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(54) **COMPRESSION BELT SYSTEM FOR USE WITH CHEST COMPRESSION DEVICES**

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SYSTÈME DE COURROIE DE COMPRESSION À UTILISER AVEC DES DISPOSITIFS DE  
COMPRESSION THORACIQUE

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(73) Proprietor: **ZOLL Circulation, Inc.**  
**Sunnyvale, CA 94089 (US)**

(72) Inventors:  
• **KATZ, Bob**  
**Sunnyvale, CA 94089 (US)**

- **ESCUDERO, Paul, Q.**  
**Sunnyvale, CA 94089 (US)**
- **QUINTANA, Reynaldo, J.**  
**Redwood City, CA 94061 (US)**
- **SWINEHART, Charles, E.**  
**San Jose, CA 95131 (US)**
- **HALL, Gregory, W.**  
**Sunnyvale, CA 94089 (US)**
- **DALBEC, Timothy, R.**  
**Sunnyvale, CA 94089 (US)**

(74) Representative: **Viering, Jentschura & Partner**  
**Grillparzerstrasse 14**  
**81675 München (DE)**

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## Description

### Field of the Inventions

**[0001]** The inventions described below relate to emergency medical devices and the resuscitation of cardiac arrest patients.

### Background of the Inventions

**[0002]** Cardiopulmonary resuscitation (CPR) is a well-known and valuable method of first aid used to resuscitate people who have suffered from cardiac arrest. CPR requires repetitive chest compressions to squeeze the heart and the thoracic cavity to pump blood through the body. Artificial respiration, such as mouth-to-mouth breathing or a bag mask apparatus, is used to supply air to the lungs. When a first aid provider performs manual chest compression effectively, blood flow in the body is about 25% to 30% of normal blood flow. However, even experienced paramedics cannot maintain adequate chest compressions for more than a few minutes. Hightower, et al., Decay In Quality Of Chest Compressions Over Time, 26 Ann. Emerg. Med. 300 (Sep. 1995). Thus, CPR is not often successful at sustaining or reviving the patient. Nevertheless, if chest compressions could be adequately maintained, then cardiac arrest victims could be sustained for extended periods of time. Occasional reports of extended CPR efforts (45 to 90 minutes) have been reported, with the victims eventually being saved by coronary bypass surgery. See Tovar, et al., Successful Myocardial Revascularization and Neurologic Recovery, 22 Texas Heart J. 271 (1995).

**[0003]** In efforts to provide better blood flow and increase the effectiveness of bystander resuscitation efforts, various mechanical devices have been proposed for performing CPR. In one variation of such devices, a belt is placed around the patient's chest and the belt is used to effect chest compressions. Our own patents, Mollenauer et al., Resuscitation device having a motor driven belt to constrict/compress the chest, U.S. Patent 6,142,962 (Nov. 7, 2000); Sherman, et al., CPR Assist Device with Pressure Bladder Feedback, U.S. Patent 6,616,620 (Sep. 9, 2003); Sherman et al., Modular CPR assist device, U.S. Patent 6,066,106 (May 23, 2000); and Sherman et al., Modular CPR assist device, U.S. Patent 6,398,745 (Jun. 4, 2002), and our application 09/866,377 filed on May 25, 2001, show chest compression devices that compress a patient's chest with a belt.

**[0004]** Since seconds count during an emergency, any CPR device should be easy to use and facilitate rapid deployment of the device on the patient. Our own devices are easy to deploy quickly and do increase the patient's chances of survival. Nevertheless, a novel compression belt cartridge has been designed to facilitate deployment, use and maintenance of chest compression devices.

**[0005]** US 6 066 106 A discloses a system for performing chest compression for cardiopulmonary resuscita-

tion. The system includes a motor and gearbox including a system of clutches and brakes which allow for controlling and limiting the movement of the compressing mechanism and includes a control system for controlling the operation and interaction of the various components to provide for automatic operation of the system. From his document there is known a system for performing chest compressions on a patient, said system comprising a compression belt and a belt drive platform which comprises a housing and a motor disposed within the housing, wherein said belt has a width along the superior-inferior height of the patient when the belt is disposed around the patient, said belt also having a length along to the medial-lateral circumference of the patient when the belt is disposed around the patient; said belt has pull straps, a first load distribution section attached to a first end of the pull straps, and a second load distribution section attached to a second end of the pull straps; wherein the first load distribution section and the second load distribution are wider than the pull straps; and the compression belt is operably connected to a compression belt cartridge which is releasably attachable to the belt drive platform.

**[0006]** US 6 616 620 B2 discloses a resuscitation device for automatic compression of a victim's chest using a compression belt which exerts force evenly over the entire thoracic cavity. The belt is constricted and relaxed through a motorized spool assembly that repeatedly tightens the belt and relaxes the belt to provide repeated and rapid chest compression.

**[0007]** US 2003/004445 A1 discloses automatic chest compression systems which use constricting belts, repeatedly inflating bladders, or reciprocating pistons to compress the chest. A bladder is placed between the chest and the particular mechanism used to compress the chest during CPR.

### Summary

**[0008]** The present invention provides a system for performing chest compressions on a patient according to claim 1. Further embodiments of the system of the present invention are described in dependent claims 2 to 8.

**[0009]** The devices and methods shown below provide for a belt cartridge for use in devices that perform chest compressions. The cartridge has a belt, a compression pad attached to the belt, a cover plate through which the belt is threaded, a belt spline for attaching the belt to a drive spool of a belt drive platform, and belt guards rotatably attached to the cover plate. During use, the cover plate and belt guards are removably attached to the housing of the belt drive platform. In turn, the belt extends out of the housing and is secured around the patient.

**[0010]** The belt itself is a single band of material that has a non-uniform width. The belt has two portions, with each portion of the belt having shared pull-straps that are narrow, a load distribution section that is wide and a trap-

ezoid-shaped transition section between the pull straps and load distribution sections. The transition sections of the belt are provided with reinforcing plates that strengthen the belt. The load distribution sections of the belt are provided with hook and loop fasteners so that the belt can be secured around the patient. In addition, a peg in the center of one load distribution section fits into a corresponding eyelet in the other load distribution section, thereby providing a means for registering the belt with the center of the patient's sternum. The compression pad is disposed beneath the load distribution sections and facilitates chest compressions.

**[0011]** The cover plate is provided with curved extensions such that the belt cartridge fits within only selected belt drive platforms. The cover plate is also provided with snap latches and hooks so that the cover plate attaches securely to the belt drive platform in a pre-determined orientation. Crossbars and reinforcing beams are provided to the cover plate so that the cover plate may be made from a thin, lightweight plate of plastic. The entire chest compression cartridge is low cost, lightweight and disposable.

**[0012]** The belt cartridge is attached to the belt drive platform via the cartridge cover plate. The belt itself is attached to a drive spool via a belt spline. The belt spline fits into a slot provided in the drive spool. The spline is provided with bosses or catches and the slot is provided with a corresponding shape so that the spline fits securely into the slot. A guide plate disposed around one end of the drive spool slot serves as a guide for inserting the spline. After the spline is inserted into the slot, the guide plate is adjusted to further secure the spline within the slot. Once the spline and belt are secured to the drive spool, the cover plate is attached to the housing of the belt drive platform.

**[0013]** Snap latches and hooks provided on the cover plate fit into corresponding detents and apertures in the housing of the belt drive platform so that the cover plate is secured to the housing. Belt guards disposed on the lateral ends of the cover plate are then closed around spindles disposed on the belt drive platform. The belt guards further secure the cover plate to the belt drive platform and protect the patient, rescuer and belt during use. In addition to the belt guards, labels are provided on the housing, cover plate and belt to indicate to the user the correct method of attaching the cartridge to the belt drive platform and on the correct method of wrapping the belt around the patient.

**[0014]** The safety mechanisms include a breakable link, liner socks, belt guards and a rapid-release connector. The breakable link is attached near the transition section of the belt. The breakable link prevents an unsafe amount of tension from developing in the belt by breaking at a pre-selected load threshold. The liner socks protect the patient from friction and contain the breakable link. The liner socks cover the belt so that the belt slides against the liner socks and not against the patient. If the link breaks, then the link remains inside a sock. The belt

guards protect foreign objects from entering the belt drive platform. Thus, articles of clothing, tools, fingers, other body parts, or other foreign objects are less likely to interfere with the belt drive platform. Similarly, the patient and rescuer are less likely to be injured by the device since the belt guards protect the moving parts of the belt drive platform. The rapid-release connector allows the belt to be removed safely even during compressions. The rapid release connector is placed on the load distribution sections of the belt. The connector is a combination of hook and loop fasteners and a peg disposed within an eyelet.

#### Brief Description of The Drawings

#### **[0015]**

Figure 1 shows the chest compression belt fitted on a patient.

Figure 2 shows a bottom view of a chest compression device that uses a belt to perform compressions.

Figure 3 shows a top (anterior) view of a belt cartridge used with a belt drive platform.

Figure 4 shows a bottom (posterior) view of a belt cartridge used with the belt drive platform.

Figure 5 shows a superior view of a belt cartridge used with the belt drive platform.

Figure 6 shows the belt used in the belt cartridge of Figures 3 through 5.

Figure 7 shows a close-up view of the cover plate used in the belt cartridge of Figures 3 through 5.

Figure 8 illustrates a method of attaching the compression belt to the drive spool.

Figure 9 shows a close-up view of the spline, the belt and the drive spool.

Figure 10 illustrates a method of attaching the belt cartridge to the belt drive platform.

Figure 11 illustrates a method of attaching a belt guard to a spindle of the belt drive platform.

Figure 12 shows a close-up view of the compression belt cartridge.

Figure 13 shows a cross-section of the belt, liner socks and breakable link.

Figure 14 shows the belt attached to the breakable link.

Figure 15 shows another cross-section of the breakable link.

#### Detailed Description of the Inventions

**[0016]** Figure 1 shows the chest compression belt fitted on a patient **1**. A chest compression device **2** applies compressions with the belt **3**, which has a right belt portion **3R** and a left belt portion **3L**. The chest compression device **2** includes a belt drive platform **4** and a compression belt cartridge **5** (which includes the belt). The belt drive platform includes a housing **6** upon which the patient rests, a means for tightening the belt, a processor and a user interface disposed on the housing. The means for tightening the belt includes a motor, a drive train (clutch, brake and/or gear box) and a drive spool upon which the belt spools during use. Various other mechanisms to tighten the belt are shown in Lach et al., Resuscitation Method and Apparatus, U.S. Patent 4,770,164 (Sep. 13, 1988) and in Kelly et al., Chest Compression Apparatus for Cardiac Arrest, U.S. Patent 5,738,637 (Apr. 14, 1998).

**[0017]** In use, the patient is placed on the housing and the belt is placed under the patient's axilla (armpits), wrapped around the patient's chest, and secured. The means for tightening the belt then tightens the belt repetitively to perform chest compressions.

**[0018]** The compression belt **3** shown in Figure 1 is provided with a structure that aids in performing compressions effectively and efficiently. Specifically, the belt is shaped like a double-bladed oar. The wider load distribution sections **16** and **17** of the belt are secured to each other over the patient's chest and apply the bulk of the compressive load during use. The narrow pull straps **18** and **19** of the belt are spooled onto the drive spool of the belt drive platform to tighten the belt during use. The trapezoid-shaped transition sections **20** and **21** reinforce the belt and transfer force from the pull straps to the load distribution sections evenly across the width of the load distribution sections. The narrow end of a trapezoid faces the pull strap and the wide end of a trapezoid faces a corresponding load distribution section.

**[0019]** The pull straps **18** and **19** of the belt are narrow so that the chest compression device may perform compressions more efficiently, thus saving battery power and prolonging the ability of the device to perform compressions. The narrow pull straps of the belt reduce the mass of the belt and reduce the torque necessary to tighten the belt around the patient's chest, particularly since the means for tightening the belt tightens the belt by spooling it around a drive spool. In addition, by using narrow pull straps, the belt may fit within a narrow channel beam in the belt drive platform. This reduces the weight and size of the belt drive platform and increases the strength of the platform by allowing a narrower channel beam (see item 45 of Figure 2) to be used with the platform.

