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(12) **United States Patent**
**Shan**

(10) **Patent No.: US 8,115,411 B2**
(45) **Date of Patent: *Feb. 14, 2012**

(54) **LED LIGHTING SYSTEM**

(75) Inventor: **Xinxin Shan**, Surrey (CA)

(73) Assignee: **LED Smart, Inc.**, Edmonton (CA)

( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 590 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **12/278,393**

(22) PCT Filed: **Feb. 9, 2007**

(86) PCT No.: **PCT/CA2007/000207**

§ 371 (c)(1),
(2), (4) Date: **Dec. 1, 2008**

(87) PCT Pub. No.: **WO2007/090292**

PCT Pub. Date: **Aug. 16, 2007**

(65) **Prior Publication Data**

US 2010/0019689 A1 Jan. 28, 2010

**Related U.S. Application Data**

(63) Continuation-in-part of application No. 11/351,074, filed on Feb. 9, 2006, now Pat. No. 7,307,391.

(30) **Foreign Application Priority Data**

Aug. 1, 2006 (CA) ..................................... 2555065

(51) **Int. Cl.**
*H05B 37/02* (2006.01)

(52) **U.S. Cl.** .................... **315/294**; 315/185 S; 315/291; 315/307; 362/545; 362/800

(58) **Field of Classification Search** .................... 315/21, 315/77, 185 S, 195, 291, 294, 307, 317, 545, 315/800; 362/234, 254, 276, 545, 800
See application file for complete search history.

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*Assistant Examiner* — Thai Pham
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(57) **ABSTRACT**

A light emitting diode lighting device and system that can be used for illuminating the interior and/or exterior of vehicles, aircraft, watercraft, signage or buildings is provided. It includes a voltage feedback constant current power supply circuitry and high power LEDs. The printed circuit assemblies are firmly mounted onto a continuous or semi-continuous mounting channel case that also works as a heat sink. By this means, it not only increases the reliability of the LED lighting tube but also it provides sufficient heat dissipation capability for the heat generated by the LEDs. Since the operating temperature of the LEDs is controlled and stays in cool condition, it dramatically increases the LED's lifetime and efficiency. The end caps of this LED lighting device are fully compatible with existing conventional fluorescent light fixtures and can directly replace those fluorescent lighting tubes in vehicles, mass-transit, watercrafts, aircrafts, signage, furniture, equipment or buildings with minimal modifications.

**20 Claims, 31 Drawing Sheets**

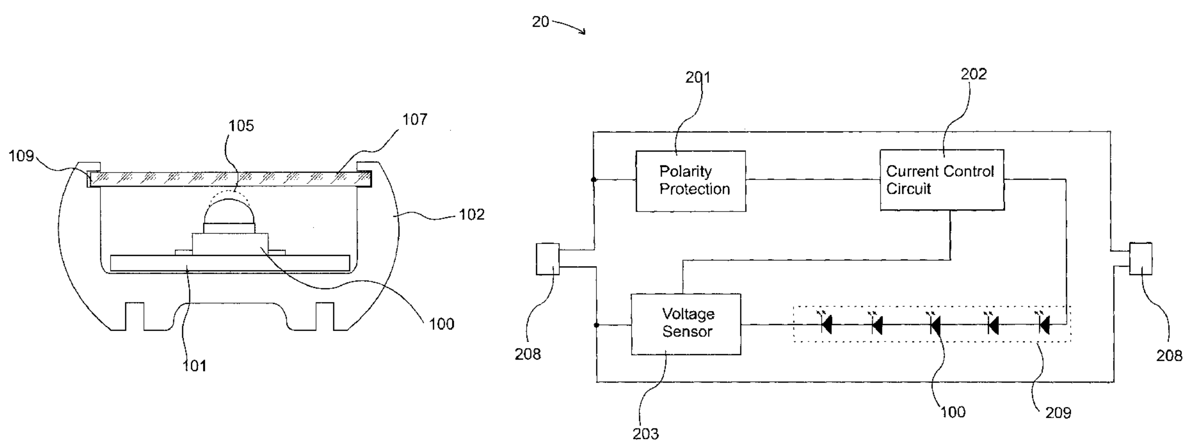

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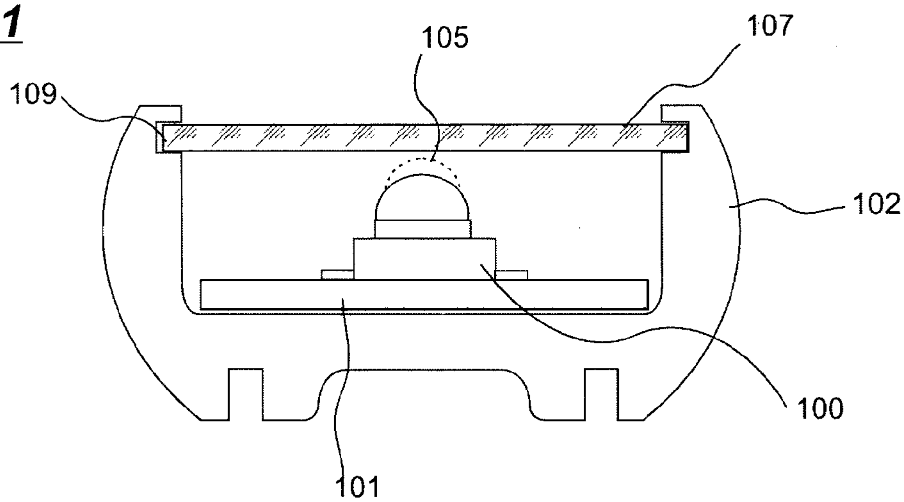
FIG. 1

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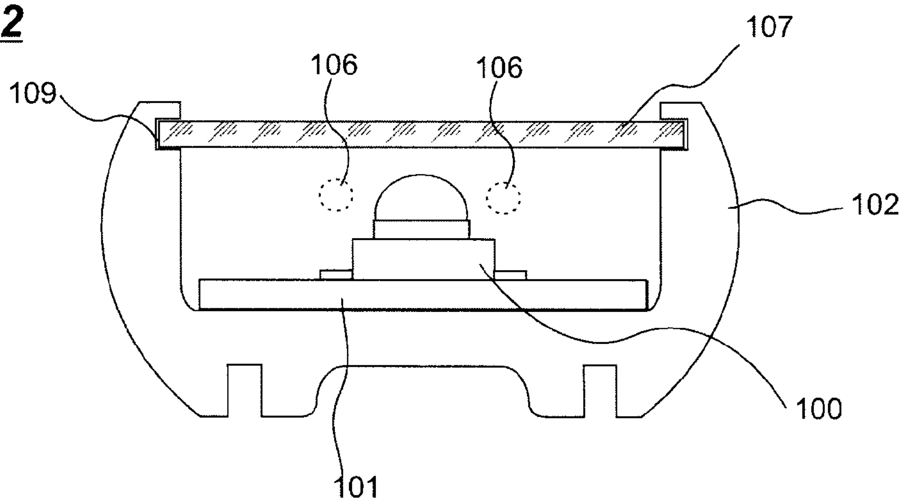


