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(54) **ILLUMINATED SEATBELT BUCKLE**

(57) A buckle for a seatbelt assembly with a belt and a locking tongue. The buckle comprises a buckle casing that defines an insertion aperture for accommodating the tongue, and an illumination device (40) inside the casing, and comprising: at least one light source (62) inside the casing and electrically connected to an internal electrical circuit (60) to receive electrical power for emitting light, and a light guide (70) arranged inside the casing, and adapted for guiding light emitted by the light source towards an indicator surface defined at an outside of the casing at or near the insertion aperture. The illumination device (40) comprises a flexible circuit board (42) accommodated inside the buckle casing, and which includes a flexible carrier substrate onto which the electrical circuit (60) and the at least one light source (62) are arranged.

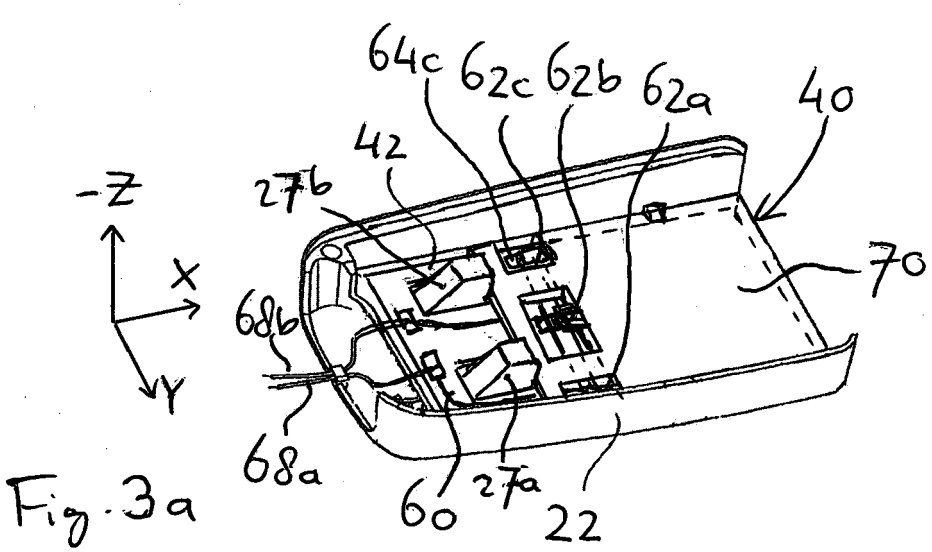

Fig. 3a

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Description

TECHNICAL FIELD

[0001] The invention relates to a buckle for a seatbelt assembly, and to a seatbelt assembly for restraining an occupant of a manned vehicle, cabin, or seat, and comprising such a buckle.

BACKGROUND ART

[0002] Seatbelt arrangements with a buckle that includes internal lighting for marking the insertion aperture for the plug-in tongue of the belt are known. The internal lighting facilitates in localizing the buckle in low ambient lighting conditions. A belt buckle casing is typically irreversibly closed by use of adhesive or welding methods, to prevent subsequent opening and tampering with the buckle mechanism. The permanent sealing of the casing makes replacement of the internal lighting device difficult, which sets high requirements on the lighting device in regard to mechanical robustness and operational life time.

[0003] Patent document US 2014/0268844 A1 describes a belt buckle assembly, which includes a buckle casing and a lighting device inside the buckle casing for marking the insertion aperture for a plug-in tongue. Specific receiving pockets and ducts need to be provided on an inside surface of the buckle casing, to accommodate the light source and cables. This makes manufacturing of the casing and installation of the lighting device inside the casing a cumbersome process.

[0004] It would be desirable to provide a belt buckle arrangement with a robust internal illumination device that is easy to position and fix inside the casing during installation.

SUMMARY OF INVENTION

[0005] Therefore, according to a first aspect of the invention, there is provided a buckle for a seatbelt assembly with a belt and a locking tongue. The buckle comprises a buckle casing, which defines an insertion aperture for accommodating the tongue. The buckle further comprises an illumination device arranged inside the casing. The illumination device comprises an electrical circuit, at least one light source that is electrically connected to the electrical circuit to receive electrical power for emitting visible light, and a light guide that is adapted for guiding light emitted by the light source towards an indicator surface defined at an outer side of the casing at or near the insertion aperture. The illumination device further comprises a flexible circuit board, which is arranged inside the casing, and which includes a flexible carrier substrate onto which the electrical circuit and the at least one light source are arranged.

[0006] The term "circuit board" refers herein to an electrically insulating substrate that comprises electrically conductive pathways forming one or more electrical circuits, which are used for mounting electric/electronic components and/or for connecting other circuits or components. The insulating substrate must undergo a certain machining process and surface treating process to form the circuit pattern. The conductive pathways are etched or printed onto the substrate, to connect different electrical and/or electronic components that are arranged on the circuit board, such as transistors, resistors, and integrated circuits. The circuit pattern can be formed on one side surface or double side surfaces of the layers in order to provide electrical interconnection among the electronic components. Here, the terms "printed circuit board" (PCB), "printed wiring board" (PWB) and "etched wiring board" (EWB) are considered synonyms for a circuit board. Dependent on the number and locations of the circuit patterns, circuit boards can be classified as single-sided, double-sided, or multi-layer arrangements.

[0007] The terms "flexible circuit board" or "flexible printed circuit board" (FPCB) represent a species of PCBs that have a flexible electrically insulating substrate carrying electrically conductive paths that are also at least partially flexible. This flexible substrate is typically thin and bendable, and the electrical circuit arranged on the flexible substrate is sufficiently bendable to allow the FPCB to be folded into a surface shape that extends (e.g. is folded or curved) in three-dimensions. FPCBs can similarly be classified into single-sided, double-sided, and multi-layered arrangements. An FPCB should be contrasted to a "rigid printed circuit board", which has a rigid substrate comprising conductive paths and terminals for connection to other devices, with limited bending capability to resist deformation (both in-plane and out-of-plane).

[0008] The carrier substrate of the flexible circuit board in the proposed buckle may for example be made of a mechanically flexible and electrically insulating foil, which consists essentially of a flexible polymer, selected from the group of polyimide (PI), polyamide (PA), polyethylene (PE), polyvinyl chloride (PVC), polycarbonate (PC), polyethylene terephthalate (PET), polypropylene (PP), polytetrafluoroethylene (PTFE), or their derivatives.

[0009] A thickness ΔZs of the carrier substrate of the flexible circuit board in the proposed buckle may for example be in a range of 10 micrometers to 500 micrometers, inclusive. Preferably, the thickness ΔZs of the carrier substrate is in a range of 50 micrometers to 100 micrometers, inclusive.

[0010] The electrical circuit may for example comprise printed electrically conducting wiring made essentially of copper, silver, or carbon. A thickness ΔZe of the electrical circuit may be in a range of 2 micrometers to 75 micrometers, inclusive.

[0011] The proposed use of a flexible circuit board inside the buckle enables a very compact and thin design of the illumination device, and may allow easy yet accurate positioning of the illumination device inside the buckle casing (where space is typically very limited).

[0012] According to an embodiment, the light source comprises one or more light emitting diode (LED) units, which are provided on the flexible carrier substrate and are in electrically coupled to the electrical circuit. The small size and considerable operational lifetime of LED packages contributes to the desired thin configuration and longevity of the illumination device. The LED units may be of the side emitting type, and mounted onto the carrier substrate with light emission lobes directed substantially parallel with the surface of the carrier substrate. The use of side emitting LED units further contributes to achieving a thin configuration of the illumination device.

[0013] According to a further embodiment, the flexible circuit board and the light guide each comprise surface portions that are arranged mutually parallel, and which extend inside the buckle casing towards the indicator surface. According to yet a further embodiment, the surface portions include a first surface region of the carrier substrate where the LED units reside, and a mounting portion of the light guide including one or more voids for accommodating the LED units. Here, the mounting portion may overlap the first surface region such that the LED units are accommodated inside the voids. The light guide may thus confer protection to the LED units from mechanical impact originating from inside the buckle casing (e.g. by the locking tongue, the release button, or the latch mechanism). Preferably, the carrier substrate with the LED units is located in an abutting arrangement between the light guide and the inner surface of the casing, with a first substrate surface carrying the LED units facing the light guide, and a second (opposite) substrate surface facing the inner surface of the buckle casing.

[0014] According to an embodiment, the light guide has a guiding portion of optically transparent material, which extends through the buckle casing from the one or more LED units on the flexible circuit board towards and up to the indicator surface in a longitudinal direction X at the outside of the buckle casing. A thickness ΔZg of the guiding portion 78 of the light guide may for example be in a range of 500 micrometers to 1000 micrometers, inclusive. The selected height for the light guide thickness allows the LED units to be physically confined and protected within the vertical boundary of the light guide. Preferably, a thickness ΔZg of the guiding portion 78 of the light guide is approximately 750 micrometers.

