cushioning function that frequently calls for relatively soft midsole material. The shoe sole thickness effectively decreases in the FIG. **12** embodiment when the soft central section is deformed under weight-bearing pressure to a greater extent than the relatively firmer sides.

In order to control this effect, it is necessary to measure it. What is required is a methodology of measuring a portion of a static shoe sole at rest that will indicate the resultant thickness under deformation. A simple approach is to take the actual least distance thickness at any point and multiply it times a factor for deformation or “give”, which is typically measured in durometer (on Shore A scale), to get a resulting thickness under a standard deformation load. Assuming a linear relationship (which can be adjusted empirically in practice), this method would mean that a shoe sole midsection of 1 inch thickness and a fairly soft 30 durometer would be roughly functionally equivalent under equivalent load-bearing deformation to a shoe midsole section of ½ inch and a relatively hard 60 durometer; they would both equal a factor of 30 inch-durometer. The exact methodology can be changed or improved empirically, but the basic point is that static shoe sole thickness needs to have a dynamic equivalent under equivalent loads, depending on the density of the shoe sole material.

Since the theoretically ideal stability plane **51** has already been generally defined in part as having a constant frontal plane thickness and preferring a uniform material density to avoid arbitrarily altering natural foot motion, it is logical to develop a non-static definition that includes compensation for shoe sole material density. The theoretically ideal stability plane **51** defined in dynamic terms would alter constant thickness to a constant multiplication product of thickness times density.

Using this restated definition of the theoretically ideal stability plane **51** presents an interesting design possibility. The somewhat extended width of shoe sole sides that are required under the static definition of the theoretically ideal stability plane **51** could be reduced by using a higher density midsole material in the naturally rounded sides.

FIG. **52** shows, in frontal plane cross-section at the heel, the use of a high density (d') midsole material on the naturally rounded sides and a low density (d) midsole material everywhere else to reduce side width. To illustrate the principle, it was assumed in FIG. **52** that density (d') is twice that of density (d), so the effect is somewhat exaggerated, but the basic point is that shoe sole width can be reduced significantly by using the theoretically ideal stability plane **51** with a definition of thickness that compensates for dynamic force loads. In the FIG. **52** example, about one-fourth of an inch in width on each side is saved under the revised definition, for a total width reduction of one half inch, while rough functional equivalency should be maintained as if the frontal plane thickness and density were each unchanging.

As shown in FIG. **52**, the boundary between sections of different density is indicated by the density edge **45** and the line **51'** parallel to the theoretically ideal stability plane **51** at half the distance from the outer surface of the foot **29**. The design in FIG. **52** uses low density midsole material, which is effective for cushioning throughout that portion of the shoe sole **28** that would be directly load-bearing from roughly 10° of inversion to roughly 10° of eversion, the normal range of maximum motion during athletics; the higher density midsole material is tapered in from roughly 10° to 30° on both sides, at which ranges cushioning is less critical than providing stabilizing support.

FIG. **53** shows the footprints of the natural foot outline **37** and conventional shoe sole **22**. The footprints are the areas of contact between the bottom of the foot **27** or shoe sole **22** and the flat, horizontal plane of the ground, under normal body weight-bearing conditions. FIG. **53**A shows a typical right footprint outline **37** when the foot **27** is upright with its sole flat on the ground.

FIG. **53**B shows the footprint outline **17** of the same foot when tilted out 20° to about its normal limit; this footprint corresponds to the position of the foot shown in FIG. **43** above. Critical to the inherent natural stability of the bare foot is that the area of contact between the heel and the ground is virtually unchanged, and the area under the base of the fifth metatarsal and cuboid is narrowed only slightly. Consequently, the bare foot maintains a wide base of support even when tilted to its most extreme lateral position.

The major difference shown in FIG. **53**B is clearly in the forefoot, where all of the heads of the first through fourth metatarsals and their corresponding phalanges no longer make contact with the ground. Of the forefoot, only the head of the fifth metatarsal continues to make contact with the ground as does its corresponding phalange, although the phalange does so only slightly. The motion of the forefoot is relatively great compared to that of the heel.

FIG. **53**C shows a shoe sole print outline of a conventional shoe sole **22** of the same size as the bare foot in FIGS. **53**A and **53**B when tilted out 20° to the same position as FIG. **53**B; this position of the shoe sole corresponds to that shown in FIG. **44** above. The shoe sole **22** maintains only a very narrow bottom edge in contact with the ground **43**, an area of contact many times less than the bare foot.

FIG. **54** shows two footprints like footprint **37** in FIG. **53**A of a bare foot upright and footprint outline **17** in FIG. **53**B of a bare foot tilted out 20°, but showing also their actual relative positions to each other as the foot **27** rolls outward from upright to tilted out 20°. The bare foot tilted outline **17** is shown hatched. The position of tilted footprint outline **17** so far to the outside of upright foot outline **37** demonstrates the requirement for greater shoe sole width on the lateral side of the shoe to keep the foot **27** from simply rolling off of the shoe sole **22**; this problem is in addition to the inherent problem caused by the rigidity of the conventional shoe sole **22**. The footprints are of a high arched foot.

FIG. **55** shows the applicant's invention of a shoe sole **22** with a lateral stability sipe **11** in the form of a vertical slit. The lateral stability sipe **11** allows the shoe sole **22** to flex in a manner that parallels the foot sole, as seen is FIGS. **53** and **54**. The lateral stability sipe **11** allows the forefoot of the shoe sole **22** to pivot off the ground with the wear's forefoot when the wearer's foot rolls out laterally. At the same time, it allows the remaining shoe sole **22** to remain flat on the ground under the wearer's load-bearing tilted footprint outline **17** in order to provide a firm and natural base of structural support to the wearer's heel, his fifth metatarsal base and head, as well as cuboid and fifth phalange and associated softer tissues. In this way, the lateral stability sipe provides the wearer of even a conventional shoe sole with lateral stability like that of the bare foot. All types of shoes can be distinctly improved with this invention, even women's high-heeled shoes.

With the lateral stability sipe **11**, the natural supination of the foot, which is its outward rotation during load-bearing, can occur with greatly reduced obstruction. The functional effect is analogous to providing a car with independent suspension, with the axis aligned correctly. At the same time, the principle load-bearing structures of the foot are firmly supported with no sipes directly underneath.

FIG. **55**A is a top view of a conventional shoe sole **22** with a corresponding outline of the wearer's footprint superimposed on it to identify the position of the lateral stability sipe **11**, which is fixed relative to the wearer's foot, since it removes the obstruction to the foot's natural lateral flexibility caused by the conventional shoe sole **22**.

With the lateral stability sipe **11** in the form of a vertical slit, when the foot sole is upright and flat, the shoe sole **22** provides firm structural support as if the sipe **11** were not there. No rotation beyond the flat position is possible with a sipe **11** in the form of a slit, since the shoe sole **22** on each side of the sipe **11** prevents further motion.

Many variations of the lateral stability sipe **11** are possible to provide the same unique functional goal of providing shoe sole flexibility along the general axis shown in FIG. **55**. For example, the sipe **11** can be of various depths depending on the flexibility of the shoe sole material used; the depth can be entirely through the shoe sole **22**, so long as some flexible material acts as a joining hinge, like the cloth of a fully lasted shoe, which covers the bottom of the foot sole, as well as the sides. The sipes can be multiple, in parallel or askew; they can be offset from vertical; and they can be straight lines, jagged lines, curved lines or discontinuous lines.

Although slits are preferred, other forms of sipe **11**, such as channels or variations in material densities as described above, can also be used, though many such forms will allow varying degrees of further pronation rotation beyond the flat position, which may not be desirable, at least for some categories of runners. Other methods in the existing art can be used to provide flexibility in the shoe sole **22** similar to that provided by the lateral stability sipe **11** along the axis shown in FIG. **55**.

The axis shown in FIG. **55** can also vary somewhat in the horizontal plane. For example, the foot outline **37** shown in FIG. **55** is positioned to support the heel of a high arched foot; for a low arched foot tending toward excessive pronation, the medial origin of the lateral stability sipe **14** would be moved forward to accommodate the more inward or medial position of a pronator's heel. The axis position can also be varied for a corrective purpose tailored to the individual or category of individual: the axis can be moved toward the heel of a rigid, high arched foot to facilitate pronation and flexibility, and the axis can be moved away from the heel of a flexible, low arched foot to increase support and reduce pronation.

It should be noted that various forms of firm heel counters and motion control devices in common use can interfere with the use of the lateral stability sipe **11** by obstructing motion along its axis; therefore, the use of such heel counters and motion control devices should be avoided. The lateral stability sipe **11** may also compensate for shoe heel-induced outward knee cant.

FIG. **55**B is a cross-section of a conventional shoe sole **22** with lateral stability sipe **11**. The shoe sole thickness is constant but could vary as do the thicknesses of many conventional and unconventional shoe soles known to the art. The shoe sole **22** could be conventionally flat like the ground or conform to the shape of the wearer's foot **27**.

FIG. **55**C is a top view like FIG. **55**A but showing the shoe sole outline **36** with a lateral stability sipe **11** when the shoe sole **22** is tilted outward 20° so that the forefoot of the shoe sole **22** is no longer in contact with the ground while the heel and the lateral section do remain flat on the ground.

FIG. **56** shows a conventional shoe sole **22** with a medial stability sipe **12** that is like the lateral stability sipe **11** but with a purpose of providing increased medial or pronation stability instead of lateral stability; the head of the first metatarsal and the first phalange are included with the heel to form a medial support section inside of a flexibility axis defined by the medial stability sipe **12**. The medial stability sipe **12** can be used alone, as shown, or together with the lateral stability sipe **11**.

FIG. **57** shows foot outlines **37** and **17**, like FIG. **54**, of a right barefoot upright and tilted out 20°, showing the actual relative positions to each other as a low arched foot rolls outward from upright to tilted out 20°. The low arched foot is particularly noteworthy because it exhibits a wider range of motion than the FIG. **54** high arched foot, so the 20° laterally tilted foot outline **17** is farther to the outside of upright foot outline **37**. In addition, the low arched foot pronates inward to inner footprint outlines **18**; the hatched area **19** is the increased area of the footprint due to the pronation, whereas the hatched area **16** is the decreased area due to pronation.

In FIG. **57**, the lateral stability sipe **11** is clearly located on the shoe sole **22** along the inner margin of the lateral footprint outline **17** superimposed on top of the shoe sole **22** and is straight to maximize ease of flexibility. The basic FIG. **57** design can of course also be used without the lateral stability sipe **11**. A shoe sole of extreme width is necessitated by the common foot tendency toward excessive pronation, as shown in FIG. **57**, in order to provide structural support for the full range of natural foot motion, including both pronation and supination. Extremely wide shoe soles are most practical if the sides of the shoe sole **22** are not flat as is conventional but rather are bent up to conform to the natural shape of the shoe wearer's foot sole.

FIGS. **58**A-**58**D shows the use of flexible and relatively inelastic fiber in the form of strands, woven or non-woven (such as pressed sheets), embedded in midsole and bottom sole material. Optimally, the fiber strands parallel (at least roughly) the plane surface of the wearer's foot sole in the naturally rounded design in FIGS. **58**A-**58**C and parallel the flat ground **43** in FIG. **58**D, which shows a section of conventional, non-rounded shoe sole **22**. Fiber orientations at an angle to this parallel position will still provide improvement over conventional soles **22** without fiber reinforcement, particularly if the angle is relatively small; however, very large angles or the omni-directionality of the fibers will result in increased rigidity or increased softness.

This preferred orientation of the fiber strands, parallel to the plane of the wearer's foot sole, allows for the shoe sole **28** to deform to flatten in parallel with the natural flattening of the foot sole under pressure. At the same time, the tensile strength of the fibers resist the downward pressure of body weight that would normally squeeze the shoe sole material to the sides, so that the side walls of the shoe sole **28** will not bulge out (or will do so less). The result is a shoe sole material that is both flexible and firm. This unique combination of functional traits is in marked contrast to conventional shoe sole materials in which increased flexibility unavoidably causes increased softness, and increased firmness also increases rigidity. FIG. **58**A is a modification of FIG. **5**A, FIG. **58**B is FIG. **6** modified, and FIG. **58**C is FIG. **7** modified. The position of the fibers shown would be the same even if the shoe sole material is made of one uniform material or of other layers than those shown here.