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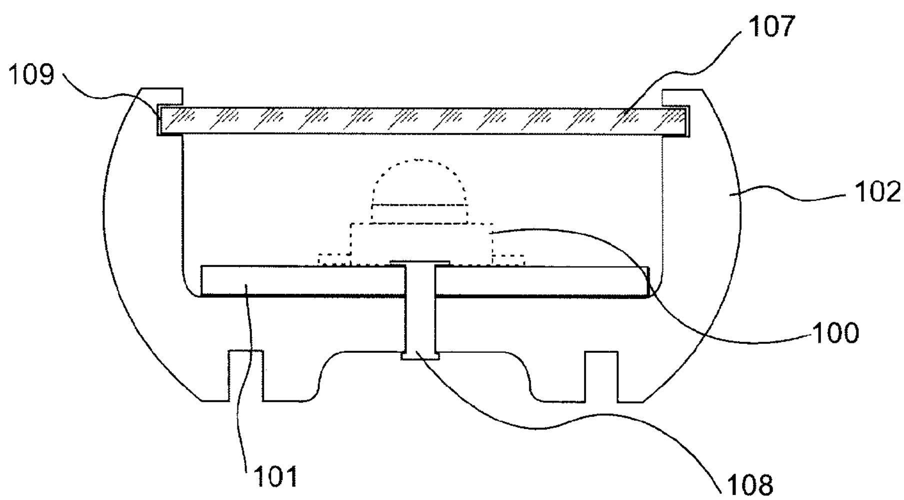

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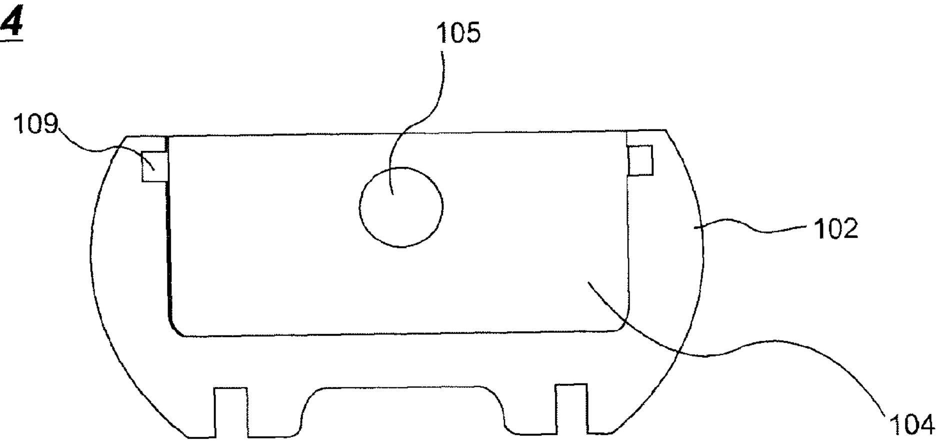


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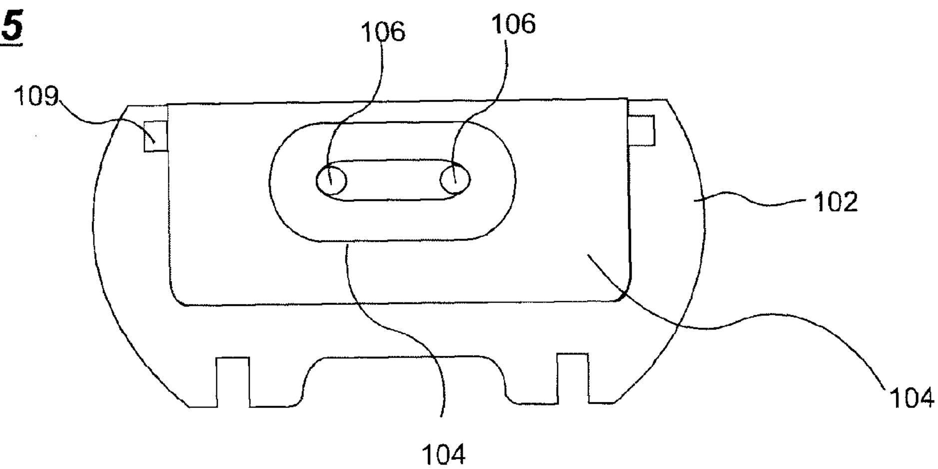


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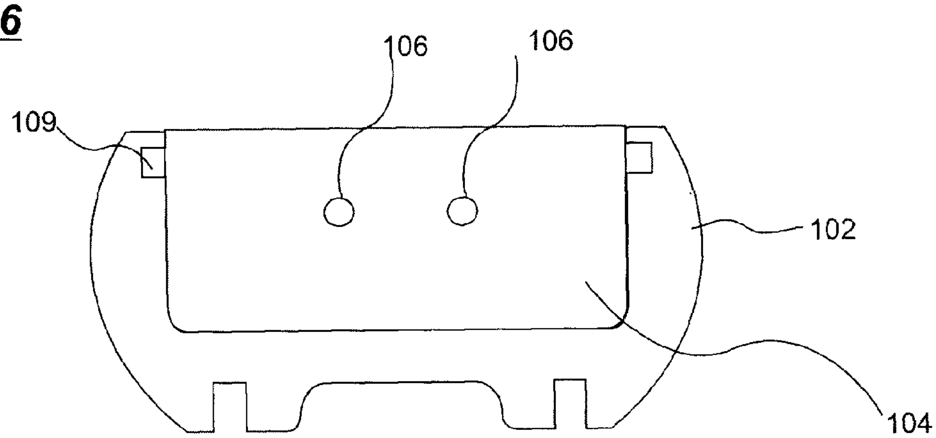