[0015] The LED units may be of the side emitting type, and mounted onto the carrier substrate with light emission lobes directed substantially parallel with the surface of the carrier substrate and toward the light guide. The indicated thickness ΔZg of the guiding portion 78 in a range of 500 micrometers to 1000 micrometers may be similar to or only slightly larger than a typical package height of the side emitting LED units, thereby allowing a large portion of the side emitted LED light to be coupled into and conveyed through the light guide.

[0016] According to an embodiment, the buckle comprises at least one cover layer of optically shielding material. The cover layer may be arranged along the light guide and the LED units on the flexible circuit board, to increase the light emission yield on an edge of the light guide arranged along the indicator surface. The cover layer(s) may be formed by printed ink or cover foil(s). Each cover layer preferably has a thickness ΔZc in a range of 1 micrometer to 40 micrometers, and more preferably in a range of 3 micrometers to 20 micrometers.

[0017] According to an embodiment, the casing defines an outer wall with an inner surface that extends up to the indicator surface, and the flexible carrier substrate extends inside the casing in an abutting arrangement with the inner surface. The known shape of the inner surface of one of the outer walls of the buckle casing can advantageously be used for reliably fixing the carrier substrate, while avoiding obstruction of the release button and/or the latch mechanism.

[0018] According to an embodiment, the buckle includes a release button at the outer side of the housing. The insertion aperture for the tongue may then also be located at this outer side, and the indicator surface and the insertion aperture may be located along opposite edges of the release button.

[0019] According to an alternative embodiment, the insertion aperture for the tongue is located at this outer side, but the indicator surface and the insertion aperture are located along the same edge of the release button.

[0020] According to embodiments, the flexible carrier substrate is provided with an adhesive layer for mechanically fixing the illumination device directly to and along the inner surface of the buckle casing. A thickness ΔZa of the adhesive layer may for example be in a range of 5 micrometers to 150 micrometers, to preserve the flexibility of the carrier substrate.

[0021] In embodiments, the LED units are arranged in a linear arrangement along the flexible circuit board, the linear arrangement being substantially parallel with one or more outer peripheral edges of the indicator surface in the buckle casing.

[0022] In embodiments, the flexible circuit board comprises electrical terminals along an opposite edge of the carrier substrate, and the electrical terminals are adapted for supplying electrical power to the flexible circuit board and the LED units, for example via electrical wires or a flat conductor cable.

[0023] According to a second aspect of the invention, and in accordance with the advantages and effects described herein above, there is provided a seatbelt assembly for restraining an occupant of a manned vehicle, cabin, or seat. The seatbelt assembly includes a belt with a tongue, and a buckle with an illumination device in accordance with the first aspect.

BRIEF DESCRIPTION OF DRAWINGS

[0024] Embodiments will now be described, by way of example only, with reference to the accompanying schematic drawings in which corresponding reference symbols indicate corresponding parts. In the drawings, like

numerals designate like elements. Multiple instances of an element may each include separate letters appended to the element number. For example, two instances of a particular element "20" may be labeled as "20a" and "20b". The element label may be used without an appended letter (e.g. "20") to refer to an unspecific instance of the element or to generally refer to every instance of the element, while the element label will include an appended letter (e.g. "20a") to refer to a specific instance of the element.

Figure 1 schematically shows a perspective view of a seatbelt assembly according to an embodiment;
Figure 2 presents a perspective view of a buckle from the seatbelt assembly shown in figure 1;
Figures 3a and 3b show perspective views of parts of the buckle in figure 2;
Figure 4 presents a more detailed perspective view of the illumination device shown in figures 3a-3b;
Figure 5 presents a perspective view of part of a buckle according to another embodiment;
Figure 6 presents a perspective view of a buckle according to an alternative embodiment, and
Figures 7a and 7b present perspective views of parts of the buckle according to the embodiment in figure 6.

[0025] The figures are meant for illustrative purposes only, and do not serve as restriction of the scope or the protection as laid down by the claims.

DESCRIPTION OF EMBODIMENTS

[0026] The following is a description of certain embodiments of the invention, given by way of example only and with reference to the figures. In the next figures, Cartesian coordinates will be used to describe spatial relations for exemplary embodiments of the seatbelt assembly.

[0027] Reference symbol X is used to indicate a longitudinal direction. Prepositions "front" and "rear" pertain to this longitudinal direction X. Reference symbol Y is used to indicate a transversal direction that is perpendicular to X. This transversal direction Y relates to the terms "left", "right", and "lateral". The longitudinal direction X and transversal direction Y span a plane that preferably is substantially parallel to the horizontal during operation of the buckle. Reference symbol Z is used to indicate a vertical direction that is perpendicular to X and Y. Prepositions "above" and "below" pertain to the vertical direction Z.

[0028] It should be understood that the directional definitions and preferred orientations presented herein merely serve to elucidate geometrical relations for specific embodiments. The concepts of the invention discussed herein are not limited to these directional definitions and preferred orientations. Similarly, directional terms in the specification and claims, such as "top," "bottom," "left," "right," "up," "down," "upper," "lower," "proximal," "distal" and the like, are used herein solely to indicate relative directions and are not otherwise intended to limit the scope of the invention or claims.

[0029] The term "surface" is used herein to generally refer to a two-dimensional parametric surface region, which may have either an entirely or piece-wise flat shape (e.g. a plane or polygonal surface), a curved shape (e.g. cylindrical, spherical, parabolic surface, etc.), a recessed shape (e.g. stepped or undulated surface), or a more complex shape. The term "plane" is used herein to refer to a flat surface defined by three non-coinciding points.

[0030] The term "substantially" is defined to be essentially conforming to the particular dimension, shape or other word that substantially modifies, such that the component need not be exact. For example, "an object that is substantially planar" means that the object has a flat planar shape, but can have minor deviations like protrusions, recesses, or curves in an out of plane direction that make the object deviate from an ideal mathematical plane.

[0031] Figure 1 schematically shows a perspective view of an embodiment of a seatbelt assembly 10 for use in or on a manned vehicle (e.g. an automobile, boat, plane, or train), cabin (e.g. pod, crane cab), seat, etc. The seatbelt assembly 10 comprises a belt 12 (e.g. seatbelt webbing or strap) and a buckle 16. The seatbelt assembly 10 is configured to allow the belt 12 to extend and retract with respect to a seat in a vehicle, or with respect to a similar region where an occupant needs to be motionally restrained to protect against considerable acceleration effects.

[0032] The belt 12 is formed by a flat elongate strap composed of a web material (e.g. nylon fabric). This strap of web material has a high mechanical strength in a longitudinal direction along the belt 12, and is pliable in a transverse direction perpendicular to the belt surface. The belt 12 is at one end anchored e.g. to a lateral or lower inner side of the vehicle. The belt 12 is at an opposite end retractably coupled to the lateral inner side of the vehicle, to allow a length of the belt 12 to vary under controlled circumstances, e.g. by spring-biased winding and unwinding.

[0033] The belt 12 is provided with a locking tongue 14. The buckle 16 has an insertion aperture for accommodating the locking tongue 14, and comprises an internal latch mechanism for releasably locking the tongue 14 when inserted through the insertion aperture. The tongue 14 is mechanically connected to the belt 12 in a manner that allows only sliding of the tongue 14 in the longitudinal direction along the belt 12 when in an unbuckled position.

[0034] The buckle 16 is at the rear side fixed to the vehicle frame via conventional means, e.g. by an anchor strap 18 that is fixed to the seat or to the lower inner side of the vehicle.

[0035] Figure 2 shows a perspective view of a buckle 16 in a seatbelt assembly 10 similar to figure 1. The buckle 16 includes a rigid protective casing 20. In this exam-

ple, the casing 20 substantially resembles a box with rounded edges and corners, and which is elongated in a longitudinal buckle direction X, and oblate in a vertical direction Z. The casing 20 defines a front side 26 and a rear side 36, which face in opposite longitudinal directions $\pm$X. The casing 20 is formed by a first casing portion 22 (upper portion) and a second casing portion 24 (lower portion), which are interconnected along corresponding edge lines to form the casing 20. Interconnections may be achieved e.g. via conventional gluing or welding methods.

[0036] The front side 26 of the casing 20 defines a front opening. A release button 28 is provided at this front opening, which is slidably arranged inside the casing 20. This release button 28 may for example be formed as a pushbutton, which can be manually pressed inwards with respect to the casing 20 along the negative longitudinal direction -X. The buckle 16 is at the rear side 36 of the casing 20 fixed to the anchor strap 18 (not shown in figure 2).

[0037] Part of an inner contour of the casing 20 and a nearby outer contour of the release button 28 jointly delineate the insertion aperture 30 for the locking tongue 14. The insertion aperture 30 may for example be formed as a substantially rectangular slot. The latch mechanism, provided inside the casing 20 and adapted for releasably locking the tongue 14 inside and with respect to the buckle 16, may include a guide track (here including guiding structures 31 e.g. longitudinal ribs), an ejector, and a latch member for engaging the tongue 14 (not shown). The release button 28 serves to actuate the latch mechanism upon depression, to allow an inserted and locked tongue 14 to be released.