**[0020]** The load distribution sections **16** and **17** of the belt are wider than the pull straps to allow the chest com-

pression device to perform compressions more effectively and more safely. The wider portions of the belt compress more of the chest, increasing blood flow and thus performing compressions more effectively. In addition, the wider portions of the belt allow more force to be applied to the patient by evenly distributing pressure on the patient's chest, thus increasing blood flow while making chest compressions safer for the patient.

**[0021]** The transition sections **20** and **21** of the belt transfer the tension from the pull straps to the load distribution sections and reinforce the belt. Thus, the transition sections narrow along the lateral portion of the belt.

**[0022]** The right load distribution section **16** and left load distribution section **17** of the belt are provided with hook and loop fasteners so that the belt may be secured to the patient's chest. (Securing the right and left load distribution sections to each other secures the belt around the patient's chest.) Preferably, the hook side of the hook and loop fastener is located on the anterior load distribution section of the belt (in this illustration, the left side is anterior to and superficial to the right load distribution section) so that the hooks do not contact carpet or other materials when the belt is open and splayed on the ground, though the hook and loop fasteners may be located anywhere on the load distribution sections of the belt. A handle **32** (more clearly shown in Figure 2) is provided on the left end of the belt to aid in placing and removing the belt. The handle and user interface are located on the same side of the belt drive platform to make applying and removing the belt an ergonomic motion.

**[0023]** An eyelet **33** is provided in the left load distribution section of the belt and a corresponding registration peg **34** is provided in the right load distribution section of the belt. (The peg, eyelet and hook and loop fasteners may be disposed on either load distribution section.) To secure the belt to the patient, the left load distribution section is laid over the right load distribution section and the eyelet is aligned with the peg. (The peg fits within the eyelet.) The eyelet and peg assist the rescuer to properly register the load distribution sections with respect to each other and the patient, and thereby properly position the belt on the patient. The eyelet and peg are also long relative to the superior/inferior direction of the patient and are located in the center of the assembled load distribution sections. Thus, the eyelet and peg help the rescuer place the center of the load distribution sections over the center of the patient's sternum. In addition, since the right and left load distribution sections tend to pull away from each other when the belt is tensioned, the peg and eyelet further secure the load distribution sections of the belt to each other by resisting shear forces that tend to pull the sections apart.

**[0024]** In addition, the peg and eyelet enable the rescuer to repeatably release the belt and then secure the belt around the patient such that the belt has the same length each time the belt is secured around the patient. (During use the rescuer may need to release the belt and re-secure the belt around the patient without replacing

the cartridge.) Since the belt maintains the same length, the chest compression device is much more likely to achieve the same depth of chest compressions after the belt has been re-secured as compared to before the belt has been re-secured.

**[0025]** The combination of hook and loop fasteners and the eyelet/peg fastener provides for a means for securing the belt around the patient. The same combination allows a rescuer to rapidly and easily release the belt. The rescuer may release the belt, even during compressions, by grasping the left end of the belt and lifting the left load distribution section from the right load distribution section. Thus, the securing mechanism is also an emergency release mechanism. To further enhance safety, the eyelet may be provided with an electrical contact switch, optical sensor or other electrical or mechanical means for determining whether the peg is inserted into the eyelet. Thus, a chest compression device with the appropriate software or hardware can sense whether the peg is fully inserted into the eyelet. If the peg is not in the eyelet, then the chest compression device will not perform compressions. The system will alert the operator if proper registration is not detected so that the operator may re-fit the belt.

**[0026]** Figure 2 shows a bottom view of the belt drive platform 4 and shows the housing 6, a belt cartridge 5 attached to the housing and a means for tightening the belt disposed within the belt drive platform. The means for tightening the belt may comprise a drive spool 42 attached to the belt and to a motor. The drive spool is shown in phantom to indicate its position beneath the cover plate. The motor and associated components are located within the belt drive platform.

**[0027]** The belt drive platform is provided with a control system that controls how the belt is wrapped around the drive spool. For example, the drive spool is controlled so that some of the belt is left wrapped around the drive spool between compressions. When the means for tightening has loosened the belt around the patient, just before beginning the next compression, a length of the belt corresponding to one revolution of the drive spool is left wrapped around the drive spool. Thus, the belt will maintain its curled shape, reducing the chance of causing folds in the belt during compressions and increasing the efficiency of spooling the belt around the drive spool.

**[0028]** The housing serves as a support for the patient. Handles 43 provide for easy transport of the housing and of the patient while on the housing. The belt cartridge has a cover plate 44 that fits within a channel beam 45 in the belt drive platform, thus securing the belt cartridge 41 to the belt drive platform 4. Labels 46 are placed on the housing and cover plate to indicate the proper alignment of the cover plate. The cover plate is secured to and aligned within the channel beam by the use of retainer clips or snap latches 47, 48, 49 and 50 which fit between corresponding paired bosses or detents in the housing. Tabs integrally formed with the snap latches extend into slots disposed in the housing of the belt drive

platform. The cover plate is also aligned and secured within the channel beam by the use of hooks 51, 52, 53 and 54 which fit into corresponding apertures in the housing. In addition, the cover plate is also provided with additional labeling 55 to provide warnings, manufacturer information, trademarks or advertising.

**[0029]** Figures 3, 4 and 5 show the belt cartridge 41. The belt cartridge is disposable so that there is no need to clean the belt, or other elements of the cartridge, after use. Thus, the belt cartridge reduces the exposure of subsequent patients and users to bodily fluids or other contaminants. If necessary, the cartridge may be replaced while the patient is still on the belt drive platform. In addition, since the belt cartridge is disposable the belt may be made of materials that readily conform to the shape of an individual patient, but have a shorter service life.

**[0030]** The cartridge includes a belt 3, a compression pad 65 attached to the belt, a belt clip, key or spline 66 for attaching the belt to a drive spool, a cover plate 44 and belt guards 67 and 68 rotatably attached to the cover plate via hinges 69 and 70. The belt guards are removably secured over spindles that are attached to the belt drive platform. A liner, sleeve or sock is disposed over the belt, as shown in Figure 5. The belt is threaded through slots 71 and 72 disposed in the belt guards 67 and 68. With regard to the belt 3, the right portion 3R and the left portion 3L of the belt share pull straps 18 and 19 and each have a load distribution section 16 and 17 and a transition section 20 and 21. Each load distribution section of the belt is provided with hook and loop fasteners so that the belt may be secured around the patient's chest. Additionally, as described above, an eyelet 33 is provided in the left load distribution section and a corresponding peg 34 is provided in the right load distribution section (see Figure 5). Preferably, the pull strap sections comprise a single strap.

**[0031]** The pull straps of the belt are secured to the drive spool of the belt drive platform with the spline 66, which is attached to the pull straps of the belt. The spline fits within a slot provided in the drive spool. When the drive spool rotates, the pull straps spool around the drive spool. The compression belt then tightens and is pulled onto the patient's chest, thereby accomplishing compressions.

**[0032]** The pull straps 18 and 19 of the belt are threaded through the belt guards 67 and 68 which are rotatably attached to the cover plate 44. The belt guards and cover plate are fashioned from a lightweight but strong plastic. The cover plate and belt guards are designed to allow the belt cartridge to be removably attached to the belt drive platform and to protect the belt during use. Specifically, the cover plate is provided with snap latches 47, 48, 49 and 50 that fit between corresponding paired bosses or detents on the housing. Integral tabs extend from the snap latches and fit into corresponding slots in the housing. The cover plate is also provided with hooks 51, 52, 53 and 54 that fit into corresponding apertures in the

housing of the belt drive platform. The snap latches and hooks are designed so that the cover plate is removably attached to the belt drive platform without the use of tools. The snap latches and hooks may have a variety of shapes and forms. The snap latches and hooks may also be asymmetrical with respect to the cover plate, thus making it possible to fit the cover plate on the belt drive platform in only one orientation. To increase the ease of use of the cartridge, the cover plate is provided with labels **46** to indicate the desired orientation of the cover plate with respect to the belt drive platform.

**[0033]** Below the load distribution sections of the belt is a compression pad **65** that affects the distribution of compression force and assists in performing chest compressions. An example of a chest compression pad may be found in our application 10/192,771, filed July 10, 2002. In one embodiment the compression pad is a three-sectioned bladder filled with foam. The compression pad is located on the belt so that it is centered over the patient's chest when the belt is in use. The compression pad is disposed below the load distribution sections of the belt and is removably attached to the belt with double-stick tape, hook and loop fasteners or comparable fastening means. The compression pad is also disposed inside the liner sock.

**[0034]** Additional safety features may be provided with the compression belt cartridge **41**. For example, spreader bars or reinforcing plates **87** may be attached to the transition sections of the belt with stitches **88**. (The reinforcing plates may be attached to the transition sections of the belt by any suitable method.) The reinforcing plates reinforce the transition sections of the belt and help prevent the transition and load distribution sections from twisting, bending, folding or otherwise deforming with respect to the pull straps, except in regard to the ability of the belt to wrap around the patient's chest. The reinforcing plates are made of a hard plastic or other non-resilient, though flexible material.

**[0035]** The belt also may be provided with one or more breakable couplings or breakable links **89** on one or both sides of the load distribution or belt transition sections. The breakable link **89** or links are interposed between sequential portions of the belt such that the belt separates if a link breaks. The link is designed to break at a predetermined tension. If the belt experiences an unsafe amount of tension, then a link breaks, the belt separates and the patient is thereby protected from excessive forces. What constitutes an unsafe amount of tension or excessive force varies, depending on the patient and the device and belt used, but is in the range of about 90.7 kg to about 226.8 kg (200 pounds to about 500 pounds) as measured in the area of the belt to the side of the patient. Preferably, the link is designed to break under about 136.1 kg (300 pounds) of tension as measured in the area of the belt to the side of the patient. In addition, the link may be designed to reattach to itself or to a clip or other mating fastener after failure. Thus, in the event of link failure, the belt may be re-attached quickly and

compressions may be restarted with minimal delay.

**[0036]** To prevent the load distribution sections from twisting relative to the other sections of the belt, the links may be designed to also serve as swivel joints, or the belt may be provided with additional swivel joints along the belt. The swivel joints connect the pull straps to the belt transition sections. The swivel joints allow the load distribution sections to twist relative to the pull straps, about the longitudinal axis of the belt, without twisting the pull straps themselves.

**[0037]** Another safety feature is a liner sock **90** for the belt (see Figure 5). The liner sock surrounds the portions of the pull straps, as well as the compression pad, that contact the patient thereby protecting the patient from friction as the belt moves during compressions. The liner socks are attached to the belt guards around the belt guard slots so that hair, other body parts or other foreign objects cannot become caught in the belt guard slots. On the other end, the socks are disposed around and are attached to the load distribution sections of the belt.

**[0038]** In use, the belt spline is inserted into the drive spool of the belt drive platform. The cover plate of the cartridge is then inserted into the channel beam of the belt drive platform and fixed into place via the hooks and snap latches. The belt is wrapped around the patient, with the load distribution sections secured over the patient's chest. Thus, the chest compression device performs compressions by repetitively tightening the belt.