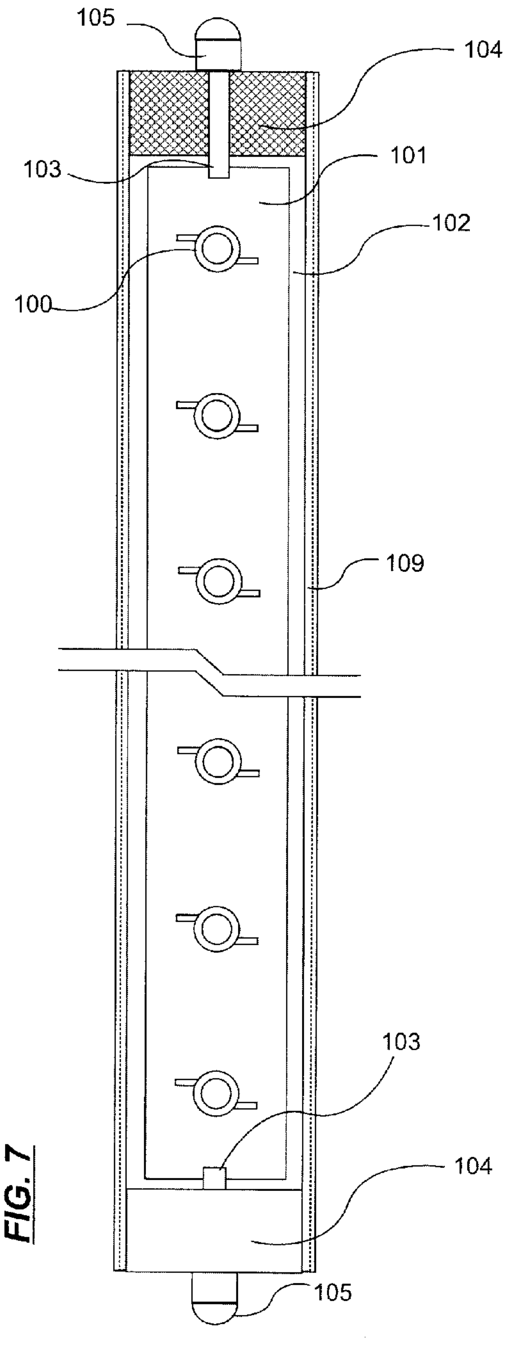
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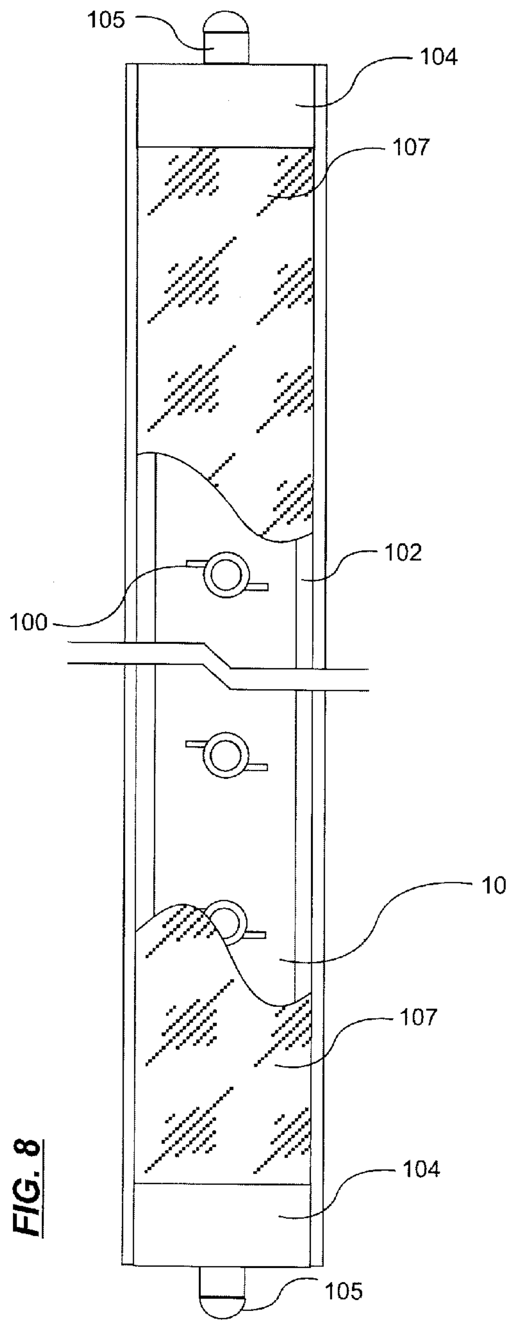
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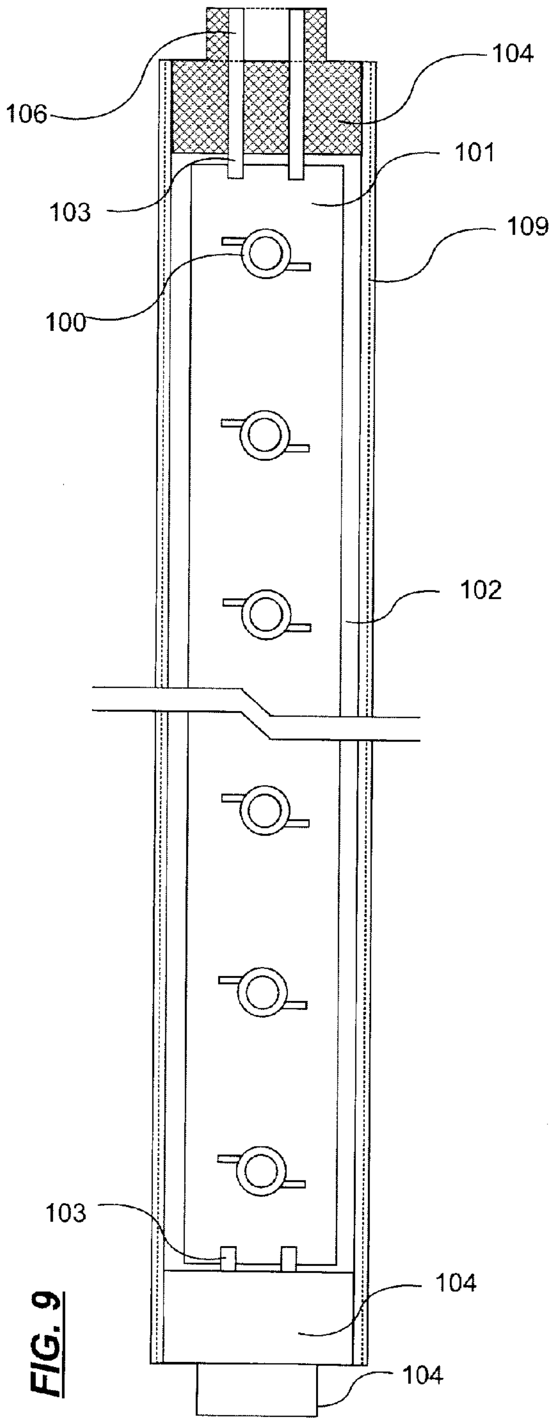
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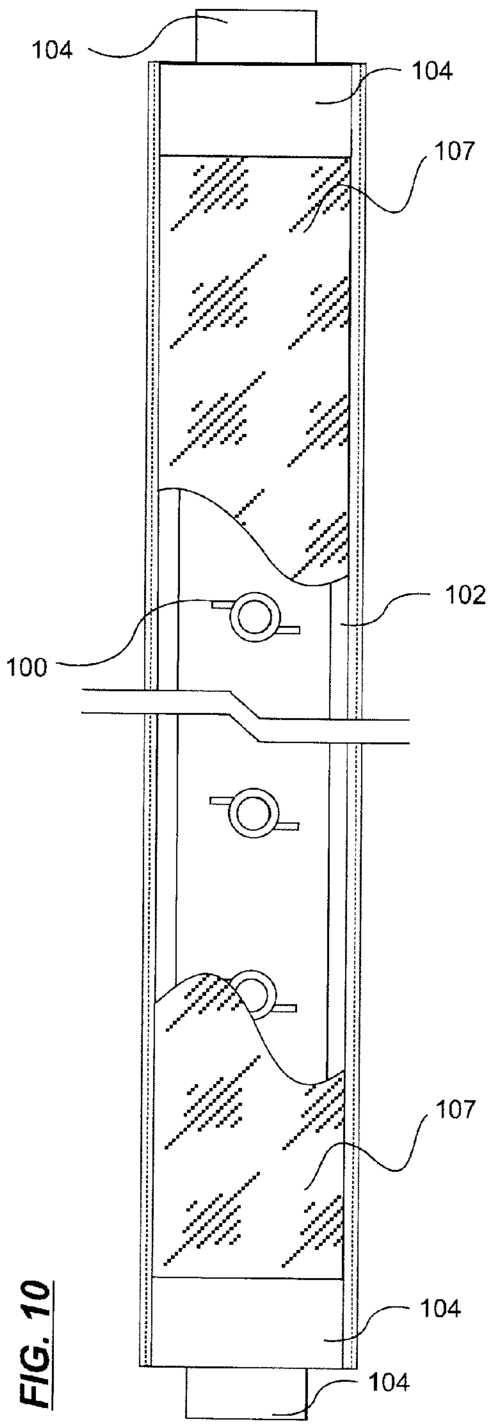