[0038] An indicator surface 34 is defined at the front side 26 of the buckle casing 20. This indicator surface 34 is located along an upper edge of the release button 28, which is opposite to the lower edge of the release button where the insertion aperture 30 resides.

[0039] The buckle 16 is provided with an illumination device, which is schematically indicated by reference numeral 40. The illumination device 40 is configured to emit light from inside the buckle casing 20 towards the indicator surface 34. The emitted light serves to provide a visual indicator to the vehicle occupant e.g. during low ambient lighting conditions. The light emitted by the illumination device 40 may help the vehicle occupant to locate the release button 28, to facilitate buckling and unbuckling.

[0040] Figures 3a, 3b, and 4 present perspective views of portions of the buckle 16 with the illumination device 40 according to an embodiment. Figure 3a illustrates a perspective view of the upper casing portion 22, wherein the illumination device 40 is arranged along an inner surface 23 of the upper casing portion 22. Figure 3b shows an exploded view of the illumination device 40, and additional functional layers 90, 94, 98. Figure 4 shows the illumination device 40 in more detail.

[0041] The illumination device 40 comprises a flexible circuit board 42, a light guide 70, two cover layers 90, 94, and an adhesive layer 98.

[0042] The flexible circuit board 42 includes a carrier substrate 44, a circuit pattern 60 of electrically conducting tracks and patches, three LED units 62a, 62b, 62c, electrical terminals 66a, 66b, and various electrical components 64a, 64b, 64c.

[0043] The carrier substrate 44 is made of a mechanically flexible and electrically insulating foil. This foil may consist essentially a flexible polymer, for example a thin foil of PI, PA, PE, PVC, PC, PET, PP, PTFE, or their derivatives. The carrier substrate 44 forms a flat structure that extends in the longitudinal and transversal directions X, Y, and has a small thickness ΔZs in the third direction Z, at least when in an unfolded state. The carrier substrate 44 defines a first surface 46 and a second surface 48, corresponding to opposite sides of the carrier substrate 44 that face away in the negative and positive third directions -Z, +Z respectively.

[0044] The first surface 46 is composed of a first surface region 52 and a second surface region 53. The first region 52 is formed along a first edge 50 of the carrier substrate 44. The first edge 50 extends in the transversal direction Y and delimits the carrier substrate 44 in the longitudinal direction X. The second region 53 is formed along a second edge 51 of the carrier substrate 44, opposite to the first edge 50. The second edge 51 also extends in the transversal direction Y and delineates the carrier substrate 44 in the longitudinal direction X. The first and second regions 52, 53 connect in a central portion of the carrier substrate 44.

[0045] The circuit pattern 60 is provided on the first surface 46. In this example, the circuit pattern 60 is made from copper tracks, and extends over both regions 52, 53 of the first surface 46. In this example, the flexible circuit board 42 thus obtained is of the single-sided type. The flexible circuit board 42 may be obtained by directly printing the copper conductor tracks onto the flexible carrier substrate 44. The printing process may be carried out by printing of a copper-paste, which techniques are well-known in the field of electronics.

[0046] The electrical terminals 66 for connecting electrical conduits 68a, 68b are provided in the second region 53 of the first substrate surface 46, e.g. to provide power to the illumination device 40. Additional electrical terminals and electrical conduits may be provided to establish signal paths between the illumination device and an external electronic device (e.g. an external indicator, control and/or or processing device; not shown). In this example, the electrical conduits are formed by individual wires 68a, 68b. Other electrical conduit types may be used.

[0047] The three LED units 62a-62c are provided in a laterally spaced linear arrangement, in the first region 52 of the flexible substrate 44. Each LED unit 62 includes a LED die prepared in a package. The LED units 62 are mounted on the carrier substrate 44 as surface mounted devices, and are electrically connected to the circuit pattern 60. The LED units 62 are configured to emit light

with a wavelength distribution in the optical range. Each of the LED units 62 may be provided with at least one optical element (e.g. lens, mirror, diffuser, etc.) for adjusting the light emission characteristics of the primary LED emissions, which are typically narrow-banded. In addition, the optical elements may comprise fluorescent and/or phosphorescent material, for altering the wavelength characteristics of the emitted light, e.g. by absorbing part of the primary light emitted by the LED die and re-emitting secondary light of a different wavelength range.

[0048] In this example, the LED units 62 are of the side emitting type, and are mounted onto the carrier substrate 44 with corresponding emission lobes directed substantially parallel with the first surface 46 of the carrier substrate 44, predominantly along the positive longitudinal direction +X. The use of side emitting LED units allows construction of the illumination device 40 (possibly in combination with optical cover layers) with a relatively small total thickness ΔZt in the third direction Z. The LED units 62 are disposed along the first edge 50 of the carrier substrate 44, and are configured to emit light toward the light guide 70. The LED units 62 may be mounted on the carrier substrate 44 at selected lead portions of the circuit pattern 60 by means of soldering paste or an electrically conductive adhesive.

[0049] Other components for driving the LED units 62 are also provided on the carrier substrate 44. These components include LED drivers 64 and resistors. The LED drivers 64 are configured for controlling and possibly dynamically adjusting the emission characteristics of the LED units 62.

[0050] The light guide 70 is provided on and along the first edge 50 of the flexible substrate 44. The light guide 70 is adapted for guiding light from the LED units 62 towards the indicator slit 34 along the front side 26 of the buckle casing 20. The light guide 70 is thereto formed of an optically transparent plastic material (e.g. transparent polycarbonate PC). The light guide 70 forms a thin structure, which is on opposite sides along longitudinal directions $\pm$X bounded by a first guide edge 76 and a second guide edge 77. The light guide 70 defines a guiding portion 78 and a mounting portion 80. The guiding portion 78 is bounded by the first guide edge 76 at one end, and extends into the mounting portion 80 at an opposite end. The mounting portion 80 is bounded by the second guide edge 77 and the guiding portion 78.

[0051] The mounting portion 80 of the light guide 70 is adapted to be positioned on and along the first surface region 52 of the flexible circuit board 42, in a flat and overlapping arrangement. In this example, the carrier substrate 44 with the LED units 62 is arranged in the third direction Z between the light guide 70 and the inner surface 23 of the casing. Here, the first surface region 52 of the first substrate surface 46, which carries the LED units 62 and driver components 64, faces the light guide 70. The second substrate surface 48 faces the inner surface 23 of the first casing portion 22. The mounting portion 80 is provided with a central aperture 82 and lateral cut-outs 83a, 83b, which in this example extend entirely through the light guide 70 in the third direction Z. Each of the aperture 82 and the lateral cut-outs 83 is sufficiently large to accommodate a corresponding LED unit 62 and associated driver unit 64. The material of the mounting portion 80 that surrounds the aperture 82 and the lateral cut-outs 83 is sufficiently thick in the third direction Z to delimit the LED units 62 from the negative third direction -Z. This helps to shield the LED units 62 and driver units 64 from mechanical forces acting on the illumination device 40 from inside the casing 20. This arrangement provides good mechanical protection for the components on the flexible circuit board 42.

[0052] Each of the central aperture 82 and lateral cut-outs 83 has a corresponding forward edge 84a, 84b, 84c with an optical surface adapted for coupling light from the corresponding LED unit 62 into the light guide 70. Unwanted light efficiency losses and illumination of other internal regions of the buckle 16 may be avoided by a first cover layer 90, which is positioned on and along the first surface 46 of the flexible circuit board 42 and the first surface 72 of the light guide 70, thereby entirely covering the guiding portion 78 and at least the LED units 62. The first cover layer 90 may be attached to the illumination device 40 after the illumination device 40 has been fixed inside the casing 20, on an inner surface of the first casing portion 22.

[0053] Similarly, the second cover layer 94 is positioned on and along the second surface 74 of the light guide 70. The cover layers 90, 94 form light shielding structures for preventing light from the LED units 62 from exiting the light guide 70 through the first and second surfaces 72, 74 respectively. The intensity of light exiting through edge 76 of the light guide 70, which is located along the indicator surface 34 of the buckle 16, may thus be increased. In this example, the cover layers 90, 94 are each formed by a thin ink layer that is opaque with respect to the wavelength(s) emitted by the LED units 62. This ink layer may for example be printed directly onto the guiding portion 78 of the light guide 70.

[0054] The adhesive layer 98 is disposed on the second surface 48 of the carrier substrate 44. By means of this adhesive layer 98, the illumination device 40 may be adhered and fixed directly to the inner surface 23 of the buckle casing 20, while ensuring that flexibility of the carrier substrate 44 is preserved. Other adhesive materials may be used.