The use of the fiber strands, particularly when woven, provides protection against penetration by sharp objects, much like the fiber in radial automobile tires. The fiber can be of any size, either individually or in combination to form strands; and of any material with the properties of relative inelasticity (to resist tension forces) and flexibility. The strands of fiber can be short or long, continuous or discontinuous. The fibers facilitate the capability of any shoe sole using them to be flexible but hard under pressure like the foot sole. The fibers used in both the cover of insoles and the Dellinger Web is knit or loosely braided rather than woven, which is not preferred, since such fiber strands are designed to stretch under tensile pressure so that their ability to resist sideways deformation would be greatly reduced compared to non-knit fiber strands that are individually (or in twisted groups of yarn) woven or pressed into sheets.

FIGS. **59**A-**59**D are FIGS. **9**A-D modified to show the use of flexible inelastic fiber or fiber strands, woven or non-woven (such as pressed sheets) to make an embedded capsule shell that surrounds the cushioning compartment **161** containing a pressure-transmitting medium like gas, gel or liquid. The fibrous capsule shell could also directly envelope the surface of the cushioning compartment **161**, which is easier to construct especially during assembly. FIG. **59**E is a figure showing a fibrous capsule shell **191** that directly envelopes the surface of a cushioning compartment **161**; the shoe sole **28** is not fully rounded, like FIG. **59**A, but naturally rounded, and has a flat middle portion corresponding to the flattened portion of a wearer's load-bearing foot sole.

FIG. **59**F shows a unique combination of the FIGS. **9** and **10** design above. The upper surface of the bottomsole **166** and the lower surface of the midsole **165** contain the cushioning compartment **161**, which is subdivided into two parts. The lower half of the cushioning compartment **161** is both structured and functions like the compartment shown in FIG. **9** above. The upper half is similar to FIG. **10** above but subdivided into chambers **192** that are more geometrically regular so that construction is simpler; the structure of the chambers **192** can be honeycombed. The advantage of this design is that it copies more closely than the FIG. **9** design the actual structure of the wearer's foot sole, while being much more simple to construct than the FIG. **10** design. Like the wearer's foot sole, the FIG. **59**F design would be relatively soft and flexible in the lower half of the chamber **161**, but firmer and more protective in the upper half, where the chambers **192** would stiffen quickly under load-bearing pressure. Other multi-level arrangements are also possible. FIGS. **60**A-**60**D show the use of embedded flexible inelastic fiber or fiber strands, woven or non-woven, in various embodiments similar those shown in FIGS. **58**A-**58**D. FIG. **60**E is a figure showing a frontal plane cross-section of a fibrous capsule shell **191** that directly envelopes the surface of the midsole section **188**.

FIG. **61**A compares the footprint made by a conventional shoe shown as shoe sole outline **36** with the relative positions of the wearer's right foot sole in the maximum supination position **37***a* and the maximum pronation position **37***b*. FIG. **61**C reinforces the indication that more relative sideways motion occurs in the forefoot and midtarsal areas than in the heel area.

As shown in FIG. **61**A, at the extreme limit of supination and pronation foot motion, the base of the calcaneus **109** and the lateral calcaneal tuberosity **108** roll slightly off the sides of the peripheral extent of the upper surface of shoe sole **35**. However, at the same extreme limit of supination, the base of the fifth metatarsal **97** and the heads of the fifth metatarsal **94** and the fifth distal phalange **93** all have rolled completely off the peripheral extent of the upper surface of the shoe sole **35**.

FIG. **61**B shows an overhead perspective of the actual bone structures of the foot.

FIG. **62** is similar to FIG. **57** above in that it shows a shoe sole that covers the full range of motion of the wearer's right foot sole, with or without a lateral stability sipe **11**. However, while covering that full range of motion, it is possible to abbreviate the rounded sides of the shoe sole to only the essential structural and propulsion elements of the foot sole as previously discussed herein.

FIG. **63** shows an electronic image of the relative forces present at the different areas of the bare foot sole when at the maximum supination position shown as **37***a* in FIG. **62** above; the forces were measured during a standing simulation of the most common ankle spraining position. The maximum force was focused at the head of the fifth metatarsal **94** and the second highest force was focused at the base of the fifth metatarsal **97**. Forces in the heel area were substantially less overall and less focused at any specific point.

FIG. **63** indicates that, among the essential structural support and propulsion elements shown in FIG. **40** above, there are relative degrees of importance. In terms of preventing ankle sprains, the most common athletic injury (about two-thirds occur in the extreme supination position **37***a* shown in FIG. **62**), FIG. **63** indicates that the head of the fifth metatarsal **94** is the most critical single area that must be supported by a shoe sole in order to maintain barefoot-like lateral stability. FIG. **63** indicates that the base of the fifth metatarsal **97** is very close to being as important. Generally, the base and the head of the fifth metatarsal **94**, **97** are completely unsupported by a conventional shoe sole **22**.

The right side of FIG. **64** includes an inner shoe sole surface **30** that is complementary to the shape of all or a portion the wearer's foot sole. In addition, this application describes rounded sole side designs wherein the upper surface of the theoretically ideal stability plane **51** lies at some point between conforming or complementary to the shape of the wearer's foot sole, that is—roughly paralleling the foot sole including its side—and paralleling the flat ground **43**; that upper surface of the theoretically ideal stability plane **51** becomes load-bearing in contact with the foot sole during foot inversion and eversion which is normal sideways or lateral motion.

Again, for illustration purposes, the left side of FIG. **64** describes shoe sole side designs wherein the lower surface of the theoretically ideal stability plane **51**, which equates to the load-bearing surface of the bottom or outer shoe sole of the shoe sole side portions is above the plane of the underneath portion of the shoe sole, when measured in frontal or transverse plane cross-sections; and that lower surface of the theoretically ideal stability plane **51** becomes load-bearing in contact with the ground during foot inversion and eversion which is normal sideways or lateral motion.

Although the inventions described in this application may in some instances be less than optimal, they nonetheless distinguish over all prior art and still do provide a significant stability improvement over existing footwear and thus provide significantly increased injury prevention benefit compared to existing footwear.

FIG. **65** provides a means to measure the rounded shoe sole sides incorporated in the applicant's inventions described above. FIG. **65** correlates the height or extent of the rounded side portions of the shoe sole **28** with a precise angular measurement from 0-180°. That angular measurement corresponds roughly with the support for sideways tilting provided by the rounded shoe sole sides of any angular amount from 0-180°, at least for such rounded sides proximate to anyone or more or all of the essential stability or propulsion structures of the foot as defined above. The rounded shoe sole sides as described in this application can have any angular measurement from 0-180°.

FIGS. **66**A-**66**F, FIGS. **67**A-**67**E, and FIG. **68** describe shoe sole structural inventions that are formed with an upper surface to conform, or at least be complementary, to the all or most or at least part of the shape of the wearer's foot sole, whether under a body weight load or unloaded, but without rounded stability sides as defined by the applicant. As such, FIGS. **66-68** are similar to FIGS. **38-40** above, but without the rounded stability sides at the essential structural support and propulsion elements, which are the base and lateral tuberosity of the calcaneus, the heads of the first and fifth metatarsals, the base of the fifth metatarsal, and the first distal phalange, and with shoe sole rounded side thickness variations, as measured in frontal plane cross sections as defined in this and earlier applications.

FIGS. **66**A-**66**F, FIGS. **67**A-**67**E, and FIG. **68**, like the many other variations of the applicant's naturally rounded design described in this application, show a shoe sole invention wherein both the upper foot sole contacting surface of the shoe sole and the bottom, ground-contacting surface of the shoe sole mirror the contours of the bottom surface of the wearer's foot sole, forming, in effect, a flexible three dimensional mirror of the load-bearing portions of that foot sole when bare.

The shoe sole shown in FIGS. **66-68** preferably include an insole layer, a midsole layer, and bottom sole layer, and variation in the thickness of the shoe sole, as measured in sagittal plane cross-sections, like the heel lift common to most shoes as well as a shoe upper **21**.

FIGS. **69**A-**69**D show the implications of relative difference in range of motions between forefoot, midtarsal, and heel areas. FIGS. **69**A-D are a modification of FIG. **33** above with the left side of the figures showing the required range of motion for each area.

FIG. **69**A shows a cross-section of the forefoot area and, therefore, on the left side shows the highest rounded sides (compared to the thickness of the shoe sole in the forefoot area) to accommodate the greater forefoot range of motion. The rounded side is sufficiently high to support the entire range of motion of the wearer's foot sole. Note that the sock liner or insole **2** is shown.

FIG. **69**B shows a cross-section of the midtarsal area at about the base of the fifth metatarsal, which has somewhat less range of motion and therefore the rounded sides are not as high (compared to the thickness of the shoe sole at the midtarsal). FIG. **69**C shows a cross-section of the heel area, where the range of motion is the least, so the height of the rounded sides is relatively the least of the three general areas (when compared to the thickness of the shoe sole in the heel area).

Each of the three general areas, forefoot, midtarsal, and heel, have rounded sides that differ relative to the height of those sides compared to the thickness of the shoe sole in the same area. At the same time, note that the absolute height of the rounded sides is about the same for all three areas and the contours have a similar outward appearance, even though the actual structure differences are quite significant as shown in cross-section.

In addition, the rounded sides shown in FIG. **69**A-D can be abbreviated to support only those essential structural support and propulsion elements identified in FIG. **40** above. The essential structural support elements are the base and lateral tuberosity of the calcaneus **95**, the heads of the metatarsals **96***c* and **96***d*, and the base of the fifth metatarsal **97**. The essential propulsion element is the head of the first distal phalange **98**.

FIG. **70** shows a similar view of a bottom sole structure **149** but with no side sections. The areas under the forefoot **126'**, heel **125'**, and base of the fifth metatarsal **97'** would not be glued or attached firmly, while the other area (or most of it) would be glued or firmly attached. FIG. **70** also shows a modification of the outer periphery **36** of the conventional shoe sole **22** (i.e. the typical indentation at the base of the fifth metatarsal is removed and replaced by a fairly straight line **100**).

FIG. **71** shows a similar structure to FIG. **70**, but with only the section under the forefoot **126'** unglued or not firmly attached; the rest of the bottom sole **149** (or most of it) would be glued or firmly attached. FIGS. **72**A-**72**B show shoe soles with only one or more, but not all, of the essential stability elements (the use of all of which is still preferred) but which, based on FIG. **63**, still represent major stability improvements over existing footwear. This approach of abbreviating structural support to a few elements has the economic advantage of being capable of construction using conventional flat sheets of shoe sole material, since the individual elements can be bent up to the contour of the wearer's foot with reasonable accuracy and without difficulty. Whereas a continuous naturally rounded side that extends all of, or even a significant portion of, the way around the wearer's foot sole would buckle partially since a flat surface cannot be accurately fitted to a rounded surface; hence, injection molding is required for accuracy. The features of FIGS. **72**A-**72**B can be used in combination with the designs shown in this application. Further, various combinations of abbreviated structural support elements may be utilized other than those specifically illustrated in the figures.

FIG. **72**A shows a shoe sole combining the additional stability corrections **96***a*, **96***b*, and **98***a* supporting the first and fifth metatarsal heads and distal phalange heads. The dashed line **98***a'* represents a symmetrical optional stability addition on the lateral side for the heads of the second through fifth distal phalanges, which are less important for stability.

FIG. **72**B shows a shoe sole with symmetrical stability additions **96***a* and **96***b*. Besides being a major improvement in stability over existing footwear, this design is aesthetically pleasing and could even be used with high heel type shoes, especially those for women, but also any other form of footwear where there is a desire to retain relatively conventional looks or where the shear height of the heel or heel lift precludes stability side corrections at the heel or the base of the fifth metatarsal because of the required extreme thickness of the sides. This approach can also be used where it is desirable to leave the heel area conventional, since providing both firmness and flexibility in the heel is more difficult that in other areas of the shoe sole since the shoe sole thickness is usually much greater there; consequently, it is easier and less expensive in terms of change, and less of a risk in departing from well understood prior art just to provide additional stability corrections to the forefoot and/or base of the fifth metatarsal area only.