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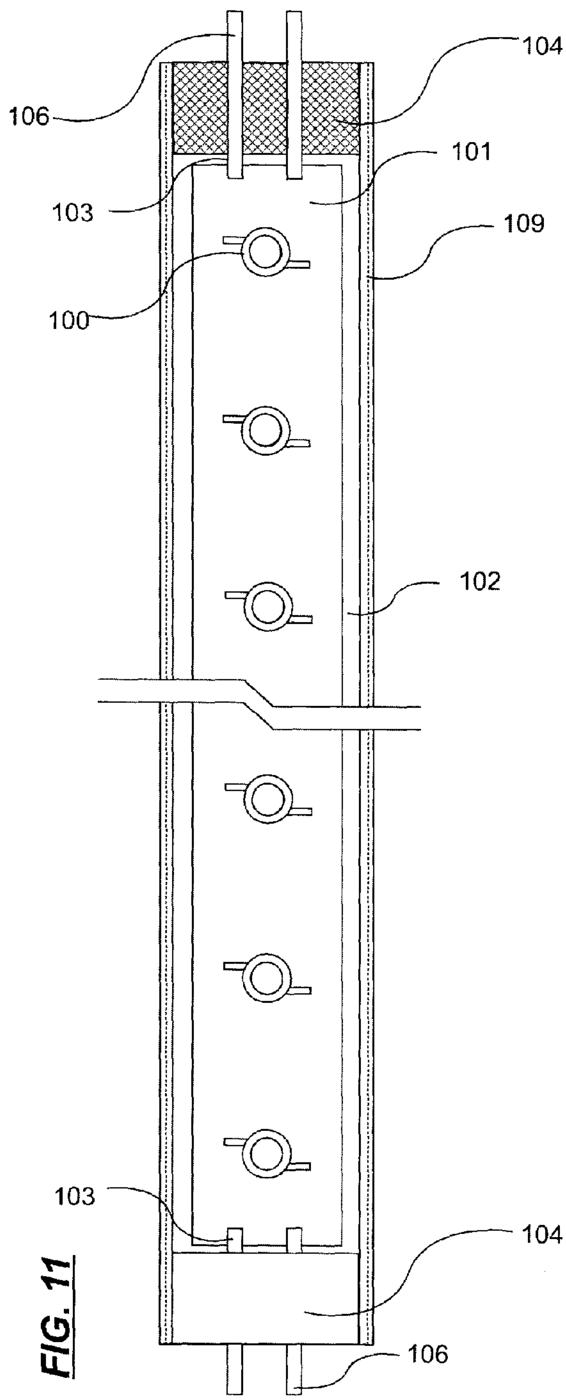
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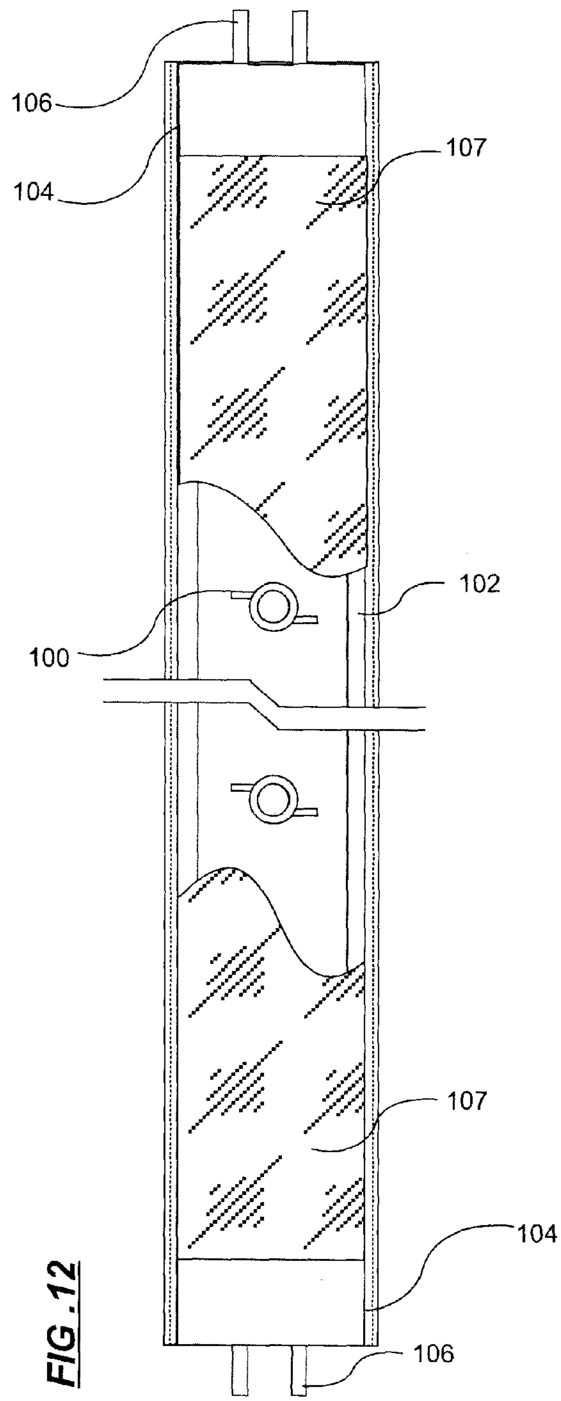
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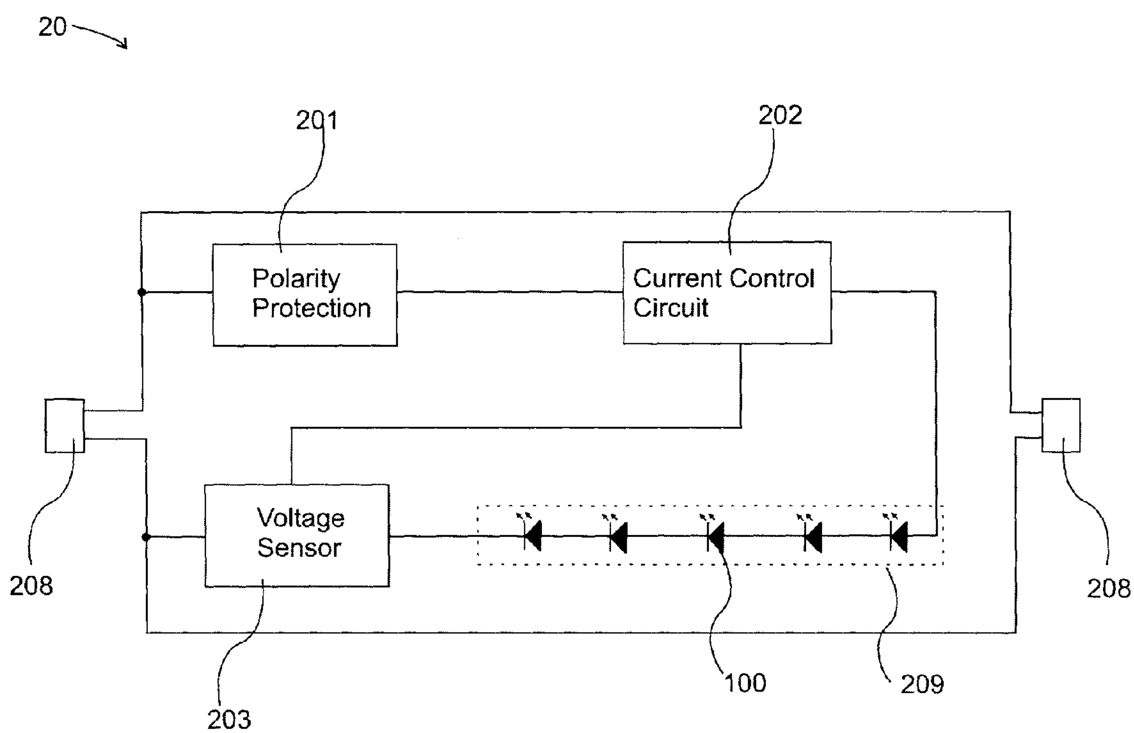
FIG. 12