[0055] The flexible carrier substrate 44 has two through holes 56a, 56b, which are formed to accommodate inwards protrusions 27a, 27b provided at/on the inner surface 23 of the buckle casing 20. The through holes 56 allow the protrusions 27 to extend through the carrier substrate 44 without affecting the functionality of the flexible circuit board 42. The shape and location of each through hole 56 in the flexible carrier substrate 44 preferably match with an outer peripheral shape of the corresponding protrusion 27 viewed along the X- and Y-

directions, to transversally fix the flexible carrier substrate 44 with respect to the casing 20. The casing may be provided with further protrusions, and the flexible carrier substrate may be provided with further though holes or cut-outs along edges (preferably with matching shapes). The through holes 56 (and other cut-outs) may be formed in the carrier substrate 44 by punching, laser cutting, or similar known techniques.

[0056] To ensure a suitable flexibility of the illumination device 40, layer thickness properties are specified as follows. The carrier substrate 44 has a thickness ΔZs in a range of 12 micrometers to 500 micrometers, more preferably in a range of 50 micrometers to 100 micrometers. The circuit 60 has a thickness ΔZe in a range of 2 micrometers to 75 micrometers. The guiding portion 78 has a thickness ΔZg in the third direction Z in a range of 500 micrometers to 1000 micrometers, for example of approximately 750 micrometers. The adhesive layer 98 has a thickness ΔZa in a range of 5 micrometers to 150 micrometers. The cover layers 90, 94 each have a thickness ΔZc in a range of 1 micrometer to 40 micrometers, preferably in a range of 3 micrometers to 20 micrometers. Hence, the resulting assembly of illumination device 40, possibly with additional optical cover layers 90, 94, may be manufactured with a total thickness of less than 2 millimeters, and more preferably with a total thickness ΔZt of approximately 1 millimeter or less.

[0057] Figure 5 presents a perspective view of a part of a buckle according to another embodiment. Features in the buckle that have already been described above with reference to the first embodiment (and in particular figures 2-4) may also be present in the buckle shown in figure 5, and will not all be discussed here again. For the discussion with reference to figure 5, like features are designated with similar reference numerals preceded by 100, to distinguish the embodiments.

[0058] Here, the flexible circuit board 142 has been formed into a rectangular U-shape, with lateral board flanges 143a, 143b that have been folded towards the negative third direction -Z, to follow the contours of the inner surface 123 of the upper portion 122 of the buckle casing 120. As a result, the outermost LED units 162a, 162c are now located along lateral inner surfaces of the buckle casing 120. The light guide 170 has been folded into a similar rectangular U-shape, with a lateral guide flanges 179a, 179b that protrude along the negative third direction -Z. As a result, the first guide edge 176 on the front side of the buckle defines a rectangular U-shape, which allows relatively uniform illumination of a U-shaped indicator surface on this front side of the buckle.

[0059] Figures 6 and 7a-7b present perspective views of a buckle 216 and internal components according to an alternative embodiment. Features in the buckle 216 that have already been described above with reference to the previous embodiments may also be present in the buckle shown in figures 6-7b and will not all be discussed here again. For the discussion with reference to figures 6-7b, like features are designated with similar reference numerals preceded by 200, to distinguish the embodiments.

[0060] Figure 6 shows a perspective view of the buckle 216 for a seatbelt assembly. The front side 226 of the buckle casing 220 defines a front opening, with a release button 228 for actuating an internal latch mechanism (not shown). The casing 220 and outer contour of the release button 228 jointly delineate the (rectangular) insertion aperture 230 for a locking tongue. Two indicator surfaces 234a, 234b are defined at the front side 226, and located along outer lower edges of the release button 228, directly adjacent to the insertion aperture 230. The buckle 216 is provided with an illumination device 240, for emitting light outwards through the indicator surfaces 234, to help the vehicle occupant to localize the insertion aperture 230.

[0061] Figures 7a and 7b present perspective views of portions of the buckle 216 and illumination device 240 from figure 6. Figure 7a illustrates a perspective view of the lower casing portion 224, which houses the illumination device 240 along an inner surface 225 of the second casing portion 224. Figure 7b shows an exploded view of the illumination device 240, and additional functional layers 290, 294a, 294b, 298. Also here, the illumination device 240 comprises a flexible circuit board 242, a light guide 270, cover layers 290, 294a, 294b, and an adhesive layer 298. Various components of the buckle 216 and illumination device 240 are similar as in the previous embodiments. Some differences will be discussed below.

[0062] Here, the flexible circuit board 242 includes two LED units 262a, 262b and electrical components 264, provided on the carrier substrate 244 and electrically connected to the circuit pattern 260. The first and second surfaces 246, 248 correspond to opposite sides of the carrier substrate 244, which face towards the inner surface of the upper casing portion 222 and the inner surface 225 of the lower casing portion 224 respectively. The circuit pattern 260 is printed on the first surface 246 of the carrier substrate 244. The two LED units 262a, 262b are of the side emitting type, and provided in the front region near opposite lateral edges of the flexible substrate 244.

[0063] The light guide 270 is formed as a thin and generally H-shaped body of an optically transparent plastic material (e.g. PC), and adapted for guiding light from the LED units 262 towards the indicator surfaces 234 along the front side 226 of the buckle casing 220. The guiding portion 278 of the light guide 270 is bounded by two laterally separated guide edges 276a, 276b at one end, and extends into the mounting portion 280 at an opposite end. The mounting portion 280 is bounded on a rear side by second guide edges 277a, 277b.

[0064] The mounting portion 280 is positioned in a flat and overlapping arrangement along the front region of the flexible circuit board 242, and accommodates the two LED units 262 and driver components 264 within corresponding apertures 282a, 282b provided in and extending vertically through the light guide 270. Each of the

apertures 282 has a corresponding forward edge 284a, 284b with an optical surface for coupling light from the corresponding LED unit 262 into the light guide 270, to allow this light to be conveyed through the light guide 270 towards the associated guide edges 276 (i.e. indicator surfaces 234). The cover layers 290, 294 are formed by thin ink or a foil layer provided on upper and lower surfaces 272, 274 of the light guide 270, to prevent LED light from vertically exiting the light guide 270.

[0065] The adhesive layer 298 is disposed on the second surface 248 of the carrier substrate 244, and helps to directly and reliably fix the illumination device 240 to the inner surface 225 of the buckle casing 220.

[0066] Longitudinal leg structures formed in the front portions of the various layers 242, 270, 290, 298 define spaces in the in-plane directions X, Y. These spaces are formed to accommodate the structure with ribs 231 for guiding the locking tongue, and provided in a front region on the inner surface 225 of the buckle casing 220. Similarly, rectangular cut-outs 257, 287, 292, 299 are formed on the rear portions of the various layers 242, 270, 290, 298. These cut-outs are formed to accommodate an abutment structure 233 with curved ribs that is provided in a central region on the inner surface 225 of the buckle casing 220, to present a stop for an inserted locking tongue. These rectangular cut-outs 257, 287, 292, 299 are formed to match the outer periphery of the abutment structure 233 in the in-plane directions X, Y, for positional stabilization of the illumination device 240 with respect to the casing 220.

[0067] Thicknesses ΔZi (i = s, e, a, c, g, t) of the various structures and layers may be in the same ranges as specified herein above with respect to the previous embodiments.

[0068] The present invention may be embodied in other specific forms without departing from its spirit or essential characteristics. The described embodiments are to be considered in all respects only as illustrative and not restrictive. The scope of the invention is, therefore, indicated by the appended claims rather than by the foregoing description. It will be apparent to the person skilled in the art that alternative and equivalent embodiments of the invention can be conceived and reduced to practice. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

[0069] For example, in the embodiments discussed above, the flexible conductor device is formed by directly printing copper conductor tracks onto the flexible carrier substrate. In alternative embodiments, other materials with considerable electrical conductivity may be used for forming the conductive patterns, e.g. silver, aluminum, or carbon. Also, the conductive pattern may be formed by direct electrolytic deposition of a pattern of electrically conductive material onto the carrier substrate. Alternatively, the flexible printed circuit board may be formed by etching a circuit pattern by selective removal from of a sheet of rolled electrically conductive material that is initially bonded to the first surface of the carrier substrate via an adhesive, or by etching of a layer of electrically conductive material that has initially been applied to the carrier substrate by electrodeposition. For example, a circuit pattern may be formed by etching of a flexible copper clad laminate (FCCL), which is initially formed as a layered structure of a flexible carrier substrate, a flexible copper foil, and intermediate adhesive layer (e.g. from acrylic resin or epoxy).

[0070] Also, in the embodiments discussed above, the flexible circuit board was formed as a single-sided flexible printed circuit board. In alternative embodiments, the flexible circuit board may be formed as a double-sided FPCB, wherein both first and second (opposite) surfaces of the substrate are provided with conductive patterns and/or electric/electronic components. In yet alternative embodiments, the flexible circuit board may be formed as a multilayered FPC structure, wherein multiple conductive pattern layers and multiple insulation layers are alternately stacked on top of each other. In this case, the flexible circuit board may have one or several through holes for accommodating electrical connections between the various conductive pattern layers.