Since the shoe sole thickness of the forefoot can be kept relatively thin, even with very high heels, the additional stability corrections can be kept relatively inconspicuous. They can even be extended beyond the load-bearing range of motion of the wearer's foot sole, even to wrap all the way around the upper portion of the foot in a strictly ornamental way (although they can also play a part in the shoe upper's structure), as a modification of the strap, for example, often seen on conventional loafers.

FIGS. **73**A-**73**D show close-up cross-sections of shoe soles modified with the applicant's inventions for deformation sipes.

FIG. **73**A shows a cross-section of a design with deformation sipes in the form of channels **151**, but with most of the channels **151** filled with a filler material **170** flexible enough that it still allows the shoe sole **28** to deform like the human foot. FIG. **73**B shows a similar cross-section with the channel sipes **151** extending completely through the shoe sole **28**, but with the intervening spaces also filled with a flexible material **170** like FIG. **73**A; a flexible connecting top layer of sipes **123** can also be used, but is not shown. The relative size and shape of the sipes **151** can vary almost infinitely. The relative proportion of flexible filler material **170** can vary, filling all or nearly all of the sipes **151**, or only a small portion, and can vary between sipes **151** in a consistent or even random pattern. As before, the exact structure of the sipes **151** and filler material **170** can vary widely and still provide the same benefit, though some variations will be more effective than others. Besides the flexible connecting utility of the filler material **170**, it also serves to keep out pebbles and other debris that can be caught in the channel sipes **151**, allowing relatively normal bottom sole tread patterns to be created.

FIG. **73**C shows a similar cross-section of a design with deformation sipes in the form of channels **151** that penetrate the shoe sole **28** completely and are connected by a flexible filler material **170** which does not reach the inner surface of the shoe sole **30**. Such an approach can create an upper shoe sole surface similar to that of the trademarked Maseur™ sandals, but one where the relative positions of the various sections of the inner surface of the shoe sole **30** will vary between each other as the shoe sole **28** bends up or down to conform to the natural deformation of the foot. The shape of the channels **151** should be such that the resultant shape of the shoe sole sections would be similar but rounder than those honeycombed shapes of FIG. **14**D of International Publication No. WO 91/05491. In fact, like the Maseur sandals, cylindrical sections with a rounded or beveled upper surface is probably optimal. The relative position of the flexible filler material **170** can vary widely and still provide the essential benefit. Preferably, the attachment of the shoe uppers **21** would be to the upper surface of the flexible filler material **170**.

A benefit of the FIG. **73**C design is that the resulting inner surface of the shoe sole **30** can change relative to the surface of the foot sole due to natural deformation during normal foot motion. The relative motion makes practical the direct contact between shoe sole **28** and foot sole without intervening insoles or socks, even in an athletic shoe **20**. This constant motion between the two surfaces allows the inner surface of the shoe sole **30** to be roughened to stimulate the development of tough calluses (called a "Seri boot"), as described at the end of FIG. **10** above, without creating points of irritation from constant, unrelieved rubbing of exactly the same corresponding shoe sole **28** and foot sole points of contact.

FIG. **73**C shows a similar cross-section of a design with deformation sipes in the form of angled channel sipes **151** in roughly and inverted V-shape. Such a structure allows deformation bending freely both up and down; in contrast deformation slits can only be bent up and channel sipes **151** generally offer only a limited range of downward motion. The FIG. **73**D angled channels would be particularly useful in the forefoot area to allow the shoe sole **28** to conform to the natural contour of the toes that curl up and then down. As before, the exact structure of the angled channel sipes **151** can vary widely and still provide the same benefit, though some variations will be more effective than others. Finally, deformation slits can be aligned above deformation channel sipes **151**, in a sense continuing the channel in circumscribed form.

FIG. **74** shows sagittal plane shoe sole thickness variations, such as heel lifts **38** and forefoot lifts **40**, and how the rounded stability sides **28***a* equal and, therefore, varying with those varying thicknesses as discussed in connection with FIG. **31**.

FIG. **75** shows, in FIGS. **75**A-**75**C, a method, mown from the prior art, for assembling the midsole shoe sole structure of the present invention, showing in FIG. **75**C the general concept of inserting the removable midsole insert **145** into the shoe upper **21** and sole combination in the same very simple manner as an intended wearer inserts his foot into the shoe upper **21** and sole combination. FIGS. **75**A and **75**B show a similar insertion method for the bottom sole **149**.

Referring to FIGS. **76** and **77**, the invention disclosed includes an inner shoe sole surface **30** with one or more rounded portions that is substantially the same as a lower surface **290** with one or more rounded portions of a shoe sole last **270** for a mass-produced shoe designed to fit an averaged size wearer as is conventional in the art. The invention adds a outer surface **31** with one or more rounded surfaces that is substantially the same or at least similar in shape to the inner surface **30**, both shoe soles as seen in a frontal plane cross-section in an unloaded, upright shoe sole condition.

The inner shoe sole surface **30** can be made with conventional molding means but can advantageously be made using a laser or other scan of the lower surface **290** of the shoe sole last **270**, using scanning means well mown in the art, such as a digital laser scanner or other conventional scanner for use with a digital computer. Scan data obtained using a laser scanning apparatus may be entered into a CAD/CAM system, which can be used to substantially reproduce the inner shoe sole surface **30** on the outer shoe sole surface **31** by copying it using the scanned data. The scan resolution can be adjusted to achieve the degree of accuracy needed or to meet the requirements of the CAD/CAM system. Using the CAD/CAM system, the outer shoe sole surface **31** can be increased in scale to create shoe soles **28** as shown in FIGS. **11**, **38**, **39**, **48**, **51**, **66**, and **67**, for example. Alternatively, any other version or modification of the shoe soles depicted in the figures shown in this application can also be made by this method. For example, the scanned data can be mathematically manipulated in any number of ways to create new designs based on the original scanned data.

The shoe last can be any shoe last, but the more accurately the shoe last fits the true anatomic form of the average wearer's foot, the more comfortable and stable will be the shoe sole **28** derived therefrom. Thus, it is preferred to employ a shoe last which accurately fits the anatomic form of an average wearer's foot, including a category or class of wearers such as pronators, supinators, flat-footed, high-arched, heavy, etc.

Use of this scanning methodology and/or CAD/CAM system invention to aid in the making of a shoe sole **28** in the manner described above allows the manufacturing of very complex and highly non-regular geometric shapes for shoe soles **28** such as those shown in FIGS. **11**, **38**, **39**, **48**, **51**, **66**, and **67**, for example. Such shoe soles **28** can be made based on the similarly complex and highly non-regular geometric shape of the wearer's human foot **27**. This invention solves an important and longstanding problem, which is that the extreme complexity of certain shoe sole embodiments of the shoe sole designs shown in FIGS. **11**, **38**, **39**, **48**, **51**, **66**, and **67**, for example, which incorporate relatively thick portions of cushioning midsole **148** with heel lift **38**, are too complicated to be produced accurately and/or economically through conventional shoe design and construction techniques. As a result, the very high degree of comfort and stability afforded by those designs are practically not obtainable except through the use of the method of the invention as described above.

The method of the present invention can be used to make any surface of a shoe, including surfaces of athletic shoes **20**, such as the inner and outer surfaces of an insole, midsole **148**, bottom sole **149**, or the shoe upper **21**. Any other elements of the shoe sole such as the shank or shanks, the compartment or compartments and any other cushioning, stability or support devices may also be made using the method of the present **15** invention. In fact, all or any part of the shoe sole **28** or shoe upper **21** can be made using the method of the above-described invention.

The lower surface of the bottom sole **149** made using the method of the present invention can include the tread pattern, if used, or exclude it.

The above invention can be used as part of a prototyping process or manufacturing process to form all or part of the shoe sole **28** or shoe upper **21** directly out of shoe sole material or materials or shoe upper material or materials. Alternatively, the invention can be used to create shoe sole manufacturing molds that may then be used to directly make all or part of the shoe sole.

Using the method of the present invention, all or any part of the shoe sole inner surface **30** can be tilted relative to the shoe sole inner surface **30** as viewed in a sagittal plane cross-section to make sagittal plane thickness variations such as heel lift, toe taper or negative heel shoe soles, for example.

In addition to being increased in scale, the shoe sole outer surface **31** described above can also be modified using the CAD/CAM system in other ways. A particularly advantageous modification is to scan one foot or both feet of the individual intended wearer's foot sole, instead of scanning a standard size shoe last with inherently a somewhat different size and shape than the individual intended wearer's foot, to create embodiments like FIGS. **14** and **15**, for example, in comparison to similar FIGS. **76** and **77**. The standard size shoe last intended for mass-production can itself be designed by using an average of the feet (either right or left or both) of a number of intended wearers who approximate the standard size or by scanning a representative individual wearer's foot or several individual wearer's feet.

An inner surface **30** based on an individual intended wearer's foot can be combined with an outer surface **31** based on a standard size or other shoe last. Also, a shoe sole inner surface **30** derived from a standard size or other size shoe last can be combined with an outer shoe sole surface **31** based on a foot sole or feet soles of an individual intended wearer or a group of intended wearers. When a group of wearers of similar size or category is employed as the basis for the design, a single design may be obtained by, for example, averaging the sizes and/or contours of the feet of the group of wearers. Any of the inner and outer surfaces **30** and **31** can be scanned and/or molded. Combinations with molded or other non-scanned shoe sole surfaces, upper and lower, is also possible.

Scanning an individual or group of intended wearers can be done directly on the wearers' bare foot or feet, or on the foot or feet wearing socks or other intermediary material. This may be useful if it is desired to fabricate a shoe design customized to a sock covered wearer's foot or feet, for example.

FIGS. **78**A-**78**E illustrate the above described method and structure, wherein generally the medial and lateral side portion outer surfaces **31** are bent out from the medial and lateral side portion inner surfaces **53***a* and from the copy **30'** of the inner surface **30** in the position of the lower surface. For comparison, outer surface **31** is a superimposed conventional flat lower surface, like that of an Adidas™ Adilette sandal which includes an inner surface **30** concavely rounded to approximately match the rounded shape of a standard sized intended wearer's upright, unloaded foot sole. Uniformly thick side portions are shown, as viewed in a frontal plane cross-section in a shoe sole upright, unloaded condition. Such uniformly thick sides as viewed in a frontal plane have a stability and comfort advantage.

The outer surface **31** of the central portion of the shoe sole shown in FIGS. **78**A-**78**E may be either a copy **30'** of the inner surface **30** with uniformly thick side portions, or may be slightly changed, if desired. This may be accomplished, for example, using the method of the present invention described above. Similar surface configurations can be made in sagittal plane cross-sections and as viewed in top view or horizontal plane views of the sole as well.

In addition, FIGS. **78**B and **78**D show a thickness adjustment in the sole designed to enhance comfort and stability in the midtarsal area of the shoe sole **28** by providing a frontal plane thickness B in the midtarsal area that is about halfway between the thickness of the heel area frontal plane thickness A and the frontal plane thickness C in the forefoot area under the heads of the metatarsals; that is, $B=C+(A-C)/2$. With this shoe sole thickness adjustment, the sole area located in the vicinity of the intended wearer's foot base of the fifth metatarsal bone can deform to flatten under a body weight load or heavier loads such as those encountered during locomotion, especially three or more times body weight during running and even higher peak forces when jumping high, in a natural manner, like the flattening of the intended wearer's bare foot on the ground.

Various features of the embodiments shown in FIGS. **76**, **77**, and **78** can be combined with the features of one or more embodiments shown in any of the preceding FIGS. **1**-**75** of this application. More specifically, anyone or more of the embodiments of FIGS. **1**-**75** of the present application may be fabricated using the method of the present invention described above.