FIG. 13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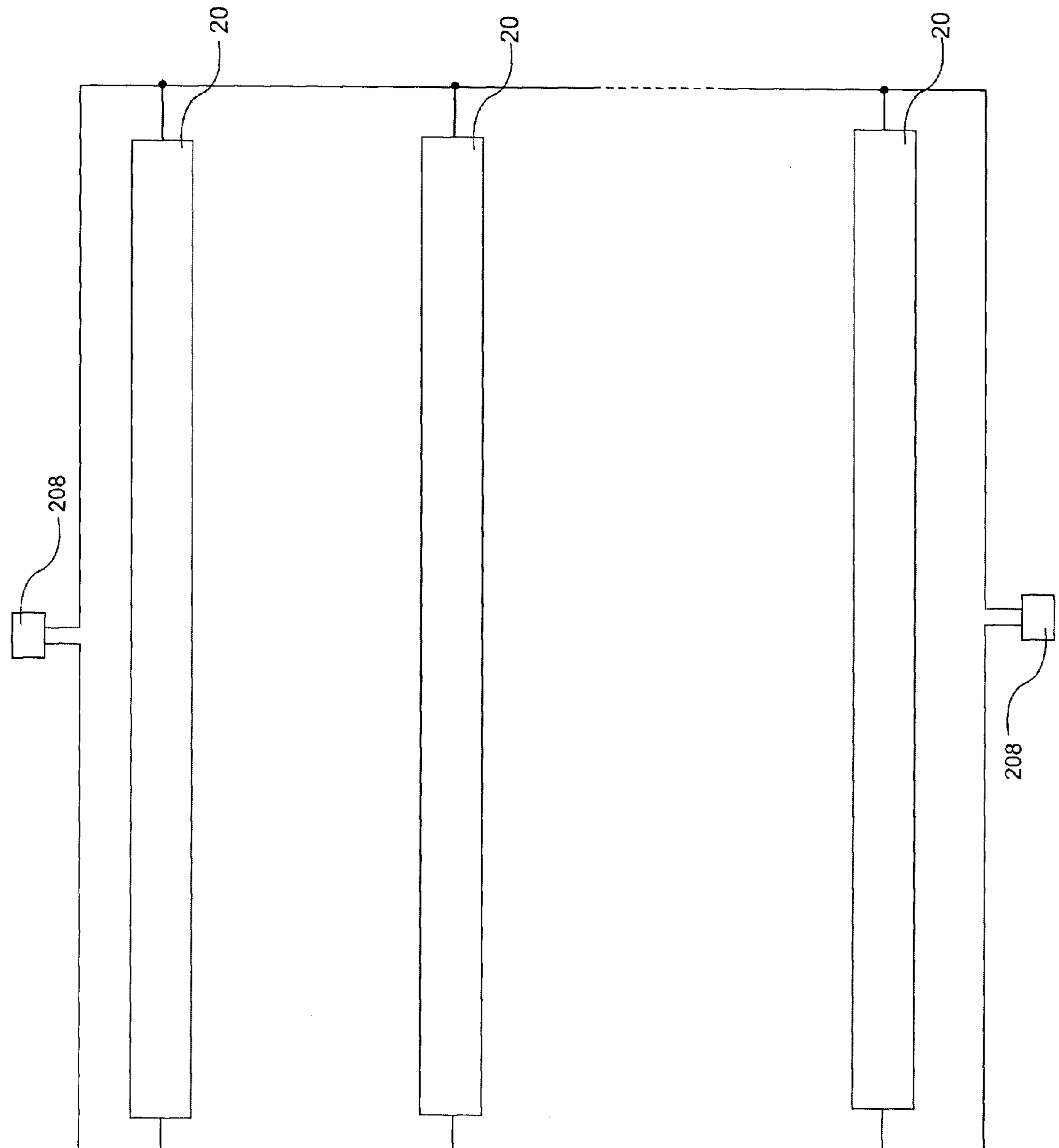