**[0039]** Figure 6 shows the belt **3** used in the belt cartridge of Figures 3 through 5. When laid out, the belt has the shape of a double-sided oar or paddle. As described above in reference to Figures 3 through 5, the right portion **3R** and the left portion **3L** of the belt each have a load distribution section **16** and **17**, a transition section **20** and **21** and pull straps **18** and **19**. The pull straps are narrow with respect to the load distribution sections. The load distribution sections are disposed opposite each other, and each load distribution section of the belt is provided with hook and loop fasteners **96** so that the belt may be secured to the patient's chest. An eyelet **33** is provided in the left load distribution section and a corresponding peg **34** is provided in the right load distribution section to further secure the belt around the patient. (The peg and eyelet may comprise a variety of shapes and sizes; for example, the peg may be a post and the eyelet a round grommet.) In addition, a spline **66** is attached to the belt by any suitable manner. The spline fits within a slot provided in the drive spool of the belt drive platform. Thus, when the drive spool rotates, the pull straps will spool around the drive spool.

**[0040]** The transition sections **20** and **21** of the belt are disposed opposite each other and are provided with corresponding thin (1/16×2.54 cm [1/16 inch]) reinforcing plates **97** and **98** of flexible plastic that reinforce the belt. (The plates may comprise different materials and may be thicker or thinner, or even of varying thickness, depending on the material used and the desired stiffness of the transition sections; however, plates with a thick-

ness of about 1/4×2.54 cm (1/4 inch) or less are preferred.) The reinforcing plates mitigate the effects of stress concentrations in the belt, stress voids in the belt, belt creasing, belt wadding and other problems caused by using a compression belt that has a non-uniform width. The reinforcing plates are attached to the transition sections of the belt and the shape of the reinforcing plates conforms to the shape of the transition sections of the belt. (The reinforcing plates may be attached to the transition sections by any suitable means and may be located above, below or within the transition sections.) The reinforcing plates also bend to conform to the shape of the patient's torso during compressions. As the plates bend around the patient, the bending stiffness of the plates along the other axes of the plates increases. To provide smooth compressions along the patient's chest, one or more edges of the reinforcing plates may be bent outwards and away from the patient (like ski tips).

**[0041]** The belt material of the pull straps, the load distribution sections and the transition sections has a constant thickness of about 0.25 mm (0.010 inches) and is made of a custom, fiber-reinforced material that can be manufactured by a number of belt manufacturers. Our belt is a material made from unidirectional layers of high-strength fibers held together with a resin. (The fibers are Spectra 2000 fibers available from Allied Signall, Inc., but may also be carbon, Kevlar™ and other fibers.) Our custom belts do not stretch or break under heavy loads, and are resistant to bodily fluids, aging, humidity and temperature.

**[0042]** The belt may also be made of a flat metal or rounded metallic cable, nylon, sail cloth or other strong and flexible materials. The belt material may also include layers of additional materials such as Tyvek™ (high-density, spun bonded polyethylene) or Teflon™ (polytetrafluoroethylene) directly bonded to the primary belt material.

**[0043]** The custom belts used with the belt cartridge have 4 laminated layers of fibers oriented at 0, 90, 6 and -6 degree angles with respect to the long axis of the belt. Placing at least some of the layers obliquely with respect to the long axis of the belt improves belt performance and longevity. The resin holding the fibers together is about 60% to 70% of the volume of the material. An additional layer is laminated on the outside of the belt to improve water resistance and lessen friction during use. A belt designed with laminated fibers at different orientations with respect to the long axis of the belt is less likely to stretch during compressions. The above belt has an average stiffness of about 34,927kg (77,000 pounds) per 2.54 cm (inch) per 2.54 cm (one-inch) length of belt, as measured along the longitudinal axis of the belt, and thus does not stretch during compressions.

**[0044]** The belt (or cable) may be pre-conditioned before distribution or sale. The cartridge and belt may be disposed on a test platform and the cartridge and belt tested before being sold. This process pre-conditions the belt. Pre-conditioning the belt deforms the belt to the

shape of the spool shaft, which allows for more efficient spooling of the belt during compressions. Preconditioning also helps prevent the belt from deforming during use. Thus, preconditioned belts will perform consistently during use. In addition, the belt is at least partially spooled around the drive spool during storage so that the pull straps are set to the shape of the drive spool prior to use.

**[0045]** The overall belt and belt cartridge are sized and dimensioned to be used with 95% of all body sizes. (Only extremely small or large patients may have difficulty benefiting from a device that includes the compression belt cartridge.) The pull straps are about 50.8 mm (2 inches) wide (along the superior-inferior dimension of the patient, as indicated by the direction of arrows **99**) and about 1016 mm (40 inches) long (along the medial-lateral dimension of the patient, as indicated by the direction of arrows **100**). The load distribution sections of the belt are about 203.2 mm (8 inches) wide and about 304.8 mm (12 inches) long. The transition sections of the belt are about 6 inches long and taper gradually between the pull straps and a load distribution section; thus, the transition sections have a trapezoidal shape. All sections of the belt material have a constant thickness of about 0.25 mm (0.010 inches), with a tolerance of 0.025 mm (0.001 inches). The belt may be thinner to reduce the weight of the cartridge and the overall device, though the belt may be as thick as 6.35 mm (0.25 inches).

**[0046]** Because the belt is thin, the overall weight of a compression device is kept to a minimum. Using a thin belt also spools less material onto a drive spool during use. This reduces the overall diameter of the drive spool plus belt material, thereby reducing the amount of torque necessary to operate the chest compression device. Thus, using a thin belt also saves energy, thereby increasing the life of a battery used to power a chest compression device.

**[0047]** Figure 7 shows a close-up view of the cover plate **44** used in the belt cartridge of Figures 3 through 5. As already described, the cover plate is designed to allow the belt cartridge to be removably attached to the belt drive platform and to protect the belt during use. Specifically, the cover plate is provided with hooks **51** and **52** that fit within apertures provided in the housing. The cover plate is also provided with snap latches **47** and **48** which fit securely between corresponding paired bosses or detents that extend from slots disposed in the housing. Tabs integrally formed with the snap latches extend into the slots when the cover plate is secured to the housing.

**[0048]** To reduce weight, the cover plate is fashioned from a thin plate of plastic. To increase strength, the cover plate is provided with intersecting reinforcing ribs **106** (also shown in Figure 3) that reinforce the cover plate and help the cover plate to resist the force of compressions. Additional aluminum reinforcement braces **107** (also shown in Figure 3) are provided to further reinforce the cover plate. The reinforcement braces span the height of the cover plate to provide the cover plate with additional strength. The reinforcement braces also brace

the channel beam, thereby protecting the belt drive platform from deforming under high forces.

[0049] The cover plate is provided with opposing curved extensions **108** and **109** so that the cover plate fits precisely within the belt drive platform. The curved extensions, as well as the overall size and dimensions of the cover plate, prevent the belt cartridge from being used with devices not designed to receive the belt cartridge. Thus, the cover plate also helps ensure that the cartridge will be used safely.

[0050] Rotatably attached to the curved extensions of the cover plate are belt guards **67** and **68** that protect the user, belt drive platform and belt when the chest compression device is in use. The belt guards are removably secured around the spindles during use. The belt guards are wider than the belt, and the pull straps are threaded through slots **71** and **72** disposed in the belt guards. Thus, during use, the belt slides within the belt guards and over the spindles. The spindles, in turn, rotate within the belt drive platform. The spindles also rotate underneath the belt guards, sliding against the belt guards where the belt guards are disposed against the spindles.

[0051] On each end of the cover plate, fingers or pawls **110** and **111** hook around corresponding catches or ratchets **112** and **113**. The ratchets are attached to corresponding hinges **69** and **70**, though may be attached to the corresponding belt guards. The pawls are attached to the cover plate and prevent the belt guards from curling away from the cover plate. However, a user may (preferably without tools) apply a force sufficient to pull the ratchets away from the pawls as the hinges rotate, thereby allowing belt guards more freedom to rotate outwardly, away from the cover plate. The user may also re-engage the pawl and ratchet so that the belt guards are once again prevented from curling outwardly.

[0052] The various components of the belt cartridge may be differently oriented with respect to each other. For example, the compression pad may be disposed beneath the liner sock instead of inside the liner sock. In other embodiments, if the geometry of the belt drive platform changes, then the compression belt cartridge may be changed accordingly. For example, if the drive spool is located to one side of the belt drive platform, then the spline would be located outside the belt guards (instead of between them) and the rest of the cartridge would be adjusted to fit to the housing and belt drive platform. The belt may have other shapes; for example, the belt may have more than one narrow region. (If the belt drive platform uses more than one drive spool then the belt may have more than one set of pull straps.) In addition, other means for tightening the belt may be used, such as multiple motors and drive spools, pistons, scissors mechanisms or other mechanical actuators.

[0053] Figures 8 through 11 illustrate devices and methods for operably inserting the belt cartridge into the housing of the belt drive platform. Figure 8 illustrates a user **124** inserting the belt spline **66** into the slot **125** in the drive spool **42**. The user sets aside the cover plate

**44** and inserts the front end **127** of the spline into the drive spool slot **125** in the direction indicated by arrow **128**. The user then fits the back end **129** of the spline into a guide slot **130** disposed in a guide plate **131**, which serves to further secure the spline in place, and secures the back end of the spline into the drive spool slot. The user then secures the cover plate over the channel beam **45**. After securing the cover plate in the channel beam, the belt guards **67** and **68** attach to opposing rods, rollers or spindles **132** fixed to the sides of the belt drive platform. The spindles decrease friction as the belt travels along the spindles.

[0054] Figure 9 shows a close-up view of the spline **66**, the guide plate **131** and the drive spool slot **125**. The spline is provided with a particular shape so that the spline will fit more securely within the drive spool slot. The shape of the spline also discourages the use of splines not designed by the manufacturer and discourages placement of the spline in an incorrect orientation. Thus, the spline is keyed to the drive spool slot.

[0055] Specifically, the spline **66** is provided in the form of a rectangular rod or bar made of a hard plastic or a metal. The front end **127** of the spline is provided with a protruding foot, boss or catch **143** shaped to fit into the front end **144** of the drive spool slot. Likewise, the back end **129** of the spline is provided with a second protruding foot, boss or catch **145** shaped to fit into the back end **146** of the drive spool slot. (The spline may have other shapes to accommodate differently shaped slots in the drive spool.)

[0056] The drive spool slot is provided with corresponding recesses **147** and **148** to accommodate the front and back catches on the spline respectively. Thus, the spline resembles a key and can function in a similar manner with respect to the use of the chest compression device. In addition to the catches, slots and recesses shown, the spline is further held in place with one or more detents in the belt drive platform that engage the front or back catches on the spline. The detents also serve as catches inside the belt drive platform that prevent the drive spool from rotating when the spline is not inserted in the drive spool slot. Thus, the device will not operate unless the spline is correctly inserted into the drive spool slot. In addition, the front end of the spline engages an electromechanical switch when inserted into the slot. When the spline engages the switch, a signal is generated (or interrupted) that informs the control system that the clip is present and properly engaged. Additionally, the belt drive platform may be provided with hardware or software that detects whether the spline is correctly inserted and informs the user of incorrect insertion and prompts the user to re-insert the spline if the spline is not correctly inserted.

[0057] The spline, cover plate or belt drive platform may be provided with a means for ensuring that a particular compression belt cartridge will only be used once (that is, used on only one patient during one rescue attempt). For example, the spline may be provided with a

breakaway or deformable tab that, on insertion into the drive spool slot, renders the spline unusable after the spline has been removed from the spool shaft slot. Additionally, the spline may have a means for identifying whether the spline was produced by an approved manufacturer or whether the spline previously had been attached to the drive spool slot of a belt drive platform. For example, an RF identification tag or other wireless communication mechanism could be attached to the spline, wherein the RF tag transmits data corresponding to a unique identifying number. A magnetic strip may also be attached to the spline that stores a unique identifying number. A given belt drive platform will operate only if the identifying number corresponds to a number provided to the platform by the manufacturer and only if that number has not been used with the belt drive platform in the past. If the belt drive platform is connected to a network, then any belt drive platform connected to the network may be programmed to recognize when a particular belt cartridge has been used with any other belt drive platform. Moreover, the belt drive platform may be programmed to alter the identifying number on the spline, thereby rendering the cartridge unusable with any other belt drive platform. If this feature is implemented, the belt drive platform may be accompanied by an over-ride feature that allows a used cartridge to be used again. Thus, in the unusual situation where multiple heart attack victims are encountered or where a used cartridge is the only available cartridge, the cartridge may be used again.