The combinations of the many elements of the applicant's invention introduced in the preceding figures are shown because those embodiments are considered to be at least among the most useful. However, many other useful combinations embodiments are also clearly possible but are not shown simply because of the impossibility of showing them all while maintaining reasonable brevity and conciseness in what is already an unavoidably long description due to the highly interconnected nature of the features shown herein, each of which can operate independently or as part of a combination of others.

FIG. **79** shows a method of measuring shoe sole thickness which may, for example, be used to construct the theoretically ideal stability plane of the naturally contoured sole design. The shoe sole thickness may be measured at any point on the outer surface **31**. The thickness is defined as the length of a line extending to the inner surface **30** from a selected point on the outer surface **31** in a direction perpendicular to a line tangent to the outer surface **31** at the selected point, as viewed in a frontal plane cross-section when the shoe sole **28** is in an upright, unloaded condition.

FIG. **80** illustrates another approach to constructing the theoretically ideal stability plane, and one that is easier to use, i.e., the circle radius method. Using the circle radius method, the pivot point or circle center of a compass is placed at the beginning of the foot sole's natural side contour, as viewed in a frontal plane cross-section. Then, up to a 90° arc of a circle having a radius (s) which is same as the shoe sole thickness (s), is drawn to proscribe the area farthest away from the foot sole contour, as viewed in a frontal plane cross-section when the shoe sole **28** is in an upright, unloaded condition. The process is repeated along the length of the foot sole's natural side contour at very small intervals; the smaller the interval, the more accurate the construction of the theoretically ideal stability plane. When all the circle sections have been drawn, the outer edge farthest from the foot sole contour, as viewed in a frontal plane cross-section, is established at a distance of (s) and the established outer edge coincides with the theoretically ideal stability plane. Both this method and that described in FIG. **79** may be used for both manual and CAD/CAM design applications.

FIG. **81** illustrates an expanded explanation of a preferred approach for measuring shoe sole thickness according to the naturally contoured design, as described above in FIGS. **79-80**. The tangent line described with reference to those figures is parallel to the ground when the shoe sole **28** is tilted out sideways, so that measuring shoe sole thickness along the perpendicular line, as described with reference to FIG. **79**, will provide the least distance between the point on the inner surface **30** of the shoe sole **28** closest to the ground and the closest point on the outer surface **31** of the shoe sole **28**, as viewed in a frontal plane cross-section when the shoe sole is in an upright, unloaded condition.

FIG. **82** shows a frontal plane cross-section of an alternate embodiment for the invention showing the shape of two component rounded stability sides **28***a* that may be determined in a mathematically precise manner to conform approximately to the shape of the sides of the foot **27**. The component stability sides **28***a* form a quadrant of a circle of radius $(r+r^1)$, where the distance (r) is equal to sole thickness (s). Consequently, the sub-quadrant $(r+r^1)$ of radius $(r^1)$ is removed from quadrant $(r+r^1)$ as shown in FIG. **82** to create the inner surface contour. In geometric terms, the component stability side **28***a* is a section of a ring, such as a quarter of a ring. The center of rotation **115** of the quadrants is selected to achieve a sole side inner surface **30***a* that closely approximates the natural contour of the side of the human foot **27**. This method may also be used for both manual and/or CAD/CAM design applications.

FIGS. **83-107** show the applicant's new inventions incorporating new forms of devices with one or more internal (or mostly internal) sipes, including slits or channels or grooves and other shape, including geometrically regular or non-regular shapes, such as anthropomorphic shapes, into a large variety of products, including footwear and orthotics, athletic, occupational and medical equipment and apparel, padding for equipment and furniture, balls, tires and any other structural or support elements in a mechanical, architectural or any other device.

FIGS. **83-97**, **99**, and **104-107** show, as numeral **510**, examples of a device or flexible insert including siped compartments **161** or chambers **188** or bladders (another term used in the art) for use in any footwear soles, including conventional soles **22** or the applicant's prior inventions, including footwear/shoe soles **28** and midsole inserts **145**, or for orthotics **145** as described in the applicant's WO 02/09547 WIPO publication, including for uppers for footwear or orthotics (or including uppers), or for other flexibility uses in athletic equipment like helmets and apparel including protective padding and guards, as well as medical protective equipment and apparel, and other uses, such as protective flooring, improved furniture cushioning, balls and tires for wheels, and other uses.

The device or flexible insert with siped compartments or chambers **510** include embodiments like two or more of either compartments **161** or chambers **188** or bladders (or a any mix including two or more of a compartment, a chamber, and a bladder) that are separated at least in part or in several parts or mostly or fully by an internal sipe **505**. The flexible insert **510** can be inserted during assembly of an article by a maker or manufacturer or is insertable by a user or wearer (into an article like a shoe, for example, as part of a removable midsole insert **145** described above), or integrated into the construction of a device as one or more components.

Siped compartments or chambers **510** include example embodiments such as FIGS. **83-97**, **99**, and **104-107** which generally show at least one inner compartment **161** or chamber **188** inside at least one other outer compartment **161** or chamber **161**; and the two compartments/chambers **161**/**188** being separated by an internal sipe **505**.

One practical example embodiment of the invention is any prior commercial embodiment of Nike Air™ gas bladder or compartment (like typical examples in FIGS. 12-16 of U.S. Pat. No. 6,846,534, which is hereby incorporated by reference) that is installed unattached, as is, located within the space enclosed partially or fully by a new, slightly larger outer compartment of one additional layer of the same or similar material, with the same or a simpler or the simplest geometric shape; that is, not necessarily following indentations or reverse curves, but rather incorporating straighter or the straightest lines, as seen in cross-section: for example, following the outermost side curvature seen in FIGS. **12-16**, but with upper and lower surfaces that are substantially flat and parallel (or curved and parallel), to facilitate ease of movement between the two surfaces of the sipe **505** formed, increasing the resulting flexibility.

The new additional, outer compartment thus thereby has created by its presence an internal sipe **505** between the two unconnected compartments. The new internal sipe **505** provides much greater flexibility to any footwear sole **22** or **28**, since it allows an inner, otherwise relatively rigid Nike Air™ compartment structure to become an inner compartment **501** (instead of typically being fixed into the other materials such as EVA of the footwear sole) to move freely inside the new outer compartment **500**, which becomes a new compartment that is fixed to the footwear sole, rather that the conventional Nike Air™ bladder. The flexibility improvement allows the shoe sole to deform under a body weight load like a wearer's bare foot sole, so that stability is improved also, especially lateral stability.

The result is that the conventional, inner Nike Air™ compartment now contained by a new outer compartment can move easily within the overall footwear sole, allowing the sole to bend or flex more easily in parallel with the wearer's bare foot sole to deform to flatten under a body weight load, including during locomotion or standing, so that footwear sole stability is improved also, especially lateral stability. The extent to which the inner Nike Air™ compartment is "free-floating" within the new outer compartment can be controlled or tuned, for example, by one or more attachments (permanent or adjustable) to the outer compartment or by the media in the internal sipe.

The internal sipe **505** includes at least two surfaces that can move relative to each other to provide a flexibility increase for a footwear sole so that the shape of the footwear sole can deform under a body weight load to better parallel to the shape of the barefoot sole of a wearer under a same body weight load. The relative motion between the two internal sipe **505** surfaces increases the capability of the footwear sole to bend during locomotion under a wearer's body weight load to better parallel the shape of said wearer's bare foot sole.

In an analogous way, especially to the thicker heel portion of a typical shoe sole, a thick urban area telephone book has in effect hundreds of "internal sipes", each page being in effect separated by a sipe from each adjacent page, each of which thereby is able to move freely relative to each other, resulting in a flexible telephone book that bends quite easily. In contrast, if the same wood fiber material with the same dimensions as a thick telephone book were formed instead into a single piece with no pages, like a solid particle board, it would be quite rigid.

Also, the sliding motion between internal support surfaces within the shoe sole **28** allowed by internal sipe **505** in response to torsional or shear forces between a wearer's foot and the ground assists in controlling and absorbing the impact of those forces, whether sudden and excessive or chronically repetitive, thereby helping to protect the wearer's joints from acute or chronic injury, especially to the ankles, knees, hips, lower back, and spine.

A benefit of the siped compartments/chambers **510** is that, as a single unitary component, it can be used in a conventional manner in constructing the footwear sole **28**, generally like that used with a conventional single layer compartment such as used in Nike Air™; i.e. the outer surface of **510** can, as a useful embodiment, adhere to the adjacent materials like plastic such as PU (polyurethane) or EVA (ethyl vinyl acetate) or rubber of the footwear sole that contact the **510** component, just as would be the case with the outer surface of existing single compartment **161** or chamber **188** of commercial examples of Nike Air™. However, the internal sipe **505** formed by the use of an inner compartment/chamber **501** in the siped compartment/chamber **510** provides flexibility in a footwear sole **28** that is absent in the relatively rigid footwear sole **28** formed with a conventional, single layer compartment **161** or chamber **188** of the many Nike Air™ commercial examples.

The sipe surfaces can in one useful example embodiment be formed by the inner surface (or part or parts of it) of the outer compartment **500** and the outer surface (or part or parts of it) of the inner compartment **501**. Such sipe surfaces can be substantially parallel and directly contact each other in one useful embodiment example, but the two surfaces are generally not attached to each other, so that the sipe surfaces can move relative to each other to facilitate a sliding motion between the two surfaces.

The sipe surfaces can be in other useful forms that allow portions of the surfaces to be proximate to each other in an unloaded condition, rather than contacting; such surfaces can make partial or full direct contact under a wearer's body weight load (which can vary from a fraction of a "g" to multiple "g" forces during locomotion) or remain somewhat separated; the amount of sipe surface area making direct contact can also vary with a wearer's body weight load. The sipes surfaces also may not be parallel or only partially parallel, such as the areas of direct surface contact or proximal surface contact.

To preclude the surfaces of the internal sipe **505** from directly contacting each other (whether loaded or unloaded), the sipe surfaces can include an internal sipe media **506** located between the surfaces to reduce friction by lubrication and increase relative motion and therefore flexibility. Useful example embodiments of the internal sipe media **506** include any useful material known in the art (or equivalent), such as a liquid like silicone as one example, a dry material like polytetrafluoroethylene as another example, or a gas like that used in Nike Air™ as a further example. The media **506** can be located in all of the sipe **505** or only part or parts, as shown in FIGS. **83-88**.

The media **506** can be used to decrease (or increase) sliding resistance between the inner surfaces of the sipe; for example, to lubricate with any suitable material known in the art. The internal sipe media **506** is an optional feature.

The siped compartments/chambers **510** can be located anywhere in the footwear sole or orthotic or upper and can be used in other applications, including non-footwear applications where flexibility increases are useful). The siped compartments/chambers **510** can be made, for example, with any methods and materials common in the footwear arts or similar arts or equivalents, like those in various Nike Air™; see for example U.S. Pat. Nos. 4,183,156 and 4,219,945 to Rudy (which show fluid-filled bladder manufacturing through a flat sheet bonding technique), U.S. Pat. No. 5,353,459 to Potter et al. (which shows fluid-filled bladders manufactured through a blow-molding process), as well as U.S. Pat. No. 6,837,951 and FIGS. 12-16 of U.S. Pat. No. 6,846,534, all of which patents are hereby incorporated by reference) or similar commercial examples like Reebok DMX™ compartments in its original form, as seen for example U.S. Pat. No. 6,845,573 (hereby incorporated by reference), column 5, line 41 to column 6, line 9), or New Balance N-ergy™ (see for example FIG. 1 of WIPO Pub. No. WO 00/70981 A1, but note that, as a example, at least the initial production versions of the N-erny compartment should have less rigidity to allow desirable flexibility) or Asics Gel™ (many versions) compartments or future equivalents of any, or with less common materials, such as fibers described above incorporated into or on the surface of the material of the siped compartment/chambers **510**, including either elastic fibers or inelastic fibers or a mix. The siped compartment/chambers **510** can be of any practical number in a footwear sole or any shape, of which useful example embodiments include regular geometric shapes or irregular shapes, including anthropomorphic shapes; and the **510** number or shape can be symmetrical or asymmetrical, including between right and left footwear soles.