FIG. 14

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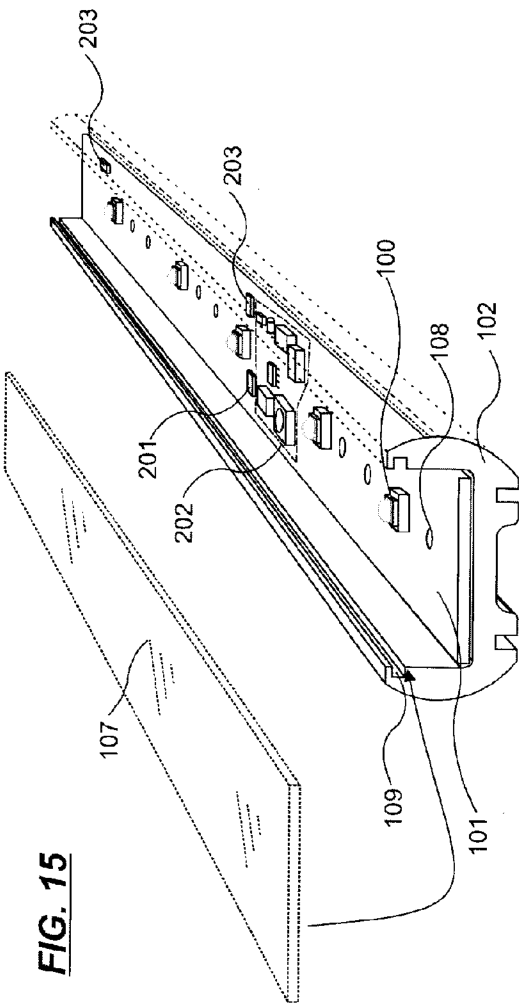
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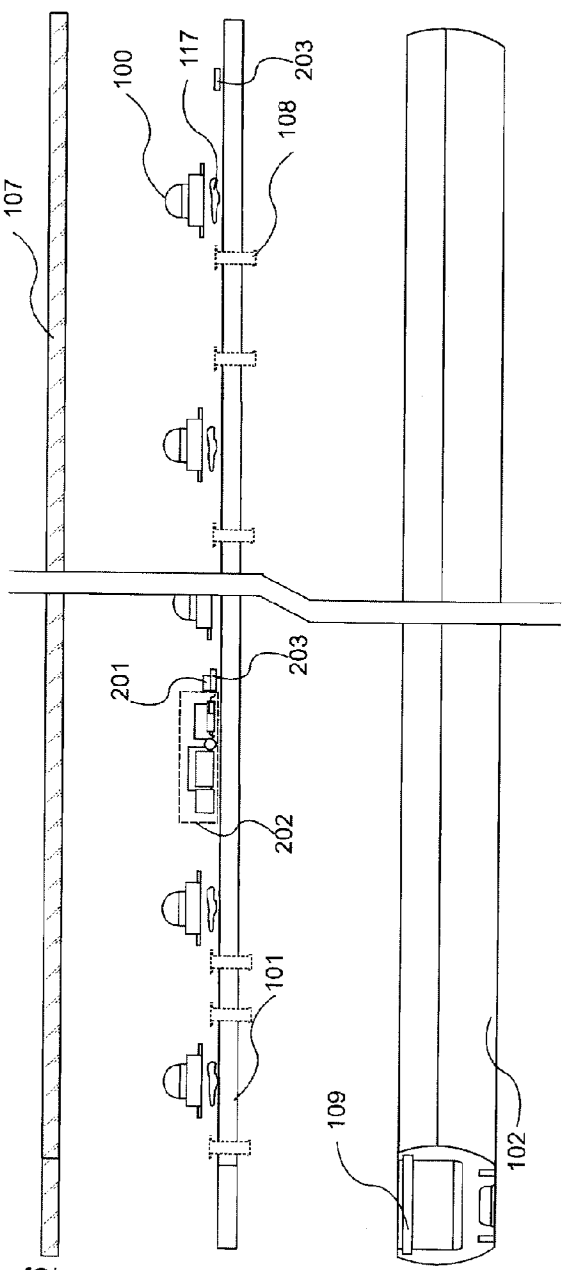
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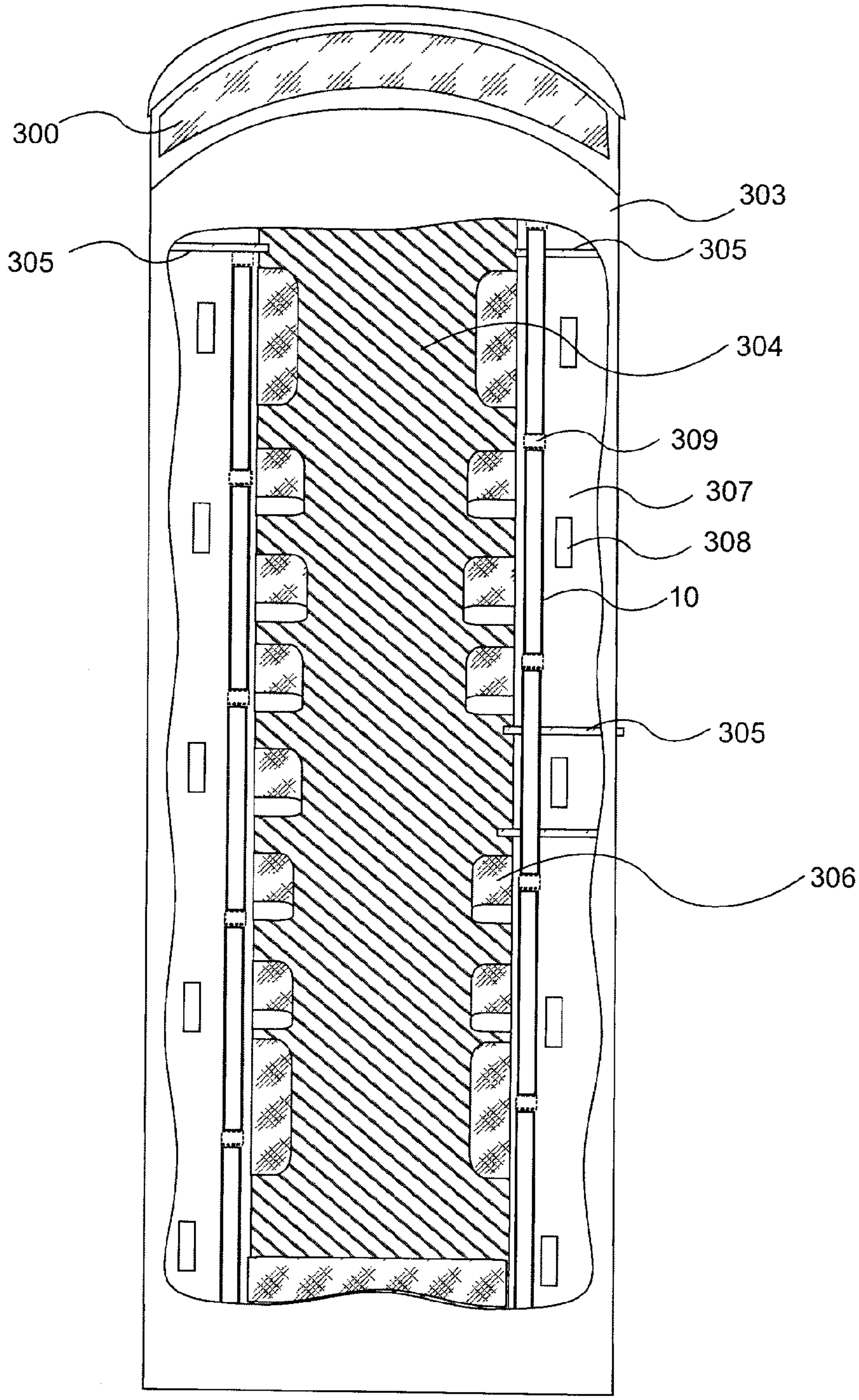

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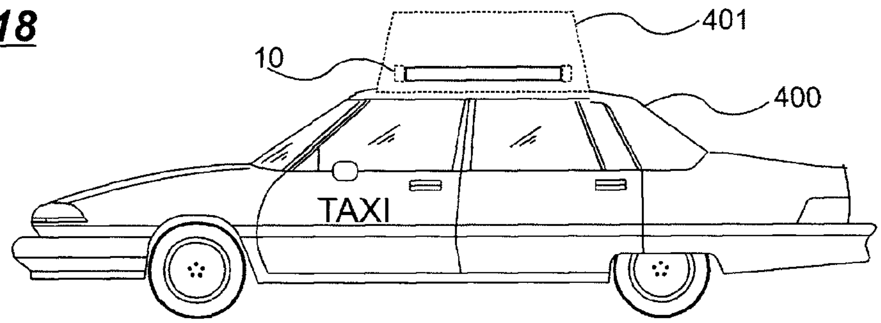


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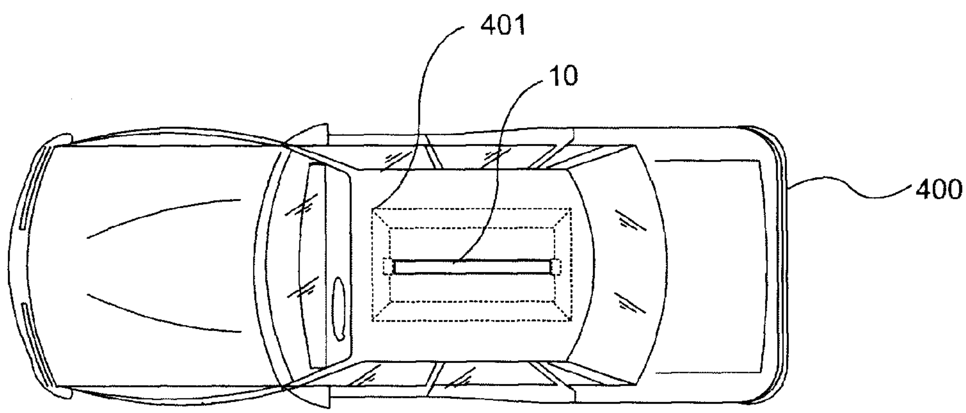