[0071] In the embodiments discussed herein above, electrical wiring was provided for connecting the electrical terminals on the first substrate surface, to an external power supply unit. In alternative embodiments, additional electrical terminals may be provided on the substrate surface and further electrical conduits may be provided as well, for establishing a signal communication path between the illumination device on the one hand and an external indicator, control and/or processing device on the other hand (e.g. a central processor system and/or dashboard indicator system of a vehicle). Although the electrical conduits were formed in the exemplary embodiments by individual electrical wires, it should be understood that other electrical conduit types may be used, either as an alternative to or as an addition to electrical wires. For example, a flat conductor cable (FCC) or a further flexible circuit board may be used to electrically couple an external power source and/or an indicator/control/processing device to the electrical terminals of the illumination device.

[0072] Furthermore, in the embodiments discussed above, the cover layers were formed by thin opaque ink layers that were printed on both surfaces in specific regions of the light guide. Although cover layers may be provided on both surfaces of the light guide, it may be considered to omit one such cover layer in the case that the lighting device is arranged inside the buckle casing directly along a continuous and opaque surface thereof, e.g. along a top inner surface of a black buckle casing. Instead of opaque ink, one or all of the cover layers may alternatively be formed by thin foil, which is opaque and/or highly reflective with respect to the light in the optical wavelength(s) emitted by the LED units. Such a cover foil may for example consist essentially of a suitable opaque plastic (e.g. PE, PP, PET, PC, PVC, PA, or PI),

a suitable opaque paper, or equivalent material. A thickness of this cover foil may be in a range between 12 micrometers and 500 micrometers.

[0073] Note that for reasons of conciseness, the reference numbers corresponding to similar elements in the various embodiments (e.g. element 116 and 216 being similar to element 16) have been collectively indicated in the claims by their base numbers only i.e. without the multiples of hundreds. However, this does not suggest that the claim elements should be construed as referring only to features corresponding to base numbers. Although the similar reference numbers have been omitted in the claims, their applicability will be apparent from a comparison with the figures.

LIST OF REFERENCE SYMBOLS

[0074] Similar reference numbers that have been used in the description to indicate similar elements (but differing only in the hundreds) have been omitted from the list below, but should be considered implicitly included.

10	seatbelt assembly
12	belt
14	tongue
16	buckle
18	anchor strap
20	casing
22	first casing portion
23	first inner casing surface
24	second casing portion
25	second inner casing surface
26	first side (e.g. front side of casing)
27	casing protrusion
28	release button
30	insertion aperture (e.g. insertion slot)
31	insertion guide structure (e.g. longitudinal rib)
34	indicator surface (e.g. indicator slit)
36	second side (e.g. rear side of casing)
40	illumination device
42	flexible circuit board (e.g. FPCB)
44	flexible carrier substrate
46	first substrate surface (e.g. lower substrate surface)
48	second substrate surface (e.g. upper substrate surface)
50	first substrate edge
51	second substrate edge
52	first surface region
53	second surface region
56	substrate through hole
60	electrical circuit
62	light source (e.g. LED unit)
64	LED driver
66	electrical terminal
68	electrical conduit (e.g. wire or FCC)
70	light guide
72	first guide surface (e.g. lower guide surface)
74	second guide surface (e.g. upper guide surface)
76	first guide edge
77	second guide edge
78	guiding portion
80	mounting portion (e.g. overlay portion)
82	guide through hole
83	guide cut-out
84	inner guide edge
90	first cover layer (e.g. lower cover layer)
94	second cover layer (e.g. upper cover layer)
98	adhesive layer
143	lateral substrate flange
179	lateral guide flange
233	abutment structure (e.g. curved ribs)
257	substrate cut-out
287	guide cut-out
292	cut-out
299	cut-out
X	first direction (longitudinal direction)
Y	second direction (transversal direction)
Z	third direction (vertical direction)
ΔZs	thickness carrier substrate
ΔZe	thickness conductive circuit
ΔZa	thickness adhesive layer
ΔZc	thickness cover layer
ΔZg	thickness light guide
ΔZt	total thickness

Claims

1. A buckle (16) for a seatbelt assembly (10) with a belt (12) and a locking tongue (14), wherein the buckle comprises:

- a buckle casing (20), which defines an insertion aperture (30) for accommodating the tongue (14);
- an illumination device (40) arranged inside the casing, and comprising:
  - an electrical circuit (60);
  - at least one light source (62), which is electrically connected to the electrical circuit to receive electrical power, and configured to emit visible light;
  - a light guide (70), adapted for guiding light emitted by the light source towards an indicator surface (34) defined at an outer side (26) of the casing at or near the insertion aperture;

wherein the illumination device (40) comprises a flexible circuit board (42), which is arranged inside the casing, and which includes a flexible carrier substrate (44) onto which the electrical circuit (60) and the at least one light source (62) are arranged.

2. The buckle (16) according to claim 1, wherein the at least one light source (62) comprises one or more LED units (62a, 62b, 62c), which are provided on the flexible carrier substrate (44) and are in electrically coupled to the electrical circuit (60), wherein the LED units are preferably of the side emitting type.

3. The buckle (16) according to claim 2, wherein the flexible circuit board (42) and the light guide (70) each comprise surface portions (52, 53, 78, 80) that are arranged mutually parallel, and which extend inside the buckle casing (20) towards the indicator surface (34).

4. The buckle (16) according to claim 3, wherein the surface portions (52, 53, 78, 80) include a first surface region (52) of the carrier substrate (44) where the LED units (62) reside, and a mounting portion (80) of the light guide (70) including one or more voids (82, 83) for accommodating the LED units (62), and wherein the mounting portion overlaps the first surface region such that the LED units are accommodated inside the voids.

5. The buckle (16) according to any one of claims 2-4, wherein the light guide (70) has a guiding portion (78) of optically transparent material, which extends through the buckle casing (20) from the one or more LED units (62) on the flexible circuit board (42) towards and up to the indicator surface (34) in a longitudinal direction X at the outside of the buckle casing (20).

6. The buckle (16) according to claim 5, comprising a cover layer (90, 94) of optically shielding material, wherein the cover layer is arranged along the light guide (70) and the LED units (62a, 62b, 62c) on the flexible circuit board (42), to increase the light emission yield on an edge (76) of the light guide arranged along the indicator surface (34).

7. The buckle (16) according to any one of claims 1-7, wherein the casing (20) defines an outer wall with an inner surface (23, 24) that extends up to the indicator surface (34), and wherein the flexible carrier substrate (44) extends inside the casing in an abutting arrangement with the inner surface, preferably with the flexible carrier substrate arranged between the light guide (70) on one surface side (46) and the inner surface (23, 24) of the casing on the opposite surface side (48).

8. The buckle (16) according to any one of claims 1-7, wherein the buckle (16) includes a release button (28) at the outer side (26) of the housing (20), wherein the insertion aperture (30) for the tongue (14) is also located at this outer side, and wherein the indicator surface (34) and the insertion aperture (30) are located along opposite edges of the release button.

9. The buckle (216) according to any one of claims 1-7, wherein the buckle (216) includes a release button (228) at the outer side (226) of the housing (220), wherein the insertion aperture (230) for the tongue (214) is also located at this outer side, and wherein the indicator surface (234) and the insertion aperture (230) are located along the same edge of the release button.

10. The buckle (16) according to claim 7, wherein the flexible carrier substrate (44) is provided with an adhesive layer (98) for mechanically fixing the illumination device (40) to and along the inner surface (23) of the buckle casing (20).

11. The buckle (16) according to any one of claims 2-10, wherein the LED units (62a, 62b, 62c) are arranged in a linear or piece-wise linear arrangement along the flexible circuit board (42), the linear or piece-wise linear arrangement being substantially parallel with one or more outer peripheral edges of the indicator surface (34) in the buckle casing (20).

12. The buckle (16) according to any one of the preceding claims, wherein a thickness (ΔZs) of the carrier substrate (44) is in a range of 10 micrometers to 500 micrometers, inclusive, and preferably in a range of 50 micrometers to 100 micrometers, inclusive.

13. The buckle (16) according to any one of the preceding claims, wherein the carrier substrate (44) is made of a mechanically flexible and electrically insulating foil, which consists essentially of a flexible polymer, selected from the group of polyimide (PI), polyamide (PA), polyethylene (PE), polyvinyl chloride (PVC), polycarbonate (PC), polyethylene terephthalate (PET), polypropylene (PP), polytetrafluoroethylene (PTFE), or their derivatives.

14. The buckle (16) according to any one of the preceding claims, wherein a thickness (ΔZg) of the guiding portion 78 of the light guide (70) is in a range of 500 micrometers to 1000 micrometers, inclusive, and preferably approximately 750 micrometers.

15. A seatbelt assembly (10) for restraining an occupant of a manned vehicle, cabin, or seat, comprising:

- a belt (12) with an tongue (14);
- a buckle (16) with an illumination device (40) in accordance with any one of claims 1-14.