**[0058]** To further secure the spline within the drive spool slot, a collar or guide plate **131** is provided around one or both ends of the drive spool **42**. The guide plate is provided with a guide plate slot **130** through which the back end of the spline is inserted. After the spline is inserted, the guide plate is adjustable to firmly secure the spline within the drive spool slot. A user may manually move the guide plate sufficiently to insert the spline into and remove the spline from the slot.

**[0059]** The guide plate may be spring loaded and pushed into the wall of the channel beam to make room for inserting the spline, or the guide plate may be rotated (or rotated and pushed) to secure the back end of the spline within the drive spool slot. If the guide plate is spring loaded, the spring comprises a means for providing a biasing force to the guide plate; however, other means for biasing the guide plate may be used, such as a flexible tab. In any case, the guide plate may be disposed in relation to the drive spool such that the spline may not be inserted into or removed from the drive spool slot unless the guide plate or the drive spool is moved. This ensures that the spline will remain secured to the drive spool during use and during storage (while the drive spool is rotating and while the drive spool is stationary).

**[0060]** In use, the spline is inserted into the drive spool slot as shown by arrows **149** and **150**. When the drive spool rotates, the belt **3** wraps or spools around the drive spool, thereby tightening the belt. As the belt is tightened the patient's chest is compressed. The patient's chest is

decompressed as the drive spool rotates in the opposite direction, thereby allowing the belt to unwind and relax. After use, the process of inserting the belt may be reversed to detach the belt cartridge from the belt drive platform. Thus, the belt cartridge may be replaced after each use of the belt drive platform. Preferably, all of the attachment mechanisms are releasable, as described above, so that the operator can replace the belt without the use of special tools.

**[0061]** Figure 10 illustrates a method of attaching the belt cartridge to the housing of the belt drive platform. The belt cartridge cover plate **44** is attached to the channel (established by beam **45**) in the belt drive platform. Labels **46** allow the user to easily align the cover plate within the channel beam. Hooks **53** on the cover plate fit into corresponding apertures **158** in the belt drive platform. Belt guards **67** are removably disposed around spindles **132**. (The spindle is shown in phantom to indicate its position underneath the belt guard and within the belt drive platform). In addition, snap latches **47** fit within paired detents that extend from the edges of slots **159** in the belt drive platform. Tabs extending from the snap latches fit within the slots themselves.

**[0062]** The labels include an arrow **160** disposed in a recess **161** in the belt drive platform and an arrow **162** disposed in a recess **163** on the cover plate **44**. The cover plate is correctly aligned within the channel beam when the arrow on the belt drive platform is pointing at the arrow on the cover plate. The hooks and snap latches on the cover plate then fit within corresponding apertures and slots within the belt drive platform.

**[0063]** The snap latches are designed so that an audible click is heard when a snap latch is fully inserted into a corresponding slot. The snap latches may be designed so that they bend as they fit between the detents. When fully inserted, a flange on the end of the snap latch slips with respect to the detents, making an audible click when the flange strikes the edge of the slot. In addition, the hooks and snap latches may be aligned so that the belt cartridge only fits in one orientation with respect to the belt drive platform. For example, the snap latches or hooks may be spaced asymmetrically with respect to cover plate so that if the cover plate is incorrectly oriented the cover plate will not fit into the channel beam.

**[0064]** Figure 11 shows a method of attaching a belt guard **68** to a spindle **132** of the belt drive platform **4**. The cover plate **44** has already been secured to the belt drive platform, though the hinges **70** allow the belt guard to rotate with respect to the belt drive platform and cover plate. The belt guards are provided with a hook-shape so that they securely attach around the spindles **132** fixed to the belt drive platform. The user may secure the belt guards around the spindles, as indicated by arrow **173**.

**[0065]** In use, the belt guards protect the patient, rescuer, belt, belt cartridge and belt drive platform. The belt guards prevent foreign objects from entering the belt drive platform and becoming caught in the channel beam. Thus, a user's fingers or clothes, patient's clothes or body

parts, or debris located near the site of emergency cannot enter the belt drive platform and damage the patient, the rescuer or the various parts of either the belt drive platform or the belt cartridge.

**[0066]** Figure 12 shows a close-up view of the compression belt cartridge **41**. Instructions **174** on how to deploy the compression belt cartridge or the belt drive platform are printed on the outer surface of the belt **3**, belt liner, cover plate, compression pad or any other component of the compression belt cartridge. Specifically, indicia including pictorial instructions and written instructions (including Braille) show the rescuer how to correctly secure the compression belt around the patient.

**[0067]** Markings **175** on the outside of the belt liner indicate when the belt straps have been twisted. The markings may be lines that are oblique or skew to the longitudinal axis of the belt or belt liner, but may also be areas of solid colors on one side of the belt or belt liner. Preferably, less than the entire surface of one side of the belt liner is painted or marked. (Excessive ink, dye, transfer or adhesive elements, such as stickers, cause the liner to become too stiff, thereby significantly increasing the chances that the belt liner will wear prematurely.) The markings **175** may also serve as a means for identifying the manufacturer; for example, the markings may show the manufacturer name or other advertising information.

**[0068]** In addition, markings are provided to show a rescuer how to correctly align the compression belt and the belt drive platform with the patient. A yellow or other brightly colored orientation line is disposed along the superior edge of the load distribution sections of compression belt, parallel to the longitudinal axis of the compression belt. When the compression belt is correctly placed on the patient the yellow line will line up with the patient's axilla (armpits). Furthermore, the yellow line also lines up with a corresponding yellow strip disposed on the housing of the belt drive platform. Thus, a rescuer can easily visualize when the belt and belt drive platform are correctly oriented with respect to the patient and to each other. (Other marking schemes may also be used in relation to other anatomical landmarks such that the placement of the orientation lines may be varied.)

**[0069]** Similarly, the alignment peg on the load distribution section indicates that the patient should be aligned on the center of the belt drive platform and that the load distribution sections should be aligned on the center of the patient's chest. Thus, when the belt is placed correctly, the peg lies over the center of the patient's sternum. Preferably, the peg is long relative to the superior-inferior direction such that the longitudinal axis of the peg lies directly over and parallel to a superior-inferior line in the center of the patient's sternum.

**[0070]** The instructions, alignment arrows and cartridge components are color coded (or otherwise uniquely marked) to be easier to read and understand, or to indicate the purpose of the instructions. For example, the eyelet **33** and peg **34** are colored yellow (or otherwise uniquely colored or marked) to indicate that they mate.

The belt cartridge also may be provided with colored warning or instruction labels **176** (multiple colors and color schemes may be used). Examples of warning or instruction labels include: "Align the armpits onto the yellow line," "LifeBand straps 90 degrees to platform," "Do not cut," "Do not twist" or "Single patient use do not re-use." Each warning may be assigned a different color, such as red, blue, black and gray.

**[0071]** The devices and methods shown above in reference to the figures may be modified. For example, the spline may be a hemisphere and attach to a corresponding hemisphere on the drive spool. The slot in the drive spool may extend through the drive spool and the belt threaded through the slot. The spline may also be provided with arms that clip around the drive spool and thereby secure the spline to the drive spool. The spline may be provided with magnets, a collar, detents or other latching features to ensure that the spline remains attached to the drive spool during use. In the case of a magnet, the wrapped portion of the belt around the drive spool holds the belt in place when the load becomes large.

**[0072]** The hook and loop fasteners may be replaced with buckles. The cartridge may be provided with a processor and a speaker, with the processor programmed to give audio instructions to the user. In addition, other means for tightening the belt may be used, such as multiple motors and drive spools, pistons, scissors mechanisms or other mechanical actuators.

**[0073]** Similarly, the drive spool or drive spools may have different shapes. If so, then the connection between the pull straps and the drive spool may have to be altered to accommodate the new drive spool shape. For example, a drive spool may have a conical shape and the pull straps replaced with pull cables or with pull straps made of a material without resin. In this case, the belt or cables may be fixedly attached to the drive spool.

**[0074]** Figures 13 through 15 show close-up views of the belt **3**, the breakable link **89** and the liner socks **182** and **183** surrounding the portions **3R** and **3L** of the belt that contact the patient and also shows the breakable link **89**. (The peg **34**, eyelet **33**, spline **66** and various sections of the belt **16**, **17**, **18**, **19**, **20** and **21** are shown for reference. The compression pad and cover plate are not shown in order to more clearly show the belt liner.) The loosely fitted liner socks protect the patient from friction. The belt generates friction along the surface of the patient as the belt repetitively compresses the patient's chest. Without some means for reducing the friction, the belt would likely cause injury during compressions, such as abrasions, contusions or other compression-related injuries. In addition, friction increases the energy required to operate the compression device and thereby reduces battery life. The liner socks protect the patient and increase energy efficiency by allowing the belt to easily slide along the liner, with the liner only moving slightly against the patient's chest. (Some bunching of the liner socks may occur during compressions.)

**[0075]** The liner socks are tubes of Tyvek™ (high-den-

sity, spun bonded polyethylene) that are attached to the belt cartridge to form socks around the right **73** and left **3L** portions of the belt. (The liner socks may comprise other materials that are water resistant and have a similar coefficient of friction to Tyvek™, Teflon™ or like substances. The liner socks may also have multiple layers of material; that is, socks within socks.) The left sock **182** is attached to the left belt guard **68** at one end and to the left load distribution section **17** of the belt at the other end. A hole in the left sock allows the peg **34** to be inserted into the eyelet **33**. The left sock is attached to the belt at any point near the free end of the load distribution section. The right sock **183** is attached to the right belt guard **67** at one end and to the right load distribution section **16** of the belt at the other end. The right sock is attached to the belt at any point near the free end of the right load distribution section. The right sock wraps around the compression pad **65** and surrounds the breakable link.

**[0076]** The breakable link **89** is a cylinder made of aluminum or other suitable material. The central portion **190** of the cylinder has a smaller diameter than the end portions **191** and **192** of the cylinder. Since the link will break at the thinnest portion of the cylinder, the amount of force required to break the link is precisely controlled by setting the radius of the central portion **190** of the cylinder. If the link **89** breaks under tension then the two remaining ends of the link remain within the sock. The liner sock thus reduces the chance that a broken link will lash out and cause injury to the patient or bystanders. In addition, a separate bag or sleeve **184** may be attached to the belt near either end of the link. The bag surrounds the breakable link and contains the link in the event that the link breaks.

**[0077]** The link or links attached to the belt may be provided with additional features. For example, a link may be additionally designed to serve as a swivel joint. The swivel joint link connects the pull straps to the belt transition sections of the belt. The swivel joint link allows the load distribution sections to twist relative to the pull straps, about the longitudinal axis of the belt, without twisting the pull straps themselves. (The pull straps are sufficiently stiff that they do not twist during use.) The swivel joint link helps prevent the device from malfunctioning as a result of the pull straps becoming twisted and helps prevent the link from breaking due to shear forces or twisting forces. In other devices, separate swivel joints are provided and attached to the belt as described above. For these devices the swivel joint and the link may be connected to each other, but may also be disposed at separate locations on the belt.

**[0078]** In addition, a link or swivel link may be designed to be re-engaged (or to be re-attached to the belt) if one or more links do separate. For example, the link or swivel link may be attached to the belt with a clip that fails at a pre-determined force, but that can be re-attached to the belt. Similarly, the swivel link may be provided in two pieces joined by a joint that separates at a pre-determined force, but that can be re-attached to each other.

(Other re-attachable links or swivel link designs may also be used.) Thus, in the event of a link failure during chest compressions, the entire belt cartridge need not be replaced. Instead, the problem that caused the failure can be addressed, the failed link or links quickly re-engaged or re-attached and chest compressions then resumed. The re-attached link will fail at the same force as the force required to cause the link to originally fail.