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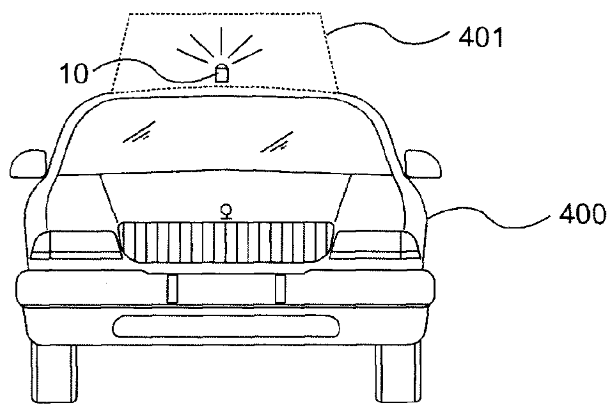

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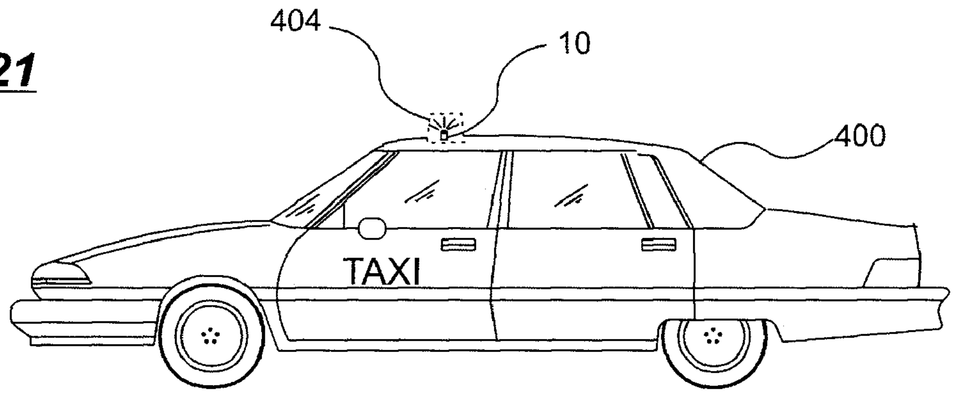


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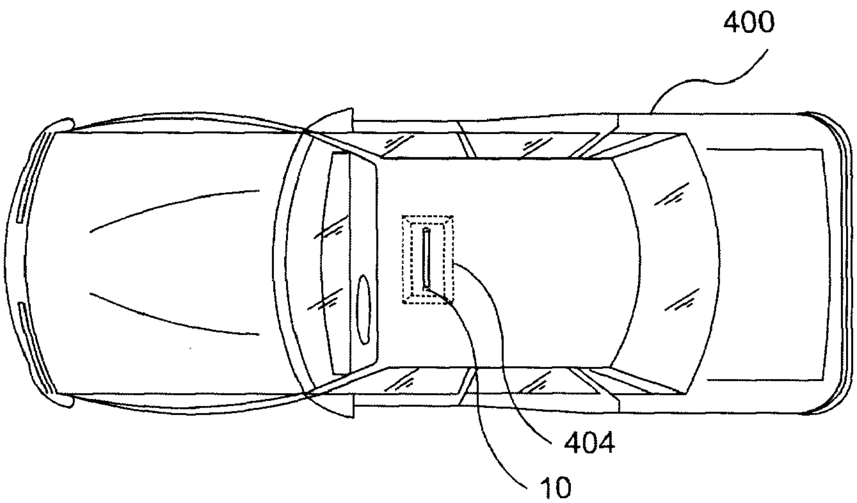


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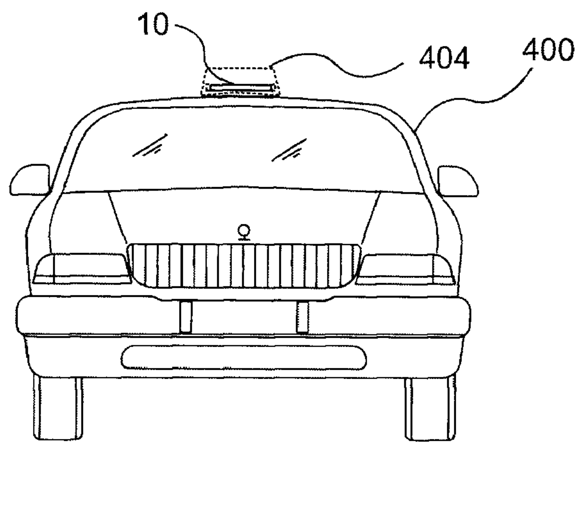