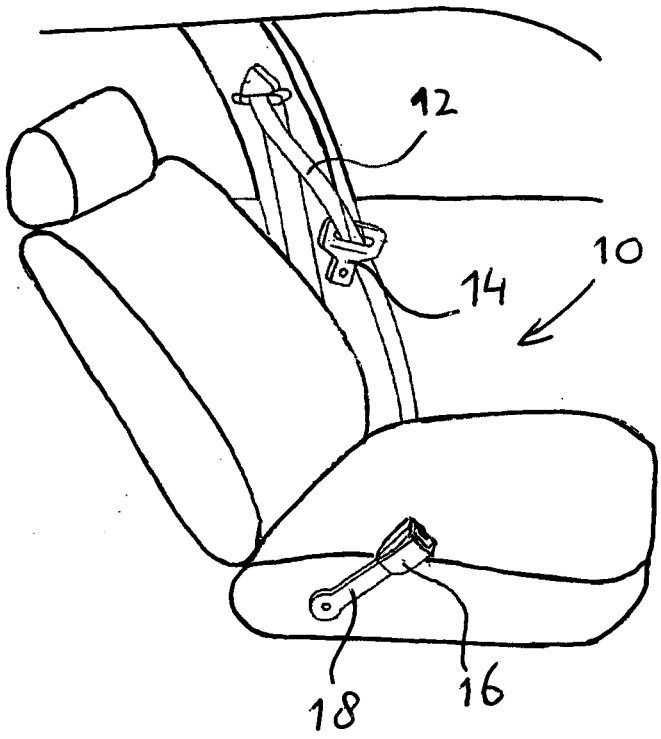

Fig. 1

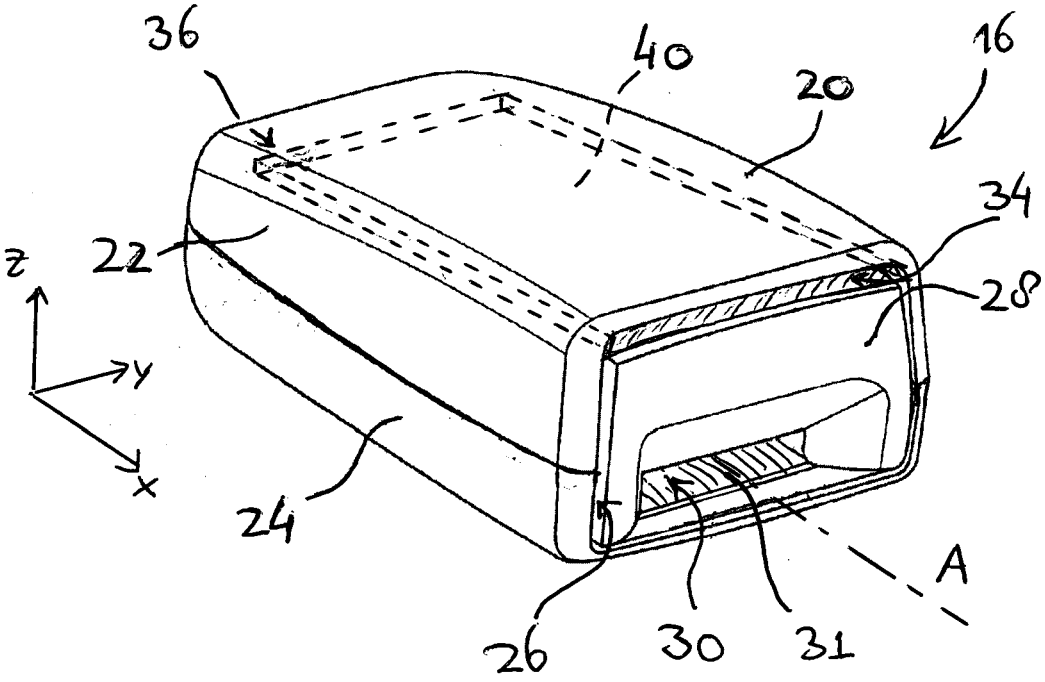

Fig. 2

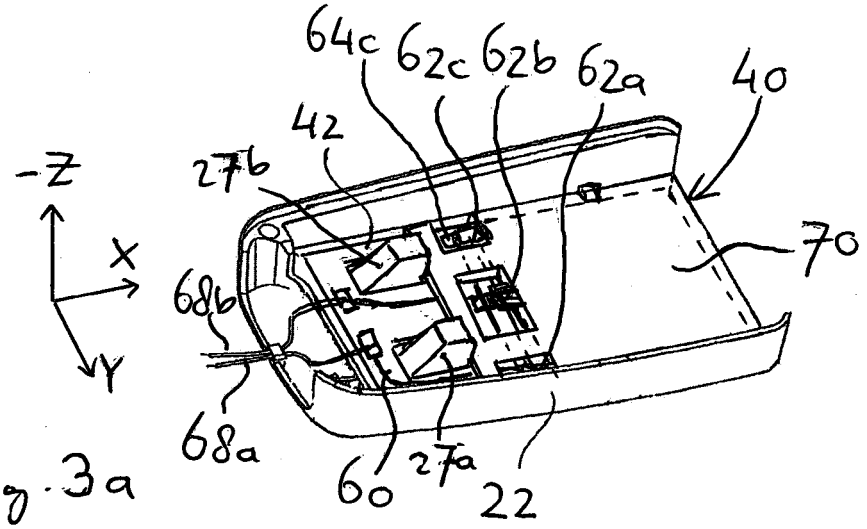
64c
62c
62b
62a
40
42
276
-Z
X
Y
70
68b
68a
60
27a
22

Fig. 3a

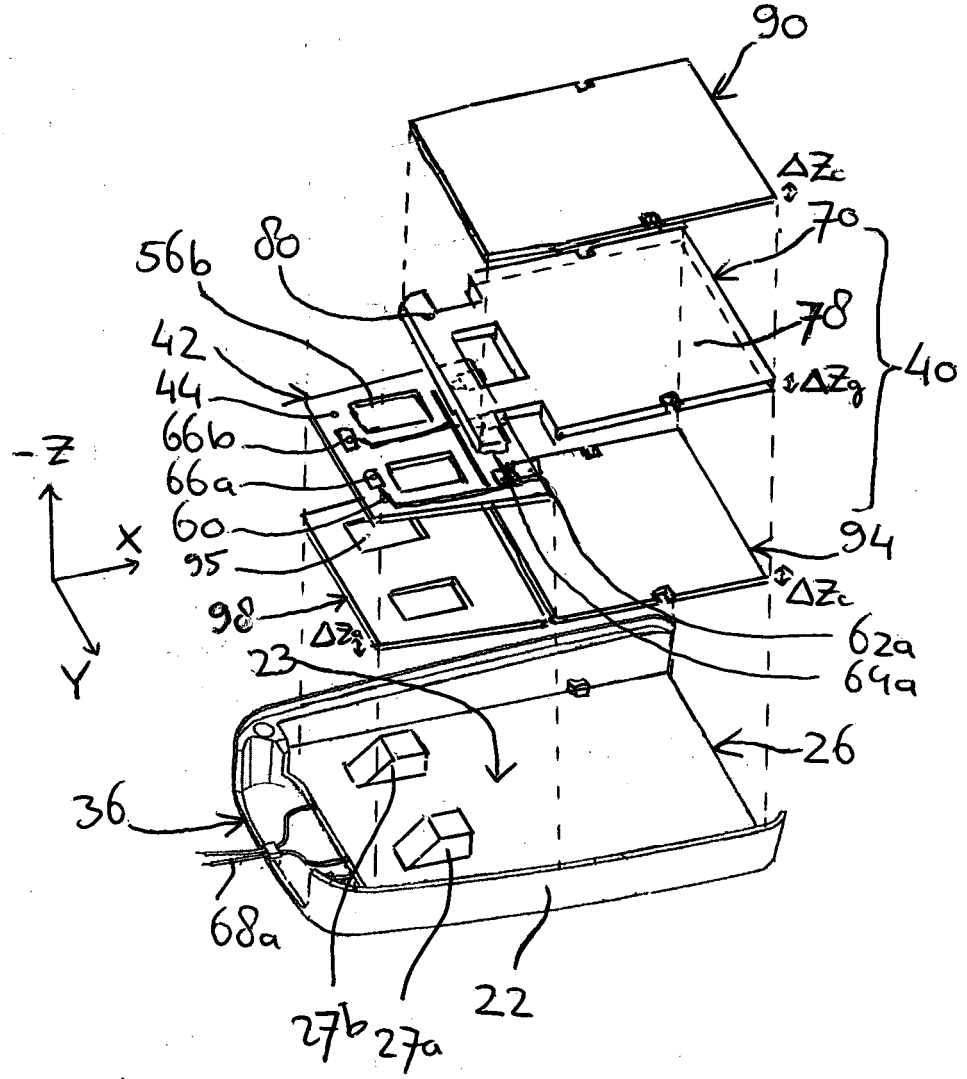
90
ΔZc
70
566
80
78
42
44
ΔZg
40
66b
66a
-Z
60
X
95
94
98
ΔZc
ΔZg
62a
23
64a
26
36
68a
22
27b
27a
Y