**[0079]** The detachable link may comprise a detachable device operably connected to a force sensor, pressure sensor or strain gauge. The detachable device is highly resistant to breaking under force, but the detachable device will separate when the force sensor, pressure sensor or strain gauge measures an excessive force. Such a detachable device may be designed so that a user may reattach the link to itself or to the belt, thereby allowing the user to restart compressions quickly.

**[0080]** Figure 14 shows the belt **3** attached to the breakable link **89**. The breakable link is located on the belt in a place where the belt tension most closely corresponds to the actual load on the patient. Thus, the breakable link **89** is located between the pull straps and the transition-section of the belt. The breakable link may be located elsewhere on the belt, though the link would have to be adjusted to break at a different amount of belt tension since the tension and shear forces on the link would be different. Multiple links may be provided on either side of the belt. Preferably, one link is provided on each side of the belt relative to the patient

**[0081]** The link is designed to break in the presence of excessive tension (over about 90.7 kg (200 pounds) to about 226.8kg (500 pounds) on one side of the patient, and preferably at about 136.1kg (300 pounds). The breakable link breaks cleanly under excessive tension and experiences little plastic deformation before breaking. Thus, if the belt experiences excessive tension, the link will break, the belt will separate and the patient will be protected from excessive forces.

**[0082]** To attach the link to the belt, the belt is separated into two sections and corresponding flaps **185** and **186** near opposing ends of each section are folded over themselves to form pockets in each belt section. The pockets are held in place by stitches **187**. A pin **188** is disposed within each pocket and held in place by the stitches. The pins are exposed in the area of holes **189** that are provided in a corresponding end of each pocket. The holes provide space to receive the ends of the link and allow the pins to be threaded through apertures provided in the link. (The unexposed portions of the pins are shown in phantom to indicate their position inside the pockets and inside the link.) Thus, a pin connects a section of the belt to the link and the belt sections are thereby connected to each other via the link. The link is designed so that the center of the link will break, thereby separating the belt, before the pins or any other part of the link will break.

**[0083]** Figure 15 shows another cross-section of the breakable link. The breakable link **89** is an aluminum cyl-

inder. The central portion **190** of the cylinder has a smaller diameter than the end portions **191** and **192** of the cylinder. Since the link will break at the thinnest portion of the cylinder, the amount of force required to break the link is precisely controlled by setting the cross-sectional area of the smallest part of the central portion **190** of the cylinder. The material used to make the link also controls the force required to break the link. Different materials will break at different levels of force depending on a number of factors, including the cross sectional area of the link, the type of alloy used, whether the link is heat treated, the type of surface finish provided and the like.

**[0084]** Each end portion of the cylinder is provided with a hole **193** to accommodate the pins. The holes are drilled from either side of the cylinder with a conical drill. The conical drill creates opposing ridges **194** in the center of each hole. A pin contacts the link in the area of the ridges so that the pin is loaded at a point. This orientation prevents excessive forces from developing in directions other than in the direction the link is intended to break. The combination of the conical holes and the pins permit the link to bend or break only in the direction the link is intended to break. To further reduce bending or shear forces, the pins and/or the link are coated with Teflon™ (polytetrafluoroethylene) so that the pins may wobble with minimal friction within the link holes.

**[0085]** The breakable link has a length of 23.93 mm (0.942 inches), has a radius of 7.87 mm (0.310 inches) at the end portions and a radius of 2.24 mm (0.088 inches) at the thinnest central portion. The end portions of the link are 7.87 mm (0.310 inches) long each and the central portion of the link is 8.18 mm (0.322 inches) long. The thinnest central portion of the link is 1.07 mm (0.042 inches) long (and is part of the overall 8.18 mm (0.322 inch) length of the central section). An aluminum link of these dimensions will break when about 136.1 kg (300 pounds) of force is applied along the long axis of the link. The dimensions of the link may be varied to vary the force required to break the link, preferably about 136.1 kg (300 pounds) for the detachable device and belt cartridge shown in Figures 3 through 5. In addition to aluminum, the link may be made of a variety of materials, including other metals (such as steel or magnesium), polymers, composites or fibers. However, the link must predictably break when exposed to a given force applied in a given direction.

**[0086]** Other devices and methods may also be used to increase the safety of using a belt to perform chest compressions. For example, other forms of reducing the coefficient of friction of the belt may be used. The liner, belt or patient may be provided with a layer of friction-reducing material. For example, a layer of Teflon™ may be placed between the belt and the liner sock, between the belt and the compression pad or between the belt and the patient. (The layer of friction-reducing material decreases the chance that the patient will be injured during chest compressions and increases the energy efficiency of chest compressions.) Thus, one or more liner

sheets can replace or be used in addition to the liner socks to prevent injury to the patient. The coefficient of friction of the belt may also be reduced by super-cooling the belt. A lubricating substance, such as talc powder or a liquid may be placed between the patient and the belt, but means for preventing the lubricant from entering the belt drive platform should also be provided.

**[0087]** Additionally, the belt and belt cartridge may be provided in different sizes to accommodate differently sized patients. The belt and belt cartridge described herein is sized to accommodate about 95% of the population. Thus, if one smaller belt size and one larger belt size are available, then the three belt sizes will accommodate the vast majority of all patient sizes (though a range of belt sizes is possible). Another design scheme uses one size of belt and cartridge and provides detachable belt extensions to increase the size of the belt. A belt extension is a length of belt having similar properties to the belt on the cartridge. A suitable fastener, such as a hook and loop fastener or a detachable link, connects the belt extension to the belt on the cartridge.

**[0088]** When multiple belt sizes are available the belt may be provided with markings that allow the rescuer to measure the length of the belt with respect to the patient. The user then manually enters the size of the belt into the belt drive platform through a user interface in the belt drive platform. To accommodate the new belt size the device's software alters how the device performs chest compressions. Thus, the device will perform chest compressions consistent with medical guidelines, regardless of the size of the belt or the size of the patient (to the design limits of the device).

**[0089]** In other devices, the belt cartridge is provided with an identifying code, pinout or other identifier that automatically inputs the size of the belt into the belt drive platform. The device changes how it performs chest compressions (in terms of how much belt slack is taken up by the means for tightening) based on the size of the belt. In the case of belt extensions, the new belt length is manually entered into the processor, though the belt extension may be provided with a switch or other identifying mechanism that automatically inputs the new overall belt length into the processor. Again, the belt drive platform's software accordingly alters how the device performs chest compressions.

**[0090]** In addition, other means for tightening the belt may be used to drive the belt, such as multiple motors and drive spools. Moreover, the belt drive platforms or housings containing such means may have a variety of shapes and sizes, so long as the belt and belt cartridge are designed to attach to a particular belt drive platform and to means for tightening the belt.

**[0091]** While the preferred embodiments of the devices and methods have been described in reference to the environment in which they were developed, they are merely illustrative of the principles of the inventions. Other embodiments and configurations may be devised without departing from the scope of the appended claims.

**Claims**

1. A system for performing chest compressions on a patient (1), said system comprising a compression belt (3) and a belt drive platform (4), wherein the belt drive platform (4) comprises a housing (6), a motor disposed within the housing and a drive spool (42) upon which the belt spools during use and which is operatively connected to the motor, wherein: said belt (3) has a width (99) along the superior-inferior height of the patient (1) when the belt (3) is disposed around the patient (1), said belt (3) also having a length (100) along the medial-lateral circumference of the patient (1) when the belt (3) is disposed around the patient (1); said belt (3) has pull straps (18, 19), a first load distribution section (17) attached to a first end of the pull straps (18, 19), and a second load distribution section (16) attached to a second end of the pull straps (18, 19); wherein the first load distribution section (17) and the second load distribution section (16) are wider than the pull straps (18, 19); and the compression belt (3) is operably connected to a compression belt cartridge (5) which is releasably attachable to the belt drive platform (4); and the compression belt (3) is further provided with means (66) for releasably attaching the compression belt (3) to the drive spool (42).
2. The system of claim 1, wherein the belt (3) further comprises a first transition section (21) attached to the first load distribution section (17) and to the pull straps (18, 19), and a second transition section (20) attached to the second load distribution section (16) and to the pull straps (18, 19), wherein the second transition section (20) is opposite the first transition section (21).
3. The system of claim 2, wherein the first and second transition sections (20, 21) have a trapezoidal shape.
4. The system of claim 2, wherein the belt cartridge (5) further comprises a first reinforcing plate (98) attached to the first transition section (21) and a second reinforcing plate (97) attached to the second transition section (20).
5. The system of claim 1, wherein the belt cartridge (5) further comprises an eyelet (33) attached to the first load distribution section (17) and a peg (34) attached to the second load distribution section (16), wherein the eyelet (33) is sized and dimensioned to receive the peg (34) and wherein the peg (34) may be inserted into the eyelet (33) when the first and second load distribution sections (16, 17) are secured over the chest of the patient (1).

6. The system of claim 5, further comprising a means for determining if the peg (34) is inserted into the eyelet (33).

7. The system of claim 1, wherein the belt (3) comprises at least one layer of unidirectional fibers held together with a resin.

8. The system of claim 1, wherein:

the belt (3) comprises a plurality of layers and each layer comprises a plurality of fibers held together by a resin; wherein all of the fibers composing any given layer are oriented along one direction; and the orientation of the fibers of one layer is different from the orientation of the fibers of a second layer.

**Patentansprüche**

1. Ein System zum Durchführen einer Brustkompression bzw. Herzdruckmassage an einem Patienten (1), wobei das System einen Kompressions-Gurt (3) und eine Gurt-Antriebs-Plattform (4) aufweist, wobei die Gurt-Antriebs-Plattform (4) ein Gehäuse (6), einen in dem Gehäuse angeordneten Motor und eine Antriebs-Spule (42) aufweist, auf welche der Gurt während der Verwendung aufgespult bzw. aufgewickelt wird und welche betriebsfähig bzw. betreibbar mit dem Motor verbunden ist, wobei:

der Gurt (3) eine Breite (99) entlang der superior-inferior-Höhe von dem Patienten (1) hat, wenn der Gurt (3) um den Patienten (1) angeordnet ist, wobei der Gurt (3) auch eine Länge (100) entlang des medial-lateral-Umfangs von dem Patienten (1) hat, wenn der Gurt (3) um den Patienten (1) angeordnet ist; der Gurt (3) Zugbänder (18, 19), einen ersten Last-Verteilungs-Abschnitt (17), der an einem ersten Ende von den Zugbändern (18, 19) angebracht ist, und einen zweiten Last-Verteilungs-Abschnitt (16) hat, welcher an einem zweiten Ende von den Zugbändern (18, 19) angebracht ist; wobei der erste Last-Verteilungs-Abschnitt (17) und der zweite Last-Verteilungs-Abschnitt (16) breiter sind als die Zugbänder (18, 19); und der Kompressions-Gurt (3) betriebsfähig bzw. betreibbar verbunden ist mit einem Kompressions-Gurt-Modul (5), welches lösbar an der Gurt-Antriebs-Plattform (4) anbringbar ist; und der Kompressions-Gurt (3) ferner mit einem Mittel (66) zum lösbaren Anbringen des Kompressions-Gurts (3) an der Antriebs-Spule (42) versehen ist.