Either of the compartments **161** or chambers **188** of the siped compartment/chambers **510** can include one or more structural elements **502** like those common in the footwear art such as in Nike Air™ as noted in the above cited Rudy and Nike patents, also including Tuned Air™ (See for example U.S. Pat. No. 5,976,451 to Skaja et al, which is hereby incorporated by reference and which shows manufacturing of fluid-filled bladders through a vacuum-forming process) or Zoom Air™ (See for example FIGS. 1-3 of U.S. App. No. 2005/0039346 A1, which is hereby incorporated by reference); a number of example embodiments of inner compartments **501** with structural elements **502** are shown in the FIGS. **83**A, **91**, **95**, and **96**. The structural elements **502** can be made of any useful material known in the art and constructed in any manner known in the art. FIGS. **106**A and **107**A show similar example embodiments wherein the structural elements **502** of the inner compartment **501** are formed with a specific shape and foamed plastic material such as PU or EVA like that of Nike Shox™ (See U.S. Pat. Nos. 5,353,523, 5,343,639, and 6,851,204, which are hereby incorporated by reference) and Nike Impax™ (U.S. D500,585 S, which is hereby incorporated by reference), respectively, and can be affixed to the inner compartment **501**, which can be reinforced as necessary (instead of to rigid lower and/or upper plates); the lower surface of the outer compartment **500** can be attached to an outer sole, at least in part or an outer sole can be integrated into the outer compartment **500** by thickening, for example, or incorporating rubber or rubber substitute material. Other commercial existing examples that can be similarly modified as a device or flexible insert or component **510** are Adidas A$^3$™ Energy-Management Technology and Adidas™ Ground Control System (GPS)™, and Reebok DMX™ Shear Heel or other cushioning technologies.

Also, as shown in the example embodiments of FIGS. **107**B and **106**B, since foamed plastic material does not require containment (unlike a gas, liquid, or most gels), if the structural elements **502** are sufficiently interconnected, like for example, Nike Impax™ in FIG. **107**B, or if the separate support columns **32** and midsole wedge **40** of Nike Shox™ are modified to interconnect like the example shown in FIG. **106**B, then those connected structural elements **502**, **502**$^1$, **502**$^2$, **502**$^3$ and **502**$^4$ can form an integral inner compartment **501**, the outer surface of which can form an internal sipe **505** with the new outer compartment **500**. The interconnection can be complete, with each structural element **502**, **502**$^1$, **502**$^2$, **502**$^3$ and **502**$^4$ connected to at least the closest other elements **502**, **502**$^1$, **502**$^2$, **502**$^3$ and **502**$^4$, as shown, or mostly complete, or partial. The Shox™ support columns **32** can be any practical number, such as existing examples of four or five or six (commercially available) or more in the heel and many more in the forefoot of the shoe sole **22** or **28**, for a total of element in existing commercial examples.

Any of the compartments or chambers **161**/**188** of the siped compartment **510** can be permanently or temporarily attached one to another with at least one attachment **503** of any useful shape or size or number or position; embodiment examples are shown in FIGS. **83**A, **84**A, **85**A, **86**A, **87**A, **88**A, and **90**. Anthropomorphic designs would include positioning attachments **503** on the internal sipe **505** closest to a wearer's foot sole, so that the remaining sipes **505** would have a U shape in cross-section, like the structure of human foot sole fat pads, which are analogous to the cushioning midsole and midsole components of footwear soles.

The attachments **503** can be simply passive (i.e. static) or actively controlled by electronic, mechanical, electromagnetic, or other useful means. The attachments **503** can, for example, be designed to break away as a failsafe feature to compensate for a predetermined extreme torsional load, for example, to reduce extreme stress on critical joints (in lieu of a wearer's cartilage, tendons, muscle, bone, or other body parts being damaged); the attachments **503** can then be reset or replaced (or, alternatively, return automatically to a normal position).

Example embodiments of the compartments and chambers **500**/**501** can include a media **504** such as a gas (like that used in Nike Air™ or ambient atmospheric air), a liquid or fluid, a gel, a foam (made of a plastic like PU or EVA, both of which are common in the footwear art, or equivalent, or of a rubber (natural or synthetic) or blown rubber or a rubber compound or equivalent or of another useful material or of a combination of two or more of the preceding foam plastic/rubber/etc.) or a useful combination of one or more gas, liquid, gel, foam, or other useful material.

Also, any inventive combination that is not explicitly described above in the example shown in FIG. **83** is implicit in the overall invention of this application and, consequently, any part of the example embodiments shown in preceding FIG. **83** and/or associated textual specification can be combined with any other part of any one or more other elements of the invention examples described in FIGS. **84**-**107** and/or associated textual specification and/or, in addition, can be combined with any one or more other elements of the inventive examples shown in earlier FIGS. **1**-**82** & **108**-**110** and/or associated textual specification of this application to make new and useful improvements over the existing art.

FIGS. **84**A, **85**A, and **86**A show examples of embodiments of siped compartment/chambers **510** wherein either the inner compartment/chamber **501** or the outer compartment **500** can have one or more openings **522**, **521**, respectively, for pressure equalization, assembly facilitation, or other purposes.

Also, any inventive combination that is not explicitly described above in the example shown in FIG. **84**-**86** is implicit in the overall invention of this application and, consequently, any part of the example embodiments shown in preceding FIG. **84**-**86** and/or associated textual specification can be combined with any other part of any one or more other elements of the invention examples described in FIGS. **83** and **87**-**107** and/or associated textual specification and/or, in addition, can be combined with any one or more other elements of the inventive examples shown in earlier FIGS. **1**-**82** & **108**-**110** and/or associated textual specification of this application to make new and useful improvements over the existing art.

FIG. **87**A shows an example embodiment with an inner compartment/chamber **501**$^1$ having a smaller inner compartment/chamber **501**$^2$; additional smaller inner compartments **501** are possible in a similar progression, either enclosed within the previous larger inner compartment **501** or within the same **501** or **500**.

FIG. **88**A shows an example embodiment with two inner compartment/chambers **501**$^1$ and **501**$^2$ which are layered within outer compartment/chamber **500**; additional compartment/chamber **501** layers can be useful also.

FIGS. **83**B, **84**B, **85**B, **86**B, **87**B and **88**B show a top view of an example embodiment of the device **510** in a horizontal plane of FIGS. **83**A, **84**A, **85**A, **86**A, **87**A, and **88**A.

Also, any inventive combination that is not explicitly described above in the example shown in FIGS. **87**-**88** is implicit in the overall invention of this application and, consequently, any part of the example embodiments shown in preceding FIG. **87**-**88** and/or associated textual specification can be combined with any other part of any one or more other elements of the invention examples described in FIGS. **89**-**107** and/or associated textual specification and/or, in addition, can be combined with any one or more other elements of the inventive examples shown in earlier FIGS. **1**-**82** & **108**-**110** and/or associated textual specification of this application to make new and useful improvements over the existing art.

FIGS. **89**-**97** and **99** show, in frontal plane cross sections in the heel area, example footwear embodiments with siped compartment/chambers **510** located in footwear soles **28**, which are shown with curved sides but which sides can also be planar in another embodiment; or which is shown with flattened inner and outer surfaces underneath the wearer's foot sole but which can be curved in a different embodiment.

FIG. **89** shows an example embodiment with single outer compartment **500** and a single inner compartment/chamber **501**.

FIG. **90** shows a similar example embodiment with an attachment **503** between **500** and **501**.

FIG. **91** is a similar example embodiment to that shown in FIG. **89** and includes also an inner compartment/chamber **501** with a number of structural elements **502**.

FIG. **92** shows an example embodiment with more than one siped compartment/chambers **510**, including outer compartment/chambers **500**, each with an inner compartment/chamber **501**; not shown is another example embodiment with more than one inner compartments/chambers **501** in each of more than one outer compartment/chamber **500**, another among many useful variations.

Also, any inventive combination that is not explicitly described above in the examples shown in FIGS. **90-92** is implicit in the overall invention of this application and, consequently, any part of the example embodiments shown in preceding FIGS. **90-92** and/or associated textual specification can be combined with any other part of any one or more other elements of the invention examples described in FIGS. **83-89** and **93-107** and/or associated textual specification and/or, in addition, can be combined with any one or more other elements of the inventive examples shown in earlier FIGS. **1-82** & **108-110** and/or associated textual specification of this application to make new and useful improvements over the existing art.

FIG. **93** shows a similar example embodiment to FIG. **89** and including a number of inner compartments **501** within a single outer compartment/chamber **500**, as does FIG. **94**. Any practical number of inner compartments **501** can be a useful embodiment of the general invention.

Also, any inventive combination that is not explicitly described above in the examples shown in FIGS. **89** and **93-94** is implicit in the overall invention of this application and, consequently, any part of the example embodiments shown in preceding FIGS. **89** and **93-94** and/or associated textual specification can be combined with any other part of any one or more other elements of the invention examples described in FIGS. **83-88**, **90-92**, and **95-107** and/or associated textual specification and/or, in addition, can be combined with any one or more other elements of the inventive examples shown in earlier FIGS. **1-82** & **108-110** and/or associated textual specification of this application to make new and useful improvements over the existing art.

FIGS. **95** and **96** show example embodiments wherein the outer compartment/chamber/bladder **500** forms substantially all of the footwear sole, exclusive of the outer sole **149** in the example shown (but the insert **510** can form the outer surface of the footwear sole also). A heel cross-section is shown, but other sections of the sole, such as the forefoot or midfoot can employ this approach, either as separate components or each can be used alone or in combination with others or as substantially all of the sole **28**. As shown, both FIGS. **95** and **96** example embodiments include multiple inner compartments **501** in layers.

Also, any inventive combination that is not explicitly described above in the examples shown in FIGS. **95-96** is implicit in the overall invention of this application and, consequently, any part of the example embodiments shown in preceding FIG. **95-96** and/or associated textual specification can be combined with any other part of any one or more other elements of the invention examples described in FIGS. **83-94** and **97-107** and/or associated textual specification and/or, in addition, can be combined with any one or more other elements of the inventive examples shown in earlier FIGS. **1-82** & **108-110** and/or associated textual specification of this application to make new and useful improvements over the existing art.

Additionally, FIG. **97** is an example embodiment similar to FIG. **11**N, with the siped chamber **510** invention applied to it.

Also, any inventive combination that is not explicitly described above in the example shown in FIG. **97** is implicit in the overall invention of this application and, consequently, any part of the example embodiments shown in preceding FIG. **97** and/or associated textual specification can be combined with any other part of any one or more other elements of the invention examples described in FIGS. **83-96** and **98-107** and/or associated textual specification and/or, in addition, can be combined with any one or more other elements of the inventive examples shown in earlier FIGS. **1-82** & **108-110** and/or associated textual specification of this application to make new and useful improvements over the existing art.

FIG. **98** shows an example embodiment of chambers **188** for any footwear soles, including conventional, or other flexibility uses with an electromagnetic shock absorption system similar to, for example, the Cadillac™ "Magnetic Ride Control" system, wherein magnetically sensitive metal particles **507** suspended in a shock absorbing fluid **508** are made less fluid in effect by controlling, on for example a millisecond basis, an electromagnetic field-creating circuit **509** that aligns the metal particles **507** into a flow resistant structure. The fluid **508** is thus a magnetorheological fluid, that is, a fluid which generally solidifies into a pasty consistency when subject to a magnetic field.

FIG. **99**A shows an example embodiment like FIG. **11**N wherein the flow between chambers **188** is controlled by controlling the flow resistance of the fluid **508** by the circuit **509** located to affect the fluid **508** in one or more of the chambers **188**; alternatively, the flow can be controlled by the circuit **509** being located between the chambers.

FIG. **99**A shows a similar embodiment and view to that shown in FIG. **97**, but including an electromagnetic shock absorption system. FIG. **99**B is a close-up view of an embodiment like FIG. **89**, but showing magnetorheological fluid **508** located within an internal sipe **505**.