Fig. 3b

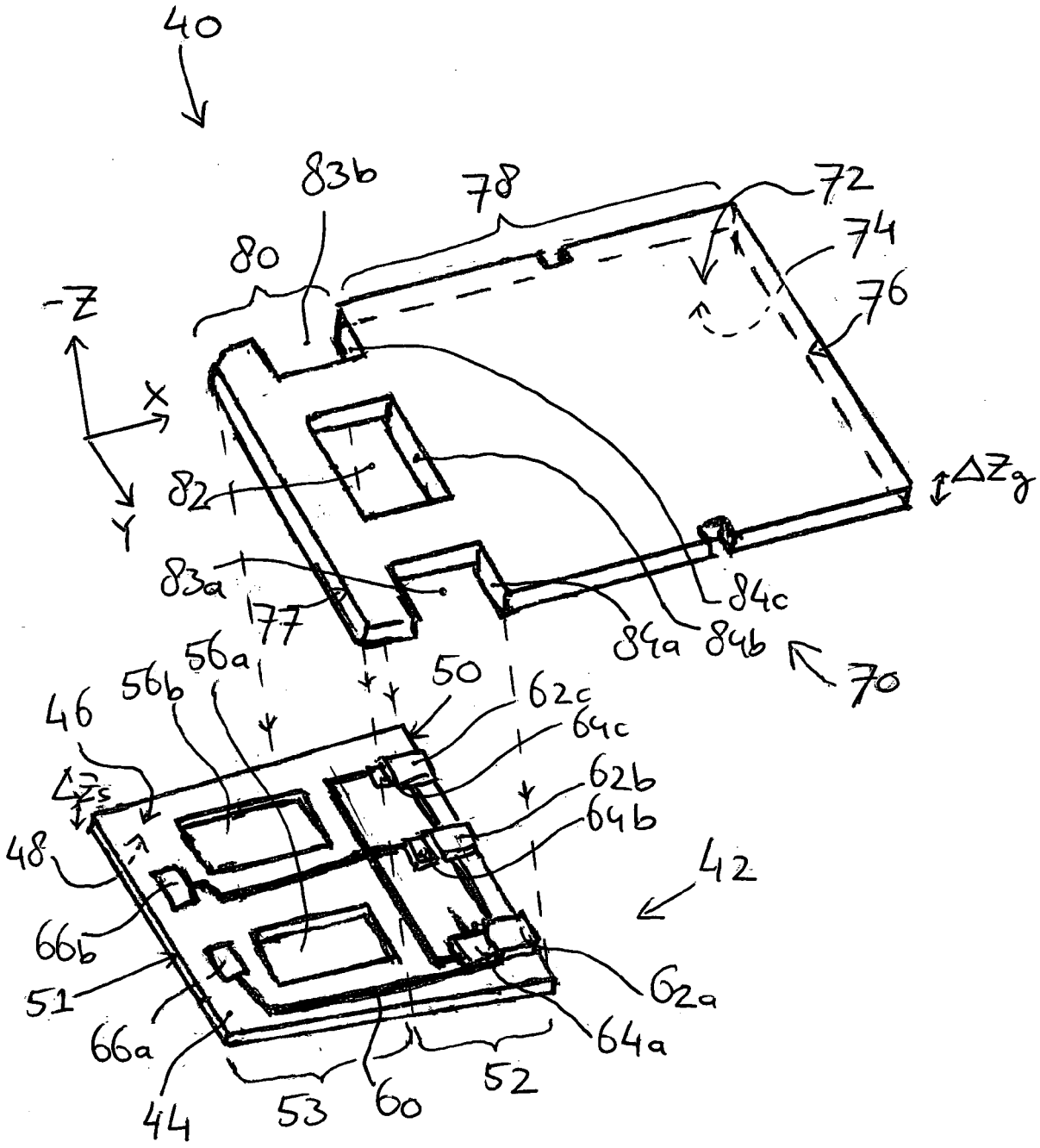
40
83b
78
72
74
80
76
-Z
X
Y
82
ΔZg
83a
77
84c
84a
84b
70
56a
56b
50
62c
64c
46
62b
64b
ΔZs
48
42
66b
51
62a
66a
64a
44
53
60
52

Fig. 4

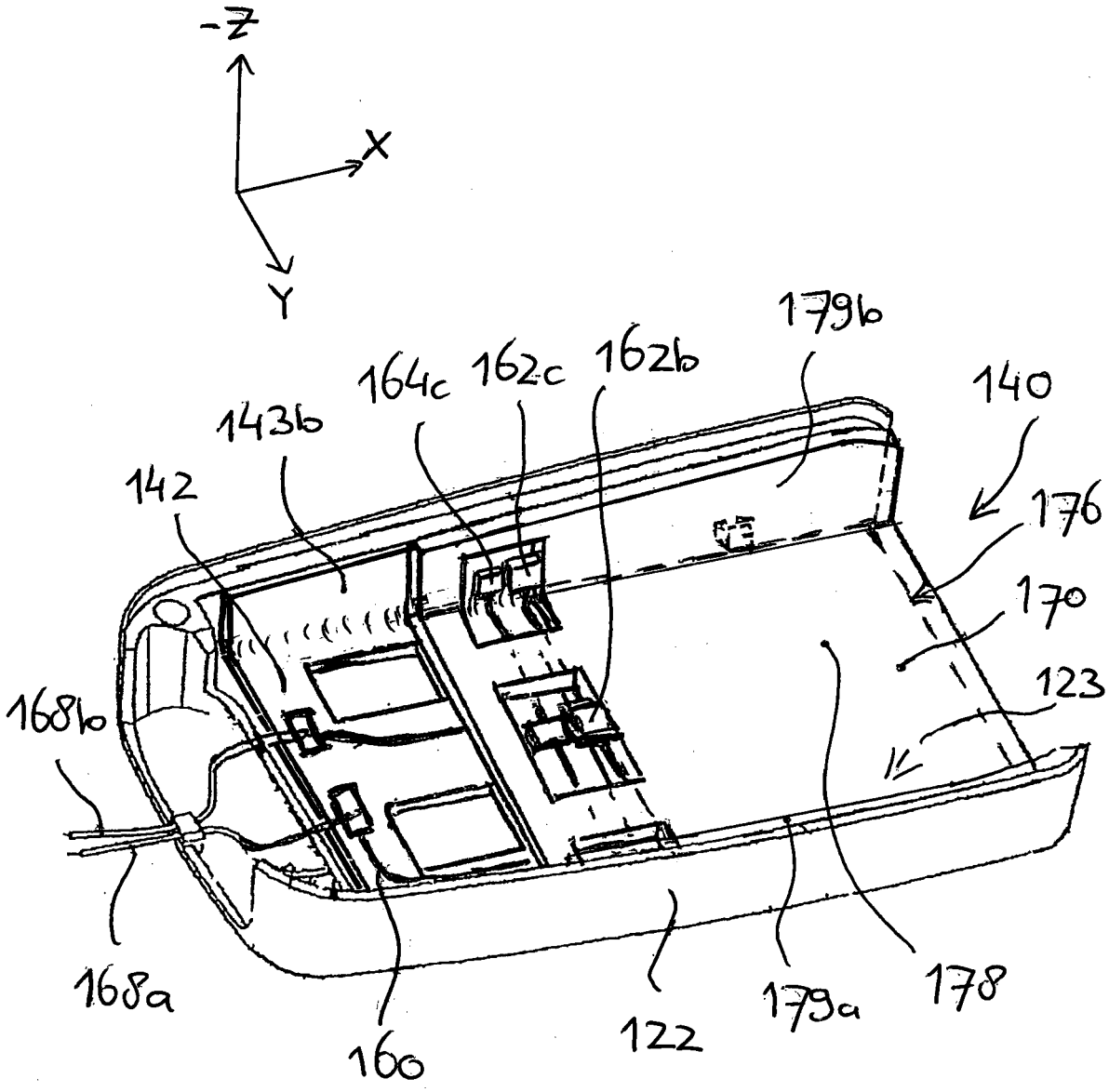
-Z
X
Y
179b
164c
162c
162b
140
143b
142
176
170
123
168b
168a
160
122
179a
178