2. Das System nach Anspruch 1, wobei der Gurt (3) ferner einen ersten Übergangsabschnitt (21), welcher an dem ersten Last-Verteilungs-Abschnitt (17) und den Zugbändern (18, 19) angebracht ist, und einen zweiten Übergangsbereich (20) aufweist, welcher an dem zweiten Last-Verteilungs-Abschnitt (16) und den Zugbändern (18, 19) angebracht ist, wobei der zweite Übergangsabschnitt (20) dem ersten Übergangsabschnitt (21) gegenüber liegt. 5
3. Das System nach Anspruch 2, wobei der erste und der zweite Übergangsabschnitt (20, 21) eine Trapezform haben. 10
4. Das System nach Anspruch 2, wobei das Gurt-Modul (5) ferner eine erste Verstärkungs-Platte (98), welche an dem ersten Übergangsabschnitt (21) angebracht ist, und eine zweite Verstärkungs-Platte (97) aufweist, welche an dem zweiten Übergangsabschnitt (20) angebracht ist. 15 20
5. Das System nach Anspruch 1, wobei das Gurt-Modul (5) ferner eine Öse oder ein Loch (33), welches an dem ersten Last-Verteilungs-Abschnitt (17) angebracht ist, sowie einen Zapfen (34) aufweist, welcher an dem zweiten Last-Verteilungs-Abschnitt (16) angebracht ist, wobei das Loch (33) eine Größe hat und dimensioniert ist, um den Zapfen (34) aufzunehmen, und wobei der Zapfen (34) in das Loch (33) eingesetzt werden kann, wenn der erste und der zweite Last-Verteilungs-Abschnitt (16, 17) über der Brust von dem Patienten (1) fixiert bzw. gesichert werden. 25 30
6. Das System nach Anspruch 5, ferner aufweisend ein Mittel zum Ermitteln, ob der Zapfen (34) in das Loch (33) eingesetzt ist. 35
7. Das System nach Anspruch 1, wobei der Gurt (3) zumindest eine Lage von unidirektionalen Fasern aufweist, welche mit einem Harz zusammengehalten sind. 40
8. Das System nach Anspruch 1, wobei: 45
 

der Gurt (3) eine Mehrzahl von Lagen aufweist, wobei jede Lage eine Mehrzahl von Fasern aufweist, welche mit einem Harz zusammengehalten sind;

wobei alle der Fasern, welche irgendeine gegebene Lage bilden, entlang einer Richtung orientiert sind; und

die Orientierung der Fasern von einer Lage unterschiedlich ist zu der Orientierung der Fasern von einer zweiten Lage. 50 55

## Revendications

1. Système destiné à réaliser des compressions thoraciques sur un patient (1), ledit système comprenant une courroie de compression (3) et une plateforme d'entraînement de courroie (4), laquelle plateforme d'entraînement de courroie (4) comprend un boîtier (6), un moteur disposé à l'intérieur du boîtier, et une bobine d'entraînement (42) sur laquelle la courroie s'enroule pendant l'utilisation et qui est raccordée de manière opérationnelle au moteur, dans lequel :

ladite courroie (3) a une largeur (99) le long de la hauteur supérieure-inférieure du patient (1) lorsque la courroie (3) est disposée autour du patient (1), ladite courroie (3) ayant également une longueur (100) le long de la circonférence médiane-latérale du patient (1) lorsque la courroie (3) est disposée autour du patient (1) ; ladite courroie (3) a des sangles de traction (18, 19), une première section de distribution de charge (17) fixée à une première extrémité des sangles de traction (18, 19), et une seconde section de distribution de charge (16) fixée à une seconde extrémité des sangles de traction (18, 19) ;

dans lequel la première section de distribution de charge (17) et la seconde section de distribution de charge (16) sont plus larges que les sangles de traction (18, 19) ; et

la courroie de compression (3) est raccordée de manière opérationnelle à une cartouche de courroie de compression (5) qui peut être fixée de manière amovible à la plateforme d'entraînement de courroie (4) ; et

la courroie de compression (3) est en outre prévue avec des moyens (66) pour fixer de manière amovible la courroie de compression (3) sur la bobine d'entraînement (42).

2. Système selon la revendication 1, dans lequel la courroie (3) comprend en outre une première section de transition (21) fixée à la première section de distribution de charge (17) et aux sangles de traction (18, 19), et une seconde section de transition (20) fixée à la seconde section de distribution de charge (16) et aux sangles de traction (18, 19), la seconde section de transition (20) étant opposée à la première section de transition (21).
3. Système selon la revendication 2, dans lequel les première et seconde sections de transition (20, 21) ont une forme trapézoïdale.
4. Système selon la revendication 2, dans lequel la cartouche de courroie (5) comprend en outre une première plaque de renforcement (98) fixée à la première

re section de transition (21) et une seconde plaque de renforcement (97) fixée à la seconde section de transition (20).

5. Système selon la revendication 1, dans lequel la car- 5  
touche de courroie (5) comprend en outre un oeillet  
(33) fixé à la première section de distribution de char-  
ge (17) et un goujon (34) fixé à la seconde section  
de distribution de charge (16), dans lequel l'oeillet  
(33) est taillé et dimensionné pour recevoir le goujon 10  
(34) et dans lequel le goujon (34) peut être inséré  
dans l'oeillet (33) lorsque les première et seconde  
sections de distribution de charge (16, 17) sont  
fixées sur la poitrine du patient (1). 15
6. Système selon la revendication 5, comprenant en  
outre des moyens pour déterminer si le goujon (34)  
est inséré dans l'oeillet (33).
7. Système selon la revendication 1, dans lequel la 20  
courroie (3) comprend au moins une couche de fi-  
bres unidirectionnelles maintenues ensemble avec  
une résine.
8. Système selon la revendication 1, dans lequel : 25  
  
la courroie (3) comprend une pluralité de cou-  
ches et chaque couche comprend une pluralité  
de fibres maintenues ensemble par une résine ;  
dans lequel toutes les fibres composant l'une 30  
quelconque des couches données sont orien-  
tées le long d'une direction ; et  
l'orientation des fibres d'une couche est diffé-  
rente de l'orientation des fibres d'une seconde  
couche. 35