*FIG. 24*

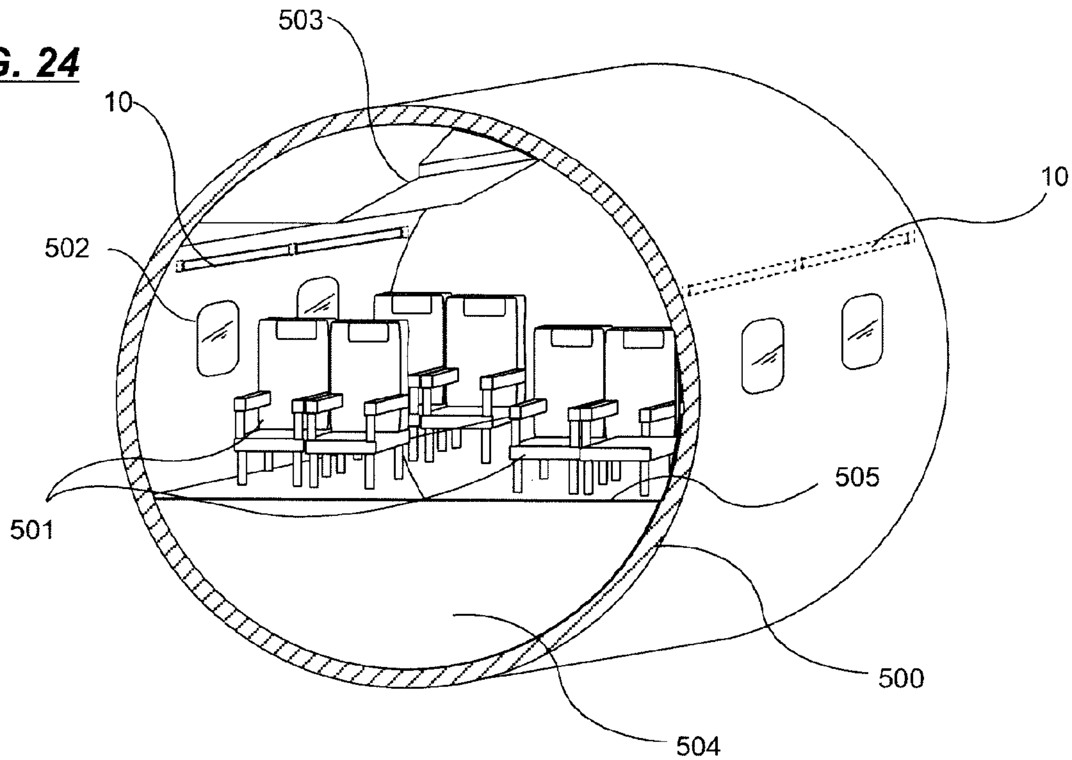



*FIG. 25*

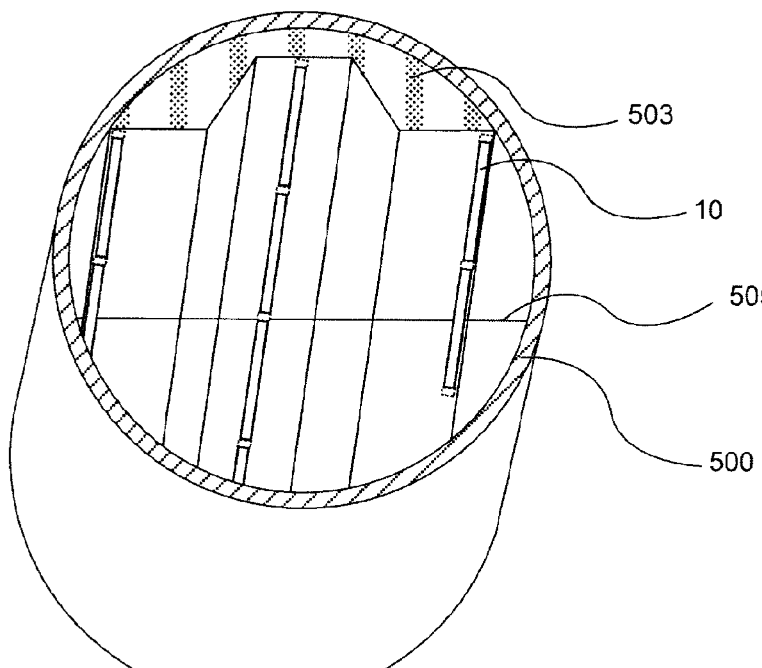
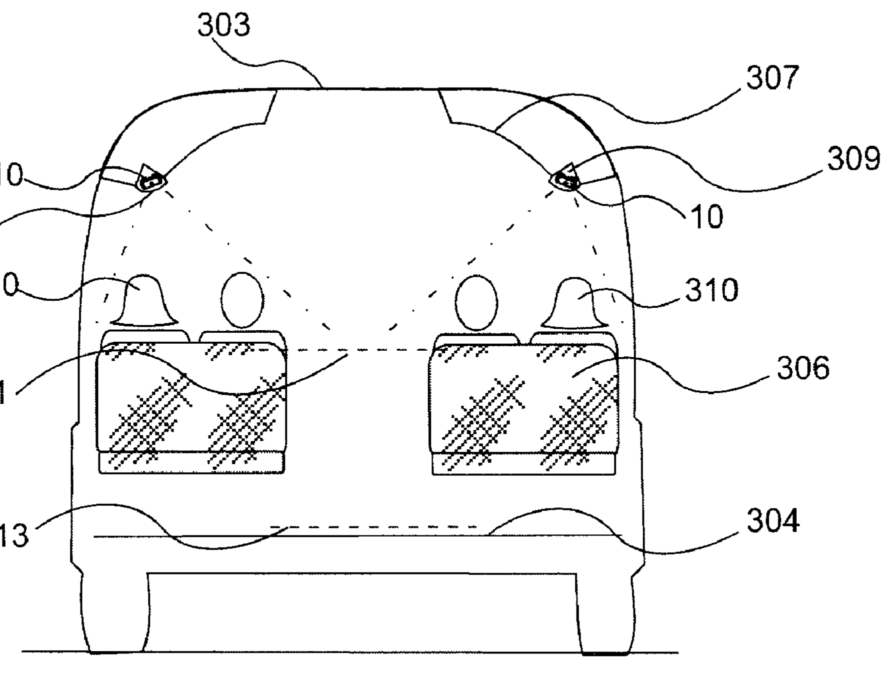


*FIG. 26*



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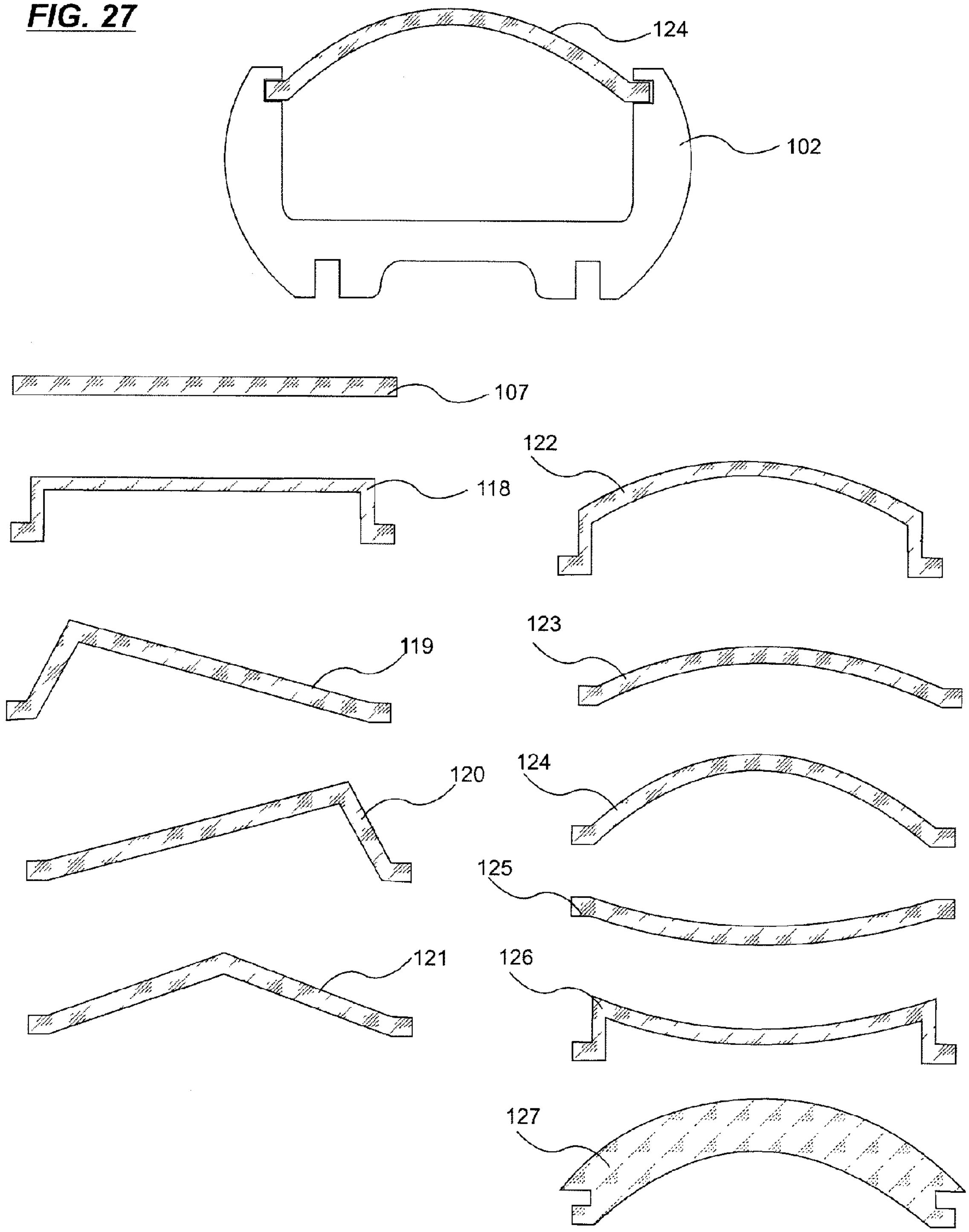