The FIG. **98-99** example embodiments can be located anywhere in the footwear sole (and can be used in other applications, including non-footwear applications where flexibility increases are useful). The FIG. **98-99** embodiments can be made with any materials common in the footwear art, like those in various Nike Air™ commercial examples, or future equivalents, or with less common materials, such as fibers described earlier, including either elastic fibers or inelastic fibers or a mix. The FIG. **98-99** example embodiments can be of any practical number in a footwear sole, or any shape, of which useful embodiments include regular geometric shapes or irregular shapes, including anthropomorphic shapes; and the number or shape can be symmetrical or asymmetrical, including between right and left footwear soles.

Also, any inventive combination that is not explicitly described above in the examples shown in FIG. **98-99** is implicit in the overall invention of this application and, consequently, any part of the example embodiments shown in preceding FIG. **98-99** and/or associated textual specification can be combined with any other part of any one or more other elements of the invention examples described in FIGS. **83-97** and **100-107** and/or associated textual specification and/or, in addition, can be combined with any one or more other elements of the inventive examples shown in earlier FIGS. **1-82** & **108-110** and/or associated textual specification of this application to make new and useful improvements over the existing art.

FIG. **100** shows an example embodiment of a flexible insert or component **511** including a single compartment/chamber **161/188** or bladder with an associated internal sipe **505** component, again for any footwear sole, including conventional **22**, or other flexibility uses (such as those described above relative to insert **510**), to form a single unitary siped compartment or chamber; the sipe **505** can extend to part or all of one side of the single compartment **500**, as shown, or the sipe **505** can extend around portions of the other sides of the single compartment **500**; FIG. **100**B shows an example embodiment in a horizontal plane view of **511**. The flexible insert **511** can be inserted during assembly of an article by a maker or manufacturer or is insertable by a user or wearer (into an article like a shoe, for example, as part of a removable midsole insert described above), or integrated into the construction of an article as one or more components.

A benefit of the single siped compartment/chamber **511** is that, as a single unitary component like **510**, it can be used in a conventional manner in constructing the footwear sole **28**, like that used with a conventional single layer compartment in Nike Air™; i.e. the outer surface of **511** can, as a useful embodiment, adhere to the adjacent material of the footwear sole that contact the **511** component, just as would the outer surface of a single compartment **161** or chamber **188**. However, the internal sipe **505** component of the siped compartment/chamber **511** provides flexibility in a footwear sole **28** that is absent in the relatively rigid footwear sole **28** formed with a conventional, single layer compartment **161** or chamber **188**.

The siped compartments/chamber **511** can be located anywhere in the footwear sole (and can be used in other, non-footwear applications where flexibility increases are useful). The siped compartments/chambers **511** can be made with any materials common in the footwear art, like those in various Nike Air™ commercial examples, or future equivalents, or with less common materials, such as fibers described earlier, including either elastic fibers or inelastic fibers or a mix. The siped compartment/chambers **511** can be of any practical number in a footwear sole, or any shape, of which useful embodiments include regular geometric shapes or irregular shapes, including anthropomorphic shapes; and the number or shape can be symmetrical or asymmetrical, including between right and left footwear soles.

Also, any inventive combination that is not explicitly described above in the example shown in FIG. **100** is implicit in the overall invention of this application and, consequently, any part of the example embodiments shown in preceding FIG. **100** and/or associated textual specification can be combined with any other part of any one or more other elements of the invention examples described in FIGS. **83-99** and **101-107** and/or associated textual specification and/or, in addition, can be combined with any one or more other elements of the inventive examples shown in earlier FIGS. **1-82** & **108-110** and/or associated textual specification of this application to make new and useful improvements over the existing art.

FIG. **101**A shows an example embodiment of a flexible insert or component **513** forming a unitary internal sipe for any footwear sole or orthotic or upper, including conventional sole **22**, or other flexibility uses (such as those described above relative to insert **510**), the embodiment shown employing a single internal flexibility sipe **505**; FIG. **101**B shows an example embodiment in a horizontal plane view of FIGS. **101**A, **102**A, and **103**A. Multiple unitary internal sipes **513** can be used independently or synergistically anywhere in a footwear sole in other useful embodiments not shown; the sipes **513** can be stacked proximate to one another or apart, as viewed in a frontal or sagittal plane, for example; or the sipes **513** can overlap, as viewed in a horizontal plane, for example. The flexible insert **513** can be inserted during assembly of an article by a maker or manufacturer or is insertable by a user or wearer (into an article like a shoe, for example, as part of a removable midsole insert described above), or integrated into the construction of an article as one or more components.

In one useful example embodiment, the unitary internal sipe **513** can be made as a separate sole component like an extremely thin conventional gas compartment similar to a Nike Air™ compartment, but without the typical internal compartment structures (which in another useful embodiment can be present in some form if unattached to at least one inner surface so that relative motion between inner surfaces can occur to provide increased flexibility).

A benefit of the unitary internal sipe **513** is that, as a single unitary component like **510** and **511**, it can be used in a conventional manner in constructing the footwear sole **28**, roughly like that used with a conventional single layer compartment in Nike Air™; i.e. the outer surface of **513** can, as a useful embodiment, adhere to the other portions of the footwear sole that contact the **513** component, just as would the outer surface of a single compartment **161** or chamber **188**.

The unitary internal sipe **513** can be located as a separate component anywhere in the footwear sole (and can be used in other applications, including non-footwear applications where flexibility increases are useful). The unitary internal sipe **513** can be made with any materials common in the footwear art, like those in various Nike Air™ commercial examples, or future equivalents, or with less common materials, such as fibers described earlier, including either elastic fibers or inelastic fibers or a mix. The unitary internal sipe **513** can be of any practical number in a footwear sole, or any shape, of which useful example embodiments include regular geometric shapes or irregular shapes, including anthropomorphic shapes; and the number or shape can be symmetrical or asymmetrical, including between right and left footwear soles.

FIG. **102**A shows the FIG. **101**A example embodiment of a unitary internal sipe **513** positioned as a separate component in an embodiment of a footwear sole **28**; alternatively, in another example embodiment not shown, the unitary internal sipe **513** can be completely enclosed in conventional midsole material like PU or EVA or similar material.

FIG. **103**A shows the unitary internal sipe **513** in an example embodiment including three separate internal flexibility sipes **505**, which in one embodiment can be completely enclosed in conventional midsole material such as PU or EVA or similar material. Generally, unitary internal sipes **513** can thus be subdivided into any practical number of smaller unitary internal sipes that are aggregated together (or can be positioned alone, as described earlier).

Also, any inventive combination that is not explicitly described above in the examples shown in FIGS. **101-102** is implicit in the overall invention of this application and, consequently, any part of the example embodiments shown in preceding FIGS. **101-102** and/or associated textual specification can be combined with any other part of any one or more other elements of the invention examples described in FIGS. **83-100** and **103-107** and/or associated textual specification and/or, in addition, can be combined with any one or more other elements of the inventive examples shown in earlier FIGS. **1-82** & **108-110** and/or associated textual specification of this application to make new and useful improvements over the existing art.

FIG. **104** shows an example embodiment of a flexible insert or component **510** with siped compartments used in the footwear upper **21** for use in embodiments like the Reebok Pump™ and Pump 2.0™; the flexible insert or component **510** can be positioned anywhere in upper **21**, including an orthotic; **511** and **513** can be used also.

FIG. **105** shows an example embodiment of a flexible insert or component **510** that is substantially forming the footwear upper **21** in part of the heel and which can be used anywhere else are in all of the upper **21**. Note also that the flexible insert or component **510** shown as an example in FIG. **105** also shows the flexible insert or component **510** positions so that it is located in both the upper **21** and in the shoe sole or in both an orthotic and orthotic upper; **511** and **513** can be used also.

Also, any inventive combination that is not explicitly described above in the examples shown in FIGS. **104-105** is implicit in the overall invention of this application and, consequently, any part of the example embodiments shown in preceding FIG. **104-105** and/or associated textual specification can be combined with any other part of any one or more other elements of the invention examples described in FIGS. **83-103** and **106-107** and/or associated textual specification and/or, in addition, can be combined with any one or more other elements of the inventive examples shown in earlier FIGS. **1-82** & **108-110** and/or associated textual specification of this application to make new and useful improvements over the existing art.

FIGS. **106**A and **106**B, as well as FIGS. **107**A and **107**B, show a heel section of a footwear sole or orthotic with an example of a flexible insert or component **510** using specific examples of the structural elements **502** based on commercial examples of Nike Shox™ and Nike Impax™. FIGS. **106**A and **107**A show an example of those structural elements of foam material contained and affixed within an inner compartment **501**. Since use of a foamed material as a media does not require containment to maintain its structure and function (in contrast to a gas, liquid, or most gels), a foamed material do not require a separate inner compartment **501** in order to form an internal sipe **505** with the new outer compartment **500**, as noted under the section on compartment **500**/**501** media **504** below; thus, as shown in the examples of FIGS. **106**B and **107**B, suitably configured (in terms of interconnections and shape, for example) structural elements **502** of a foamed material can form an integral inner compartment **501** creating an internal sipe **505** with outer compartment **500**.

FIG. **107**C shows an example in a horizontal plane cross-section of a footwear sole **22** of a device or flexible insert or component **510** in which the inner compartment **501** includes a flexible shank **514** located in the media **504** in the general area of the instep of the shoe sole between the heel area and the forefoot area. The flexible shank **514** can be made of any rigid or semi-rigid material including plastic, metal, and composites including carbon-fiber common in the art and can have sipes **151**, of which a vertical slit is one example among a very many well known in the art, that are generally oriented from the area of the heel to the area of the forefoot (including at an angle) so that the shoe sole **22** is flexible enough to flatten in following the deformation motion of a wearer's foot sole in a full range of pronation and supination motion, while remaining sufficiently rigid to support naturally the instep area of the shoe sole **22**, a area that is relatively thin (often with tapered thickness) and therefore not ground-contacting in many common footwear soles popular in the art and therefore unstable without shank support, which is well known in the art but which is typically too narrow to support directly the base of a wearer's fifth metatarsal and too rigid in a frontal plane to follow a wearer's lateral pronation/supination motion.

FIG. **107**D shows two different examples of versions of the flexible shank **514** in frontal plane cross section. channels as another sipe variation, with the left side showing full or near full penetration (and again, a fiber or other layer can be attached) and the right side showing the channels connected by portions of the flexible shank **514**.

Also, any inventive combination that is not explicitly described above in the example shown in FIGS. **106-107** is implicit in the overall invention of this application and, consequently, any part of the example embodiments shown in preceding FIGS. **106-107** and/or associated textual specification can be combined with any other part of any one or more other elements of the invention examples described in FIGS. **83-105** and/or associated textual specification and/or, in addition, can be combined with any one or more other elements of the inventive examples shown in earlier FIGS. **1-82** & **108-110** and/or associated textual specification of this application to make new and useful improvements over the existing art.

FIGS. **108**A-**108**E and **110** show prior art frontal plane cross section examples of shoe soles **22** or **28** or midsole insert or orthotics **145** with several planar sides to approximate curvature from the applicant's WIPO publication no. WO 02/09547, which can be combined with the flexible insert or components **510**, **511**, or **513**.

FIGS. **111-117** show prior art examples of gas bladders of Nike Air™ (FIGS. **111-115**), which are FIGS. 12-16 of U.S. Pat. No. 6,846,534 and Zoom Air™ (FIGS. **116-117**), which are FIGS. 1-2 of published U.S. Patent Application 2005/0039346 A1. FIG. **118** is a cross-sectional view along line **118-118** of FIG. **117** and is a prior art example of a gas bladder as shown in FIG. 3 of published U.S. Patent Application 2005/0039346 A1.

FIG. **119** shows Adidas 1 shoe sole electronic or electromechanical cushioning system (pg. 96 Popular Science, December 2004).

Any example of a new invention shown in the preceding FIGS. **83-107** and/or associated textual specification can be combined with any other part of any one or more other of the prior art or the applicant's prior invention examples shown in FIGS. **1-3**, **5-7**, **9**, **11-42**, **44-52**, **55-62**, **64-82**, and **108-110** and/or combined with any one or more other of subsequent new inventions shown in the examples described in FIGS. **83-107** and/or associated textual specification of this application to make new and useful improvements over the existing art.

In addition, if not otherwise shown in this application, the example embodiments of the applicant's new inventions shown in the preceding new FIGS. **83-105** and **106-107** and associated textual specification can be usefully employed in combination, for example, with the applicant's previous inventive shoe soles and orthotics that: incorporate uppers that envelope the midsole and/or outsole and/or other features shown in FIGS. **5-7** and **13**; incorporate anthropomorphic shapes and/or chambers and/or other features shown in FIGS. **9** and **10**; incorporate integral or insertable orthotics or microprocessor-controlled variable pressure and/or other features shown in FIG. **11**; incorporate sipes and/or other features shown in FIG. **12**; use uniform thickness in rounded sole side or bottom portions and/or other features shown in FIGS. **14-16**, **29-46** and **76-77**; use increased or decreased (or variable) thickness in rounded sole side portions and/or other features shown in FIGS. **17-20**, **24**, and **27-28**; use increased or decreased density or firmness in rounded sole side or bottom portions and/or other features shown in FIGS. **21-23** and **25-26**; use rounding of the outer surface of the midsole on a sole side and/or other features shown in FIG. **43**A; employ bent-in rounded sides and/or other features shown in FIG. **47**; uses bulges with or without uniform thickness, at important support or propulsion areas and/or features shown in FIGS. **48** and **75**; incorporates a flat heel (meaning no heel lift) and/or other features shown in FIGS. **51**A-**51**E; incorporates negative heel embodiments and/or other features shown in FIGS. **49**A-**49**D and **50**A-**50**E; use rounded sides with variable thickness and firmness and/or other features shown in FIG. **52**; employs sipes and/or other features shown in FIGS. **53-57**, **70-71** and **73**; incorporates fiber and/or multiple layers of chambers and/or other features shown in FIGS. **58-60**;

employ shoe soles or orthotics with sufficient width throughout or at specific portions to support a wearer's bone structures throughout a full range of motion and/or other features shown in FIGS. **61-65** and **72**; uses relatively planar sides with rounded underfoot sole portions and/or other features shown in FIGS. **66** and **67**; uses similarly shaped rounding on sole sides of different thickness at different parts of the sole and/or other features shown in FIG. **69**; uses a variation of heel or forefoot lifts and/or other features shown in FIG. **74**; incorporates planar sections to approximate rounding and/or other features shown in FIGS. **108-110**; and/or other features shown in FIGS. **78-82**.

Any combination that is not explicitly described above is implicit in the overall invention of this application and, consequently, any part of the inventions shown in the examples shown in preceding FIGS. **83-107** and/or textual specification can be combined with any other part of any one or more other inventions shown in FIGS. **83-107** and/or associated textual specifications and also can be combined with any one or more other inventive examples of earlier FIGS. **1-82** & **108-110** and/or textual specification of this application to make new and useful improvements over the existing art.

New reference numerals used in the preceding FIGS. **83-107** are further defined as follows:

Ref. No **500**: Outer compartment **161** or chamber **188** or bladder at least partially or mostly or entirely enclosing a space within the outer compartment/chamber/bladder **500**, which can be located anywhere in a footwear sole or upper or both or other article described in this application. Construction and materials can be, as one embodiment example, simpler in shape but otherwise similar to those used in any commercial samples of Nike Air™.

Ref. No **501**: Inner compartment **161** or chamber **188** or bladder is located inside the enclosed space of the outer compartment/chamber/bladder **500**. Construction and materials of the inner compartment/chamber/bladder **501** can be, as one embodiment example, like those used in any commercial samples of gas bladders in Nike Air™.

Ref. No. **502**: Structural element that is optional anywhere within either outer compartment/chamber/bladder **500** or inner compartment/chamber/bladder **501**, of which a **501** embodiment is shown; any flexible, resilient material can be used, including structures molded into the shape of (and using the material of) the compartment/chamber/bladder **500** or **501**, as is very common in the art, such as many commercial samples of gas bladders used in Nike Air™, as well as foamed plastic or plastic composite or other materials, like Nike Shox™ or Impax™. In addition, other materials can be used directly within a **501**/**500** compartment or can connected to or through a **501**/**500** compartment, as in the cushioning components of the shoe sole heel of commercial samples of Adidas 1™, including electromechanical, electronic, and other components. Some devices may benefit from the use of rigid or semi-rigid materials for part or all of a media within a compartment.

Ref. No. **503**: Attachment of two compartment/chambers/bladders **500**/**501**, including particularly attachment of outer **500** to inner **501**; any practical number of attachments can be used.

Ref. No. **504**: Media contained within all or part of compartment/chamber/bladder **500** or **501**, particularly **501**, can be any useful material, such as gas (including, as an example, gas used in Nike Air™) or ambient air, liquid or fluid, gel, or foam (such as a plastic like PU or EVA or equivalent or rubber (natural or synthetic) or combination of two or more; encapsulation of foam is optional); material particles or coatings, such as dry coatings like polytetrafluoroethylene can also be used. An optional element in an outer compartment/chamber **500** (or an inner compartment/chamber **501** that itself contains an inner compartment/chamber, as in FIG. **87**).

Ref. No. **505**: Internal sipe or slit or channel or groove for flexibility, such as between inner and outer compartment/chamber **500**/**501** (or bladder) surfaces, as one embodiment example; such surfaces can be substantially parallel and directly contact in one useful embodiment example, but are not attached so that at least parts of the two surfaces can move relative to each other, such as to facilitate a sliding motion between surfaces; the surfaces can be in other useful forms that allow portions of the surfaces to be proximate to each other but not contacting in an unloaded condition or in a partially loaded condition or in a maximally loaded condition.

Ref. No. **506**: Media of internal sipe **505**; media **506** can be any useful material like those used in media **504**; media **506** can be located in part or all of **505** to decrease (or increase) sliding resistance between **500**/**501** or **505** surfaces, for example, to lubricate the surfaces with any suitable material; silicone or polytetrafluoroethylene can be used, for example; an optional element.

Ref. No. **507**: Metal particles.

Ref. No. **508**: Shock absorbing fluid containing **507**; a magnetorheological fluid.

Ref. No. **509**: Electromagnetic field-creating circuit.

Ref. No. **510**: A flexible insert or component including siped compartments **161** or chambers **188** or bladders used for example as outer and inner compartments/chambers/bladders **500**/**501** for footwear soles or orthotics or uppers; a useful embodiment being two or more compartment or chambers (or bladders) **161**/**188** (or mix) that are separated at least in part by an internal sipe **505**, including the example of at least one **501** (either **161**/**188** or bladder) inside at least one **500** (either **161**/**188** or bladder) and being separated by an internal sipe **505**.

Ref. No. **511**: A flexible insert or component including a single compartment **161** or chamber **188** or bladder with an associated internal sipe **505** component.

Ref. No. **512**: A wall of flexible insert or component **511** or **513** that is not formed by a compartment **161** or chamber **188** or bladder and that is separated from another wall by an internal sipe **505**.

Ref. No. **513**: Any flexible insert or component including an internal sipe **505**.

Ref. No. **514**: A flexible shank located generally in an instep area of a shoe sole and incorporated in a **510**/**511**/**513** device described herein previously.

FIGS. **1-82** (sheets **1-69**) and pages **1-61** of the associated textual specification above are verbatim from the applicant's PCT application No. PCT/US01/13096, published by WIPO as WO 01/80678 A2 on 1 Nov. 2001; for completeness of disclosure, WO 01/80678 A2 in its entirety is hereby incorporated by reference into this application, as is PCT/US01/23865, published by WIPO as WO 02/09547 A2 on Feb. 7, 2002.

The latter '547 WIPO publication, titled "Shoe Sole Orthotic Structures and Computer Controlled Compartments", is incorporated herein by reference to provide additional information on the applicant's prior orthotic inventions, which can usefully be combined with the orthotic inventions described and claimed in this application. However, the applicant's insertable midsole orthotic **145** in the '547 Publication is very similar to the applicant's removable midsole insert **145** as described in this application and can generally be understood to be the same in structure and materials, although with a principal difference. Typically, an orthotic **145** is designed specifically for an individual wearer, unlike almost all footwear, which is mass-produced using lasts based on average foot shapes for specific populations; the only exception is custom footwear, which is relatively rare and simply cobbled more directly to the individual shape of the wearer's feet. The principal difference is that typically orthotics **145** are designed to be prescribed, for example, by a qualified expert like a health care professional such as a doctor or podiatrist in order to treat a wearer's diagnosed footwear-related problem; generally, orthotics **145** are for prescriptive, therapeutic, corrective, or prosthetic uses.

The applicant's U.S. Pat. Nos. 4,989,349; 5,317,819; 5,544,429; 5,909,948; 6,115,941; 6,115,945; 6,163,982; 6,308,439; 6,314,662; 6,295,744; 6,360,453; 6,487,795; 6,584,706; 6,591,519; 6,609,312; 6,629,376; 6,662,470; 6,675,498; 6,675,499; 6,708,424; 6,729,046; 6,748,674; 6,763,616; and 6,810,606 are hereby incorporated by reference in their entirety into this application for completeness of disclosure.

In the following claims, the term "chamber" means a compartment **161** or a chamber **188** or a bladder and the term "sipe" means a sipe **505** or a slit or a channel or a groove as described in the textual specification above and associated figures of this application.

The foregoing shoe designs meet the objectives of this invention as stated above. However, it will clearly be understood by those skilled in the art that the foregoing description has been made in terms of the preferred embodiments and various changes and modifications may be made without departing from the scope of the present invention which is to be defined by the appended claims.

What is claimed is:

**1**. A footwear or orthotic device, comprising:

a footwear or orthotic sole; and

an insert including at least one outer bladder having an uppermost surface curved concavely relative to an intended wearer's foot location in the footwear or orthotic device, as viewed in a frontal plane cross-section when the footwear or orthotic sole is upright and in an unloaded condition; said outer bladder forming a component of the footwear or orthotic sole; and

at least one inner bladder inside the outer bladder, as viewed in a frontal plane cross-section,

said inner bladder including one or more resilient structural elements;

at least one said structural element extending from at least proximate to a part of an upper outer surface of said at least one inner bladder to at least proximate to at least a part of a lower outer surface of said at least one inner bladder, as viewed in a frontal plane cross-section when said footwear or orthotic sole is in an upright, unloaded condition, and

a gas located at least inside of said inner bladder between two inner surfaces of said inner bladder and outside of said one or more structural elements, when said insert is in an unloaded condition,

said inner bladder including one or more openings;

said outer bladder and said inner bladder being separated at least in part by an internal sipe,

wherein said internal sipe is formed by an inner surface of said outer compartment and an outer surface of said inner compartment; and the inner and outer surfaces forming the sipe oppose each other, are separate from each other and therefore can move relative to each other in a sliding motion; and at least a portion of each of said surfaces forming the sipe are proximate to each other in an unloaded condition.

**2**. The footwear or orthotic device according to claim **1**, wherein substantially the entire surface of each of said surface forming said internal sipe is in contact in the unloaded condition.

**3**. The footwear or orthotic device according to claim **1**, wherein the surfaces forming said sipe are substantially parallel to one another.

**4**. The footwear or orthotic device according to claim **1**, wherein said insert comprises fiber.

**5**. The footwear or orthotic device according to claim **1**, wherein said insert is located in an instep area of the footwear or orthotic sole between a heel area and a forefoot area.

**6**. The footwear or orthotic device according to claim **1**, wherein at least a portion of an outer surface of the insert is an outer surface of the footwear or orthotic sole.

**7**. The footwear or orthotic device according to claim **1**, wherein said footwear or orthotic sole has a thickness which is one selected from a group of: (1) greater in a heel area than in a forefoot area, and (2) greater in the forefoot area than in the heel area.