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Fig. 1

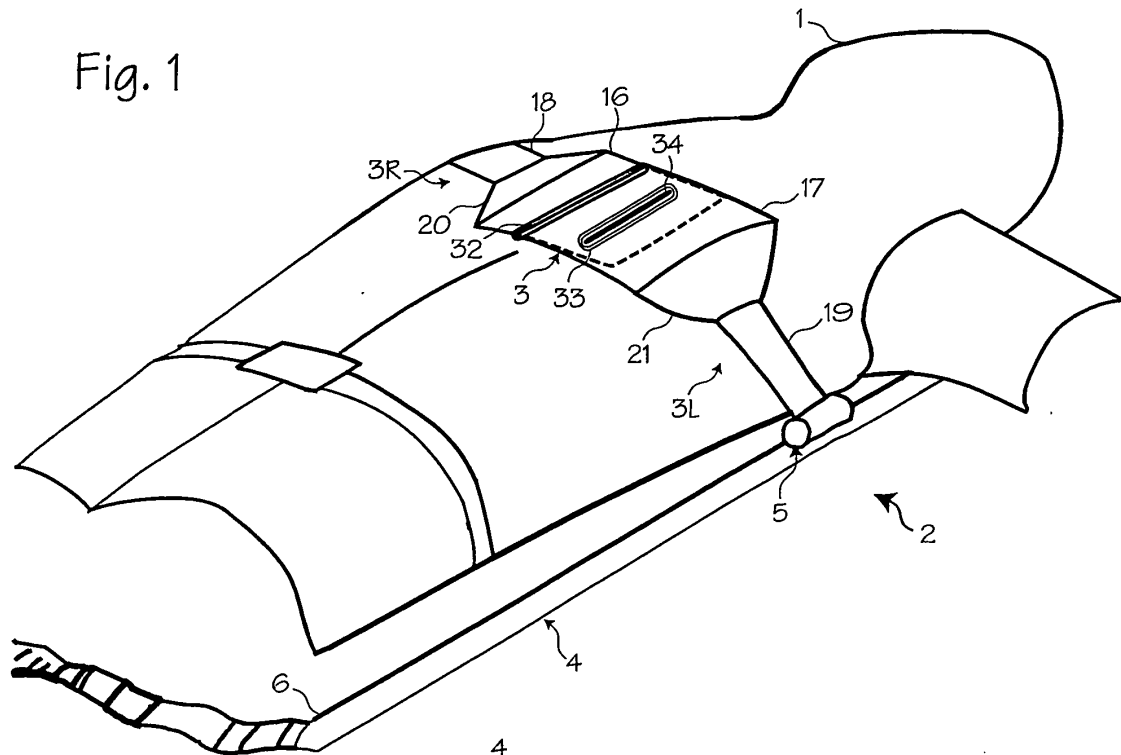


Fig. 2

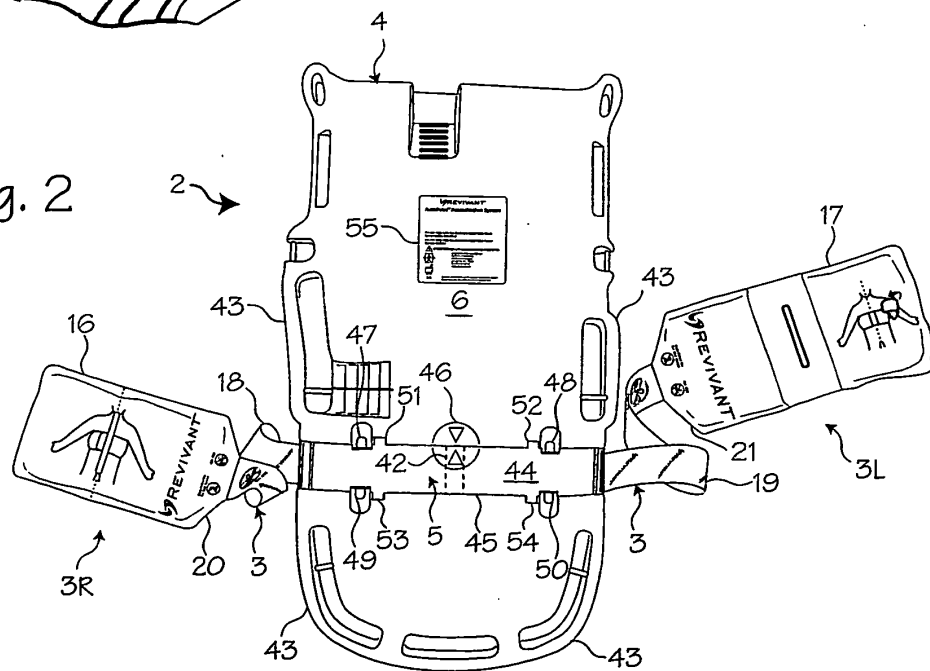


Fig. 3

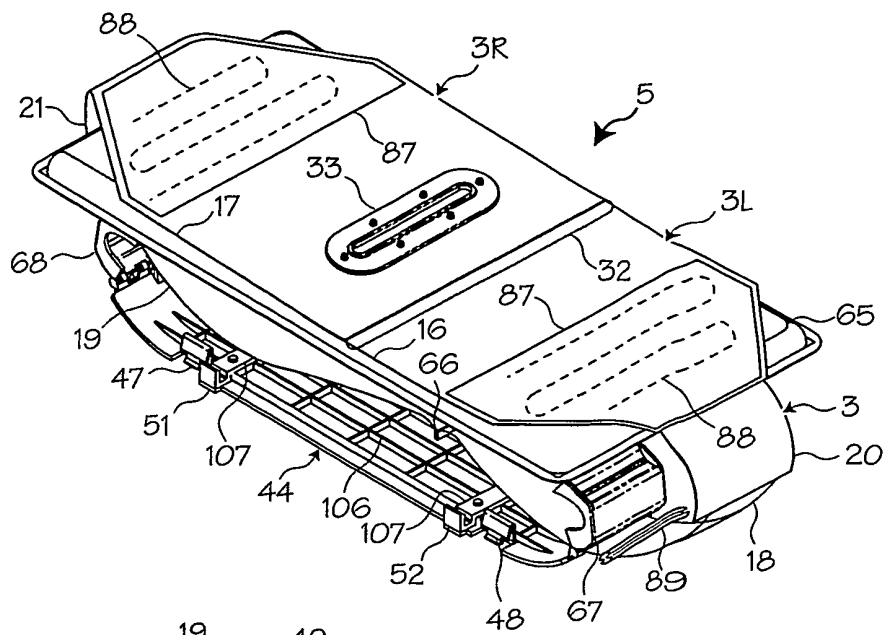


Fig. 4

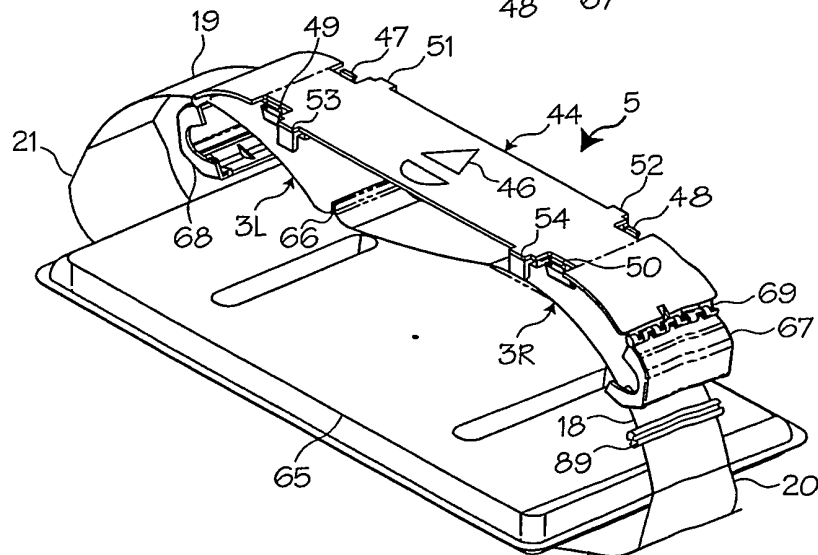
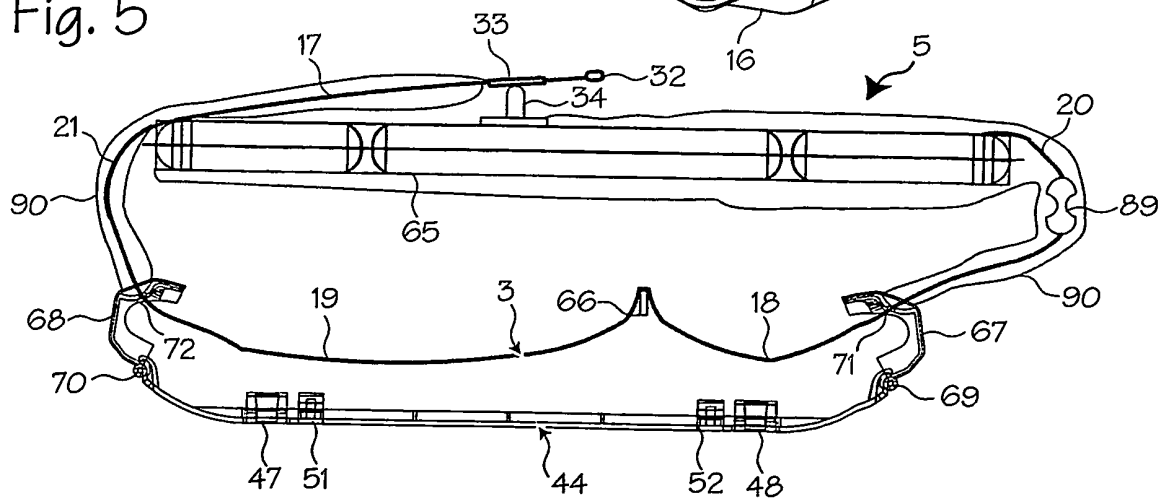


Fig. 5



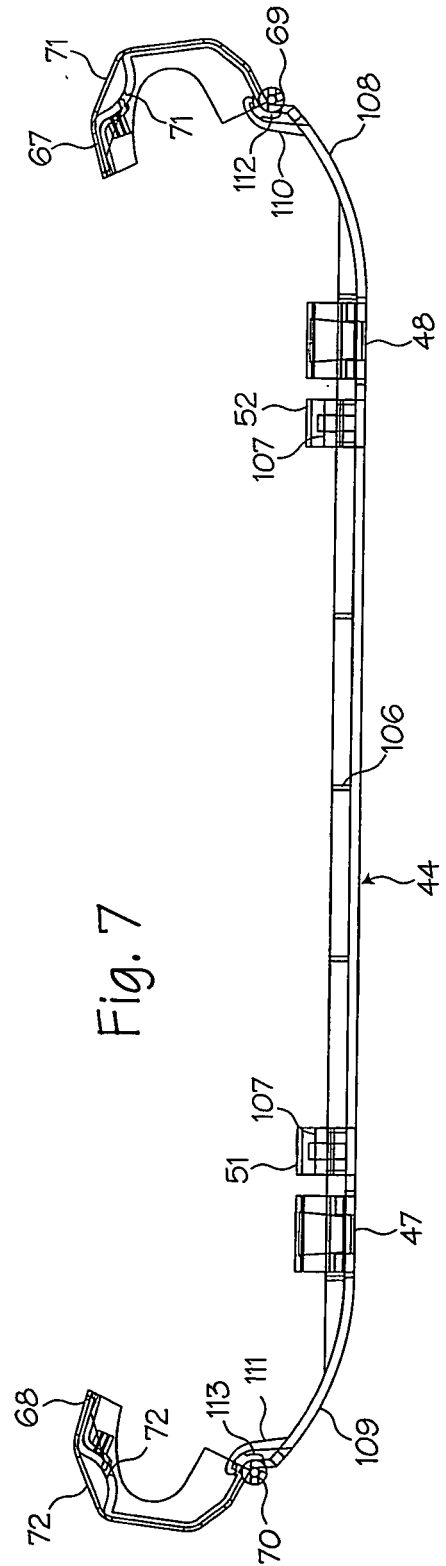
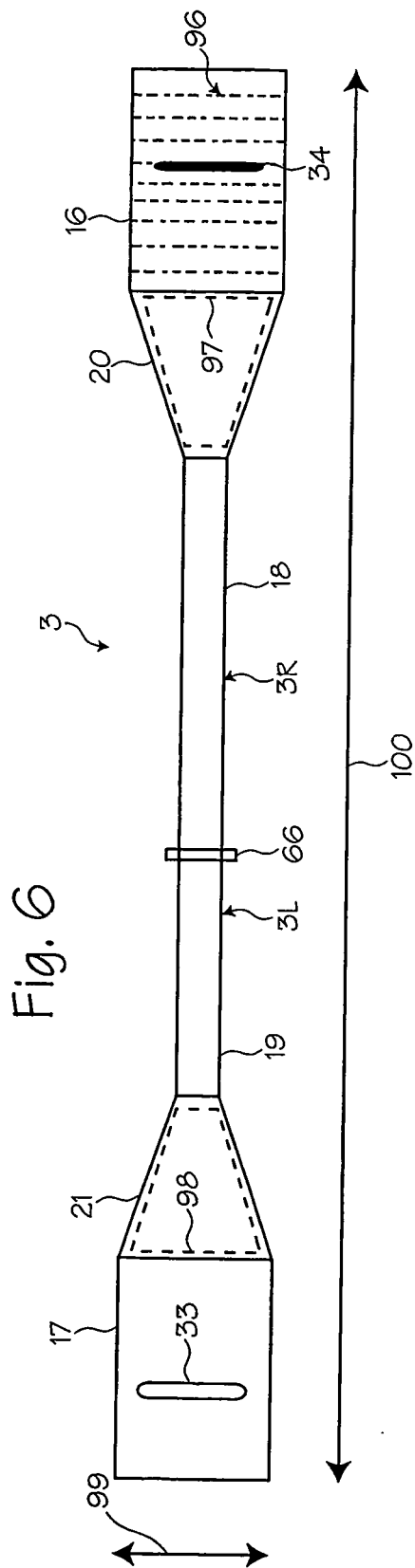