Fig. 5

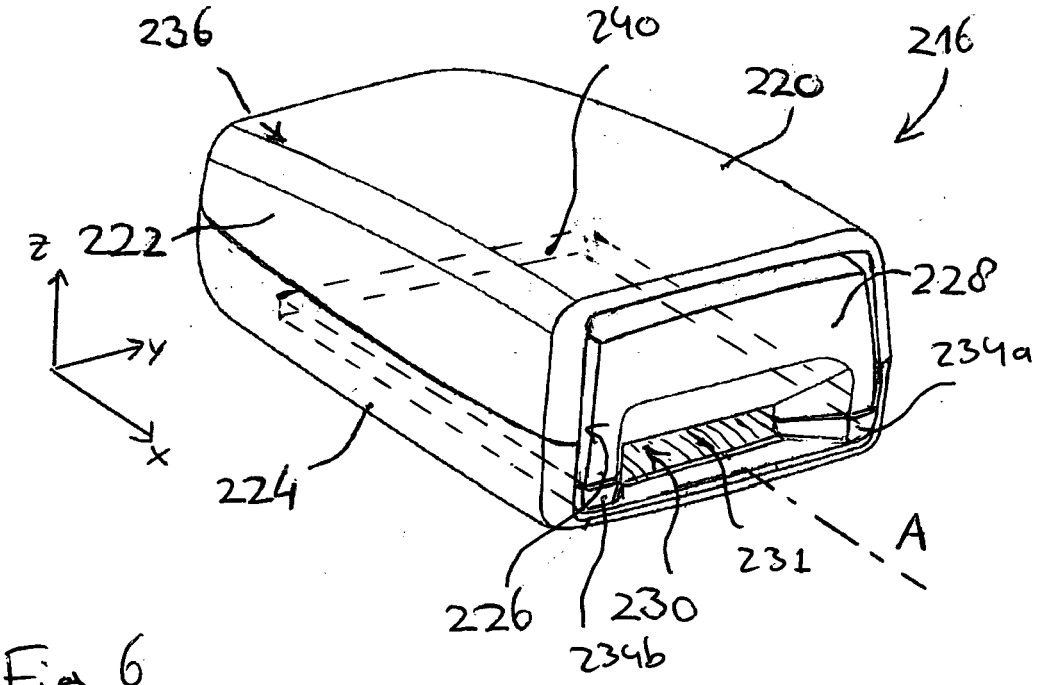
236
240
216
220
z
222
y
x
228
234a
224
231
A
226
230
234b

Fig. 6

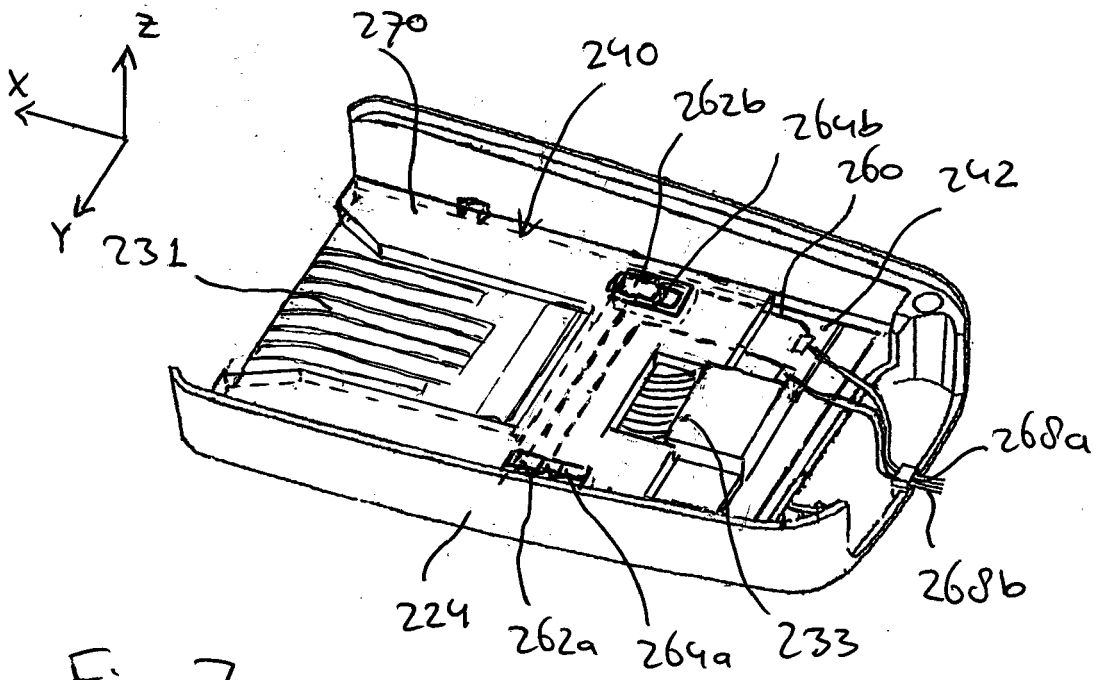
z
x
y
270
240
2626
264b
260
242
231
268a
268b
224
262a
264a
233

Fig. 7a

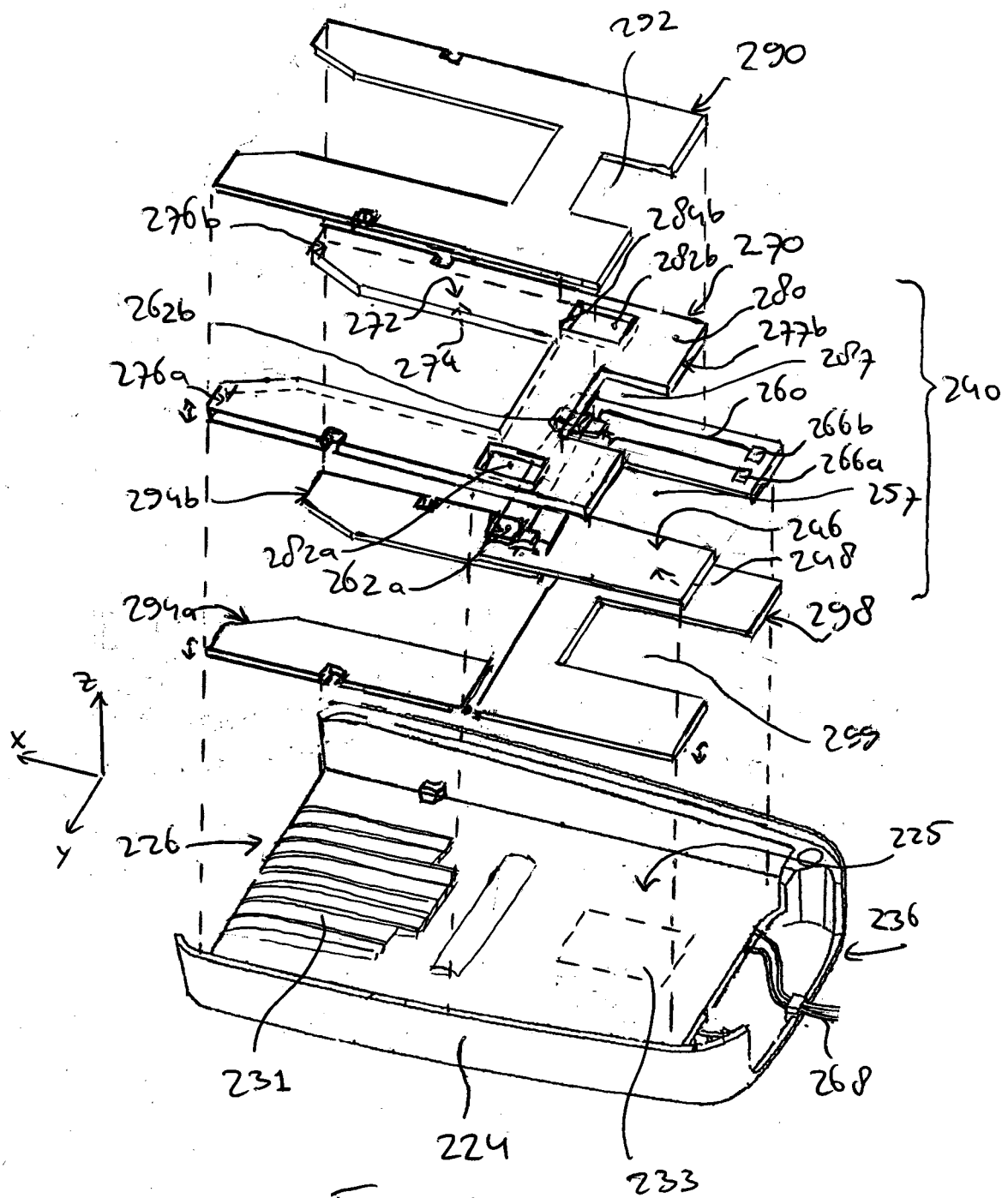
292
290
276b
284b
282b
270
280
272
274
262b
277b
287
240
276a
260
266b
266a
294b
257
282a
262a
246
248
294a
298
255
z
x
y
226
225
236
231
224
233
268

Fig. 7b

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EUROPEAN SEARCH REPORT

Application Number
EP 16 17 1886

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	US 2015/266417 A1 (SALTER STUART C [US] ET AL) 24 September 2015 (2015-09-24) * paragraphs [0043], [0044]; figures 1-5 * -----	1-4,6-15 5	INV. A44B11/25 B60R22/00
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A44B
B60R

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	13 October 2016	van Voorst, Frank

CATEGORY OF CITED DOCUMENTS

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13-10-2016

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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