**8**. The footwear or orthotic device according to claim **1**, wherein the footwear or orthotic sole includes a lateral sidemost section located outside a straight vertical line extending through the footwear or orthotic sole at a lateral sidemost extent of the inner surface of the footwear or orthotic sole, as viewed in a frontal plane cross-section when the footwear or orthotic sole is upright and in the unloaded condition;

the footwear or orthotic sole having a medial sidemost section located outside a straight vertical line extending through the footwear or orthotic sole at a medial sidemost extent of the inner surface of the footwear or orthotic sole, as viewed in a frontal plane cross-section when the footwear or orthotic sole is upright and in the unloaded condition; and

said insert extends at least from a part of said lateral sidemost section to a part of said medial sidemost section, as viewed in a frontal plane cross-section when the footwear or orthotic sole is upright and in the unloaded condition.

**9**. The footwear or orthotic device according to claim **8**, wherein said insert extends into said lateral or medial sidemost section to a height above a lowest point of an inner surface of said footwear or orthotic sole, as viewed in said frontal plane cross-section when the footwear or orthotic sole is upright and in the unloaded condition.

**10**. The footwear or orthotic device according to claim **1**, wherein an inner surface of one of a medial or lateral side of the footwear or orthotic sole comprises a convexly rounded portion, as viewed in a frontal plane cross-section during an unloaded, upright condition of the footwear or orthotic sole, the convexly rounded portion of the inner surface existing with respect to a section of the footwear or orthotic sole directly adjacent to the convexly rounded portion of the inner surface of the footwear or orthotic sole; and

an outer surface of one of the medial or lateral sides of the footwear or orthotic sole comprises a concavely rounded portion, as viewed in a frontal plane cross-section during an unloaded, upright condition of the footwear or orthotic sole, the concavely rounded portion of the outer surface existing with respect to a section of the footwear or orthotic sole directly adjacent to the concavely rounded portion of the outer surface of the footwear or orthotic sole.

**11**. The footwear or orthotic device according to claim **10**, wherein the rounded portion of at least one of said lateral or medial sides is uniformly thick between said inner and outer surfaces, said uniform thickness extending from a ground-contacting portion to a sidemost extent of said outer surface, as viewed in said frontal plane cross-section during the unloaded, upright condition of the footwear or orthotic sole.

**12**. The footwear or orthotic device according to claim **1**, wherein said footwear or orthotic sole has a uniform radial thickness between a lateral extent of each side, when measured in a frontal plane cross-section in an upright, unloaded condition, exclusive of insole or sockliner and upper.

**13**. The footwear or orthotic device according to claim **1**, wherein said insert is removable from or insertable into said footwear or orthotic sole.

**14**. The footwear or orthotic device according to claim **1**, wherein said insert is controlled by a microcomputer in the footwear or orthotic sole.

**15**. The footwear or orthotic device according to claim **1**, comprising at least two said structural elements.

**16**. The footwear or orthotic device according to claim **15**, wherein at least two of said structural elements are interconnected.

**17**. The footwear or orthotic device according to claim **16**, wherein said interconnected structural elements of said insert form an integral inner bladder of foamed plastic.

**18**. The footwear or orthotic device according to claim **17**, wherein at least a portion of one said structural element is rounded.

**19**. The footwear or orthotic device according to claim **18**, comprising at least four said structural elements inside the inner bladder, each having at least a portion that is shaped like a support column.

**20**. The footwear or orthotic device according to claim **19**, comprising at least eleven said structural elements inside the inner bladder, each having at least a portion that is shaped like a support column.

**21**. The footwear or orthotic device according to claim **1**, comprising at least three said structural elements.

**22**. The footwear or orthotic device according to claim **1**, further comprising at least one attachment of said inner bladder to said outer bladder.

**23**. A footwear or orthotic device comprising:

a footwear or orthotic sole; and

an insert including at least one outer bladder having an uppermost surface curved concavely relative to an intended wearer's foot location in the footwear or orthotic device, as viewed in a frontal plane cross-section when the footwear or orthotic sole is upright and in an unloaded condition, said outer bladder forming a component of the footwear or orthotic sole; and

at least one inner bladder inside the outer bladder,

said inner bladder being including at least two or more resilient structural elements composed of at least a foamed plastic;

at least two said structural elements extending from at least proximate to a part of an upper outer surface of said at least one inner bladder to at least proximate to at least a part of a lower outer surface of said at least one inner bladder, when said footwear or orthotic sole is in an upright, unloaded condition, and

a gas located at least inside of said inner bladder between two inner surfaces of said inner bladder and at least outside of said two or more structural elements, when said insert is in an unloaded condition,

said outer bladder and said inner bladder being separated at least in part by an internal sipe,

wherein said internal sipe is formed by an inner surface of said outer compartment and an outer surface of said inner compartment; and the inner and outer surfaces forming the sipe oppose each other, are separate from each other and therefore can move relative to each other in a sliding motion; and at least a portion of each of said movable surfaces forming the sipe are proximate to each other in an unloaded condition.

**24**. The footwear or orthotic device according to claim **23**, wherein said inner bladder includes one or more openings.

**25**. The footwear or orthotic device according to claim **23**, wherein said inner bladder includes at least one outer surface portion formed by at least said foamed plastic of at least one said structural element.

**26**. The footwear or orthotic device according to claim **25**, wherein at least two of said structural elements are interconnected.

**27**. The footwear or orthotic device according to claim **26**, wherein said interconnected structural elements of said insert form an integral inner bladder of foamed plastic.

**28**. The footwear or orthotic device according to claim **27**, wherein at least a portion of one said structural element is rounded.

**29**. The footwear or orthotic device according to claim **28**, comprising at least four said structural elements inside the inner bladder, each having at least a portion that is shaped like a support column.

**30**. The footwear or orthotic device according to claim **29**, comprising at least eleven said structural elements inside the inner bladder, each having at least a portion that is shaped like a support column.

**31**. The footwear or orthotic device according to claim **23**, wherein substantially the entire surface of each of said surface forming said internal sipe is in contact in the unloaded condition.

**32**. The footwear or orthotic device according to claim **23**, wherein the surfaces forming said sipe are substantially parallel to one another.

**33**. The footwear or orthotic device according to claim **23**, wherein said insert comprises fiber.

**34**. The footwear or orthotic device according to claim **23**, wherein said insert is located in an instep area of the footwear or orthotic sole between a heel area and a forefoot area.

**35**. The footwear or orthotic device according to claim **23**, wherein at least a portion of an outer surface of the insert is an outer surface of the footwear or orthotic sole.

**36**. The footwear or orthotic device according to claim **23**, wherein said footwear or orthotic sole has a thickness which is one selected from a group of: (1) greater in a heel area than in a forefoot area, and (2) greater in the forefoot area than in the heel area.

**37**. The footwear or orthotic device according to claim **23**, wherein the footwear or orthotic sole includes a lateral sidemost section located outside a straight vertical line extending through the footwear or orthotic sole at a lateral sidemost extent of the inner surface of the footwear or orthotic sole, as viewed in a frontal plane cross-section when the footwear or orthotic sole is upright and in the unloaded condition;

the footwear or orthotic sole having a medial sidemost section located outside a straight vertical line extending through the footwear or orthotic sole at a medial sidemost extent of the inner surface of the footwear or orthotic sole, as viewed in a frontal plane cross-section when the footwear or orthotic sole is upright and in the unloaded condition; and said insert extends at least from a part of said lateral sidemost section to a part of said medial sidemost section, as viewed in a frontal plane cross-section when the footwear or orthotic sole is upright and in the unloaded condition.

**38**. The footwear or orthotic device according to claim **37**, wherein said insert extends into said lateral or medial sidemost section to a height above a lowest point of an inner surface of said footwear or orthotic sole, as viewed in said frontal plane cross-section when the footwear or orthotic sole is upright and in the unloaded condition.

**39**. The footwear or orthotic device according to claim **23**, wherein an inner surface of one of a medial or lateral side of the footwear or orthotic sole comprises a convexly rounded portion, as viewed in a frontal plane cross-section during an unloaded, upright condition of the footwear or orthotic sole, the convexly rounded portion of the inner surface existing with respect to a section of the footwear or orthotic sole directly adjacent to the convexly rounded portion of the inner surface of the footwear or orthotic sole; and

an outer surface of one of the medial or lateral sides of the footwear or orthotic sole comprises a concavely rounded portion, as viewed in a frontal plane cross-section during an unloaded, upright condition of the footwear or orthotic sole, the concavely rounded portion of the outer surface existing with respect to a section of the footwear or orthotic sole directly adjacent to the concavely rounded portion of the outer surface of the footwear or orthotic sole.

**40**. The footwear or orthotic device according to claim **39**, wherein the rounded portion of at least one of said lateral or medial sides is uniformly thick between said inner and outer surfaces, said uniform thickness extending from a ground-contacting portion to a sidemost extent of said outer surface, as viewed in said frontal plane cross-section during the unloaded, upright condition of the footwear or orthotic sole.

**41**. The footwear or orthotic device according to claim **23**, wherein said footwear or orthotic sole has a uniform radial thickness between a lateral extent of each side, when measured in a frontal plane cross-section in an upright, unloaded condition, exclusive of insole or sockliner and upper.

**42**. The footwear or orthotic device according to claim **23**, wherein said insert is removable from or insertable into said footwear or orthotic sole.

**43**. The footwear or orthotic device according to claim **23**, wherein said insert is controlled by a microcomputer in the footwear or orthotic sole.

**44**. The footwear or orthotic device according to claim **1**, wherein said inner bladder includes two or more openings.

**45**. The footwear or orthotic device according to claim **1**, wherein said inner bladder includes at least one outer surface portion formed by at least one said structural element.

**46**. The footwear or orthotic device according to claim **23**, comprising at least three said structural elements.

**47**. The footwear or orthotic device according to claim **23**, wherein said inner bladder includes two or more openings.

**48**. The footwear or orthotic device according to claim **23**, further comprising at least one attachment of said inner bladder to said outer bladder.

**49**. A footwear or orthotic device, comprising:

a footwear or orthotic sole; and

an insert including at least one outer bladder having an uppermost surface curved concavely relative to an intended wearer's foot location in the footwear or orthotic device, as viewed in a frontal plane cross-section when the footwear or orthotic sole is upright and in an unloaded condition; said outer bladder forming a component of the footwear or orthotic sole; and

at least one inner bladder inside the outer bladder, as viewed in a frontal plane cross-section,

said inner bladder including one or more resilient structural elements;

at least one said structural element extending from at least proximate to a part of an upper outer surface of said at least one inner bladder to at least proximate to at least a part of a lower outer surface of said at least one inner bladder, as viewed in a frontal plane cross-section when said footwear or orthotic sole is in an upright, unloaded condition, and

a gas located at least inside of said inner bladder between two inner surfaces of said inner bladder and outside of said one or more structural elements, when said insert is in an unloaded condition,

said inner bladder including one or more openings;

said outer bladder including one or more openings;

said outer bladder and said inner bladder being separated at least in part by an internal sipe,

wherein said internal sipe is formed by an inner surface of said outer compartment and an outer surface of said inner compartment; and the inner and outer surfaces forming the sipe oppose each other, are separate from each other and therefore can move relative to each other in a sliding motion; and at least a portion of each of said surfaces forming the sipe are proximate to each other in an unloaded condition.

**50**. The footwear or orthotic device as claimed in claim **49**, further comprising at least one attachment of said inner bladder to said outer bladder.

**51**. The footwear or orthotic device according to claim **49**, wherein at least two of said structural elements are interconnected.

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UNITED STATES PATENT AND TRADEMARK OFFICE

# CERTIFICATE OF CORRECTION

PATENT NO. : 8,141,276 B2
APPLICATION NO. : 11/282665
DATED : March 27, 2012
INVENTOR(S) : Frampton E. Ellis

Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Claim 23, col. 79, line 51 “said inner bladder being including” should read --said inner bladder including--.

Signed and Sealed this
Fifth Day of June, 2012

David J. Kappos

David J. Kappos
*Director of the United States Patent and Trademark Office*