Fig. 8

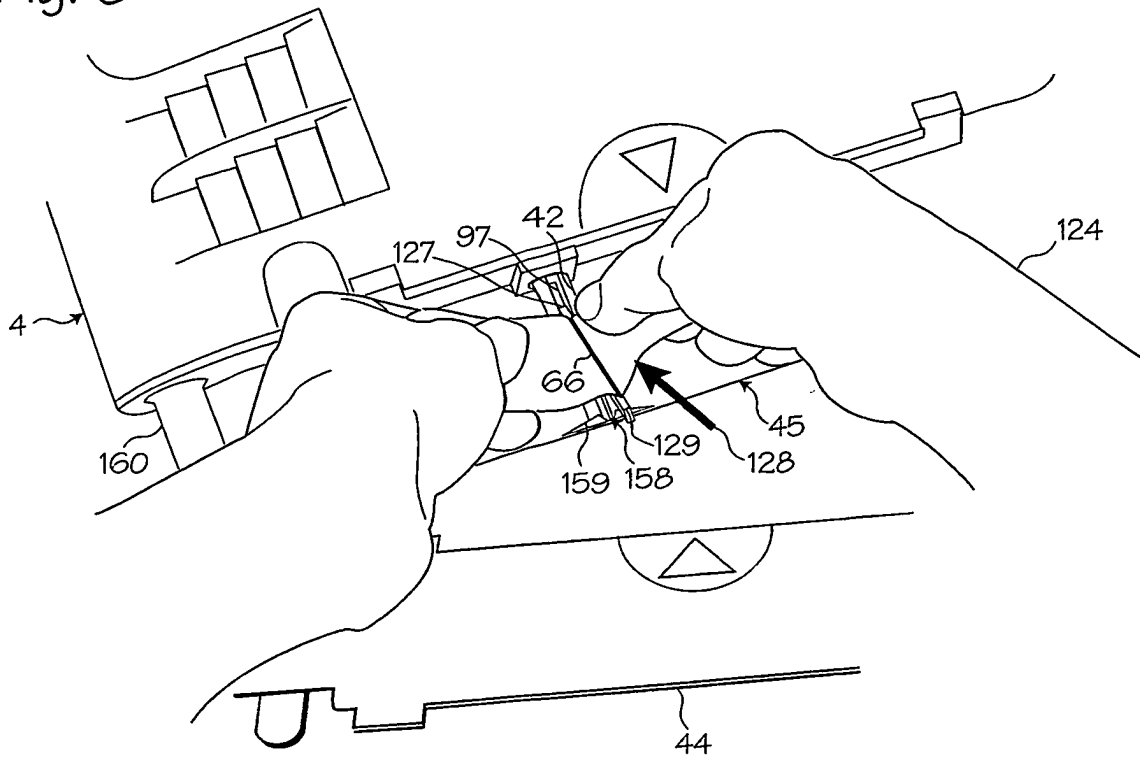


Fig. 9

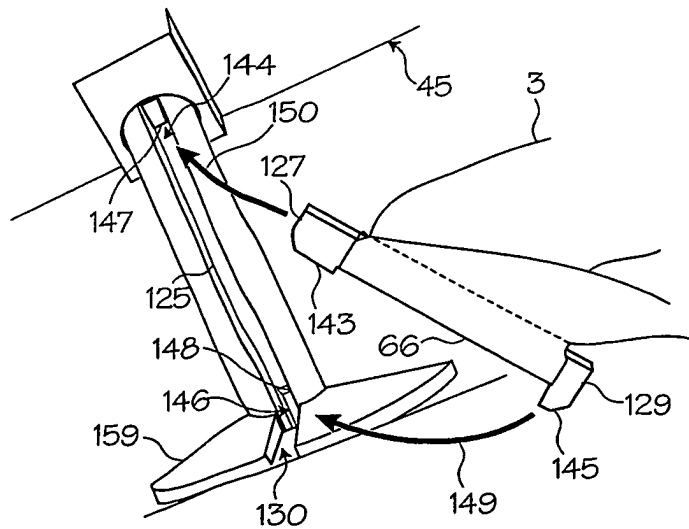


Fig. 10

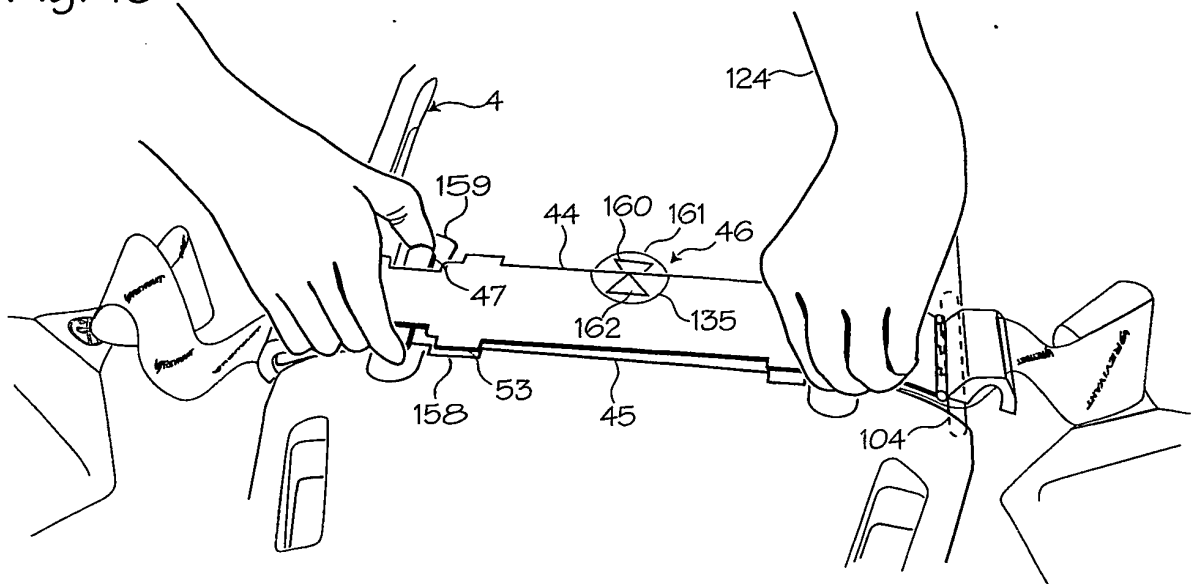


Fig. 11

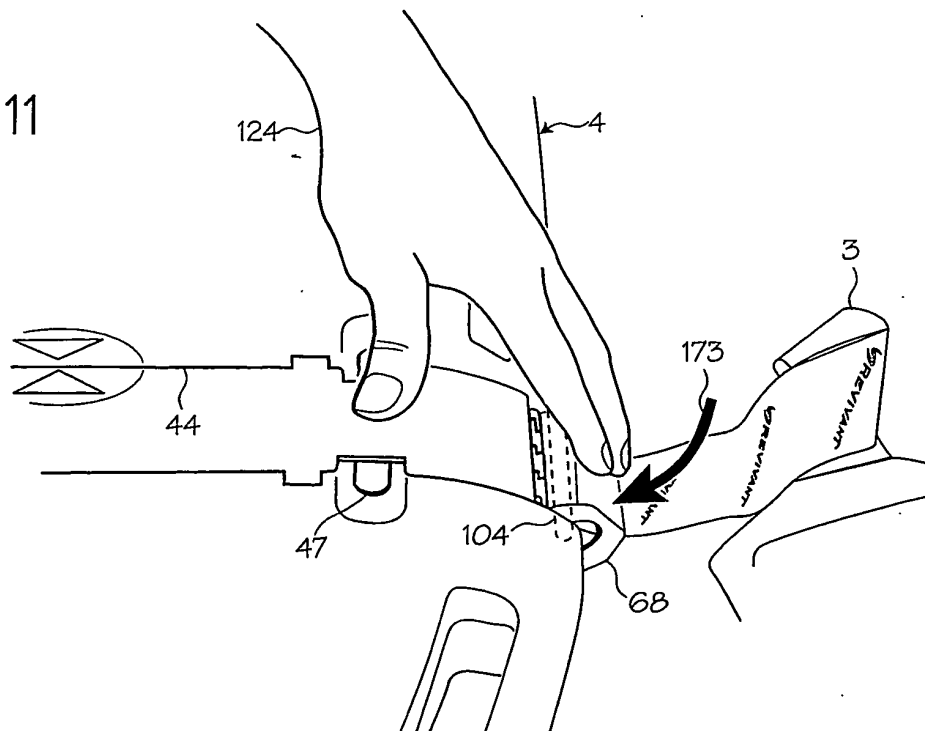
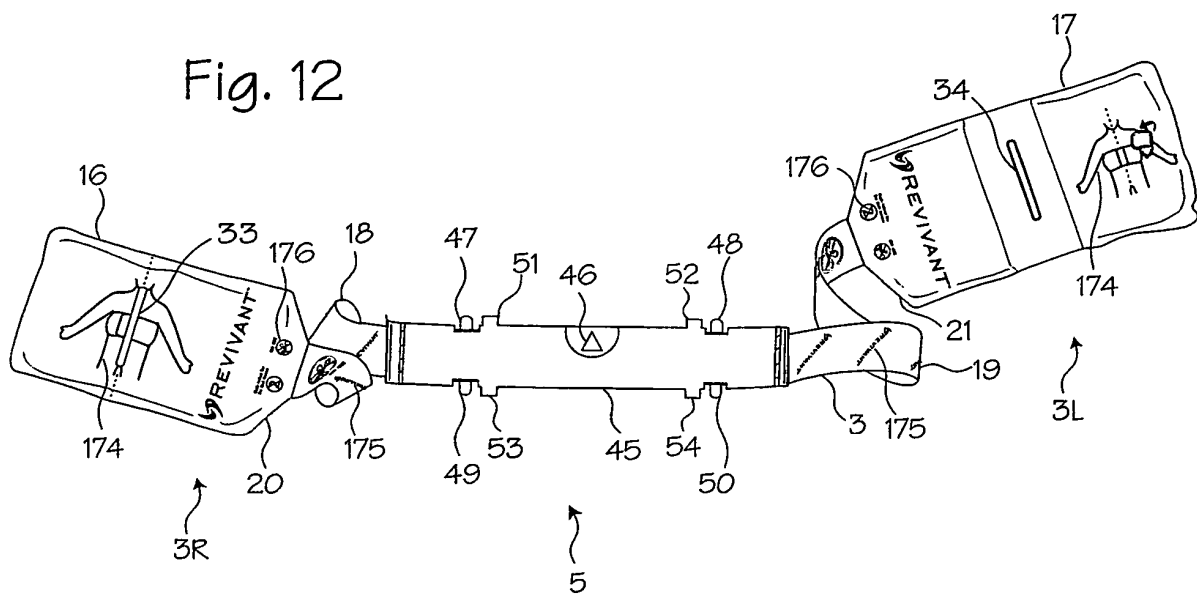
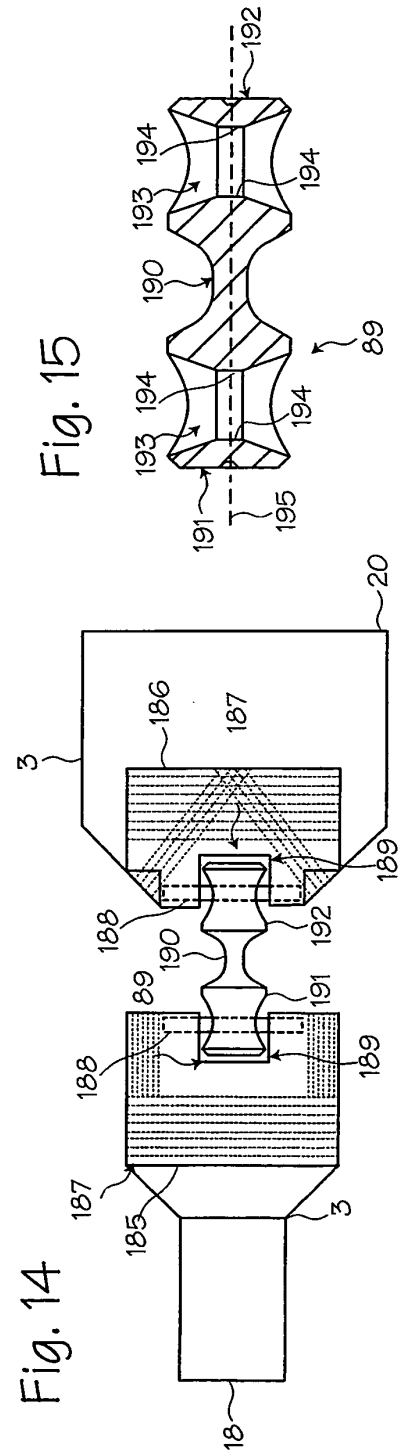
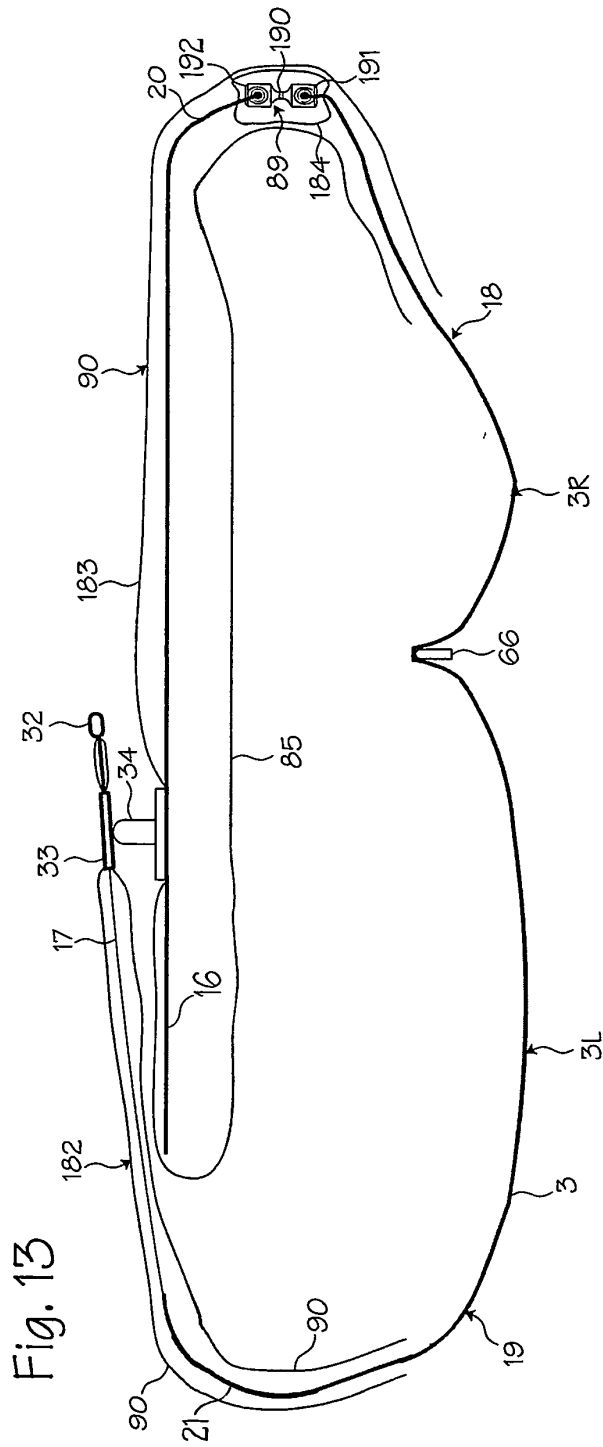


Fig. 12





## REFERENCES CITED IN THE DESCRIPTION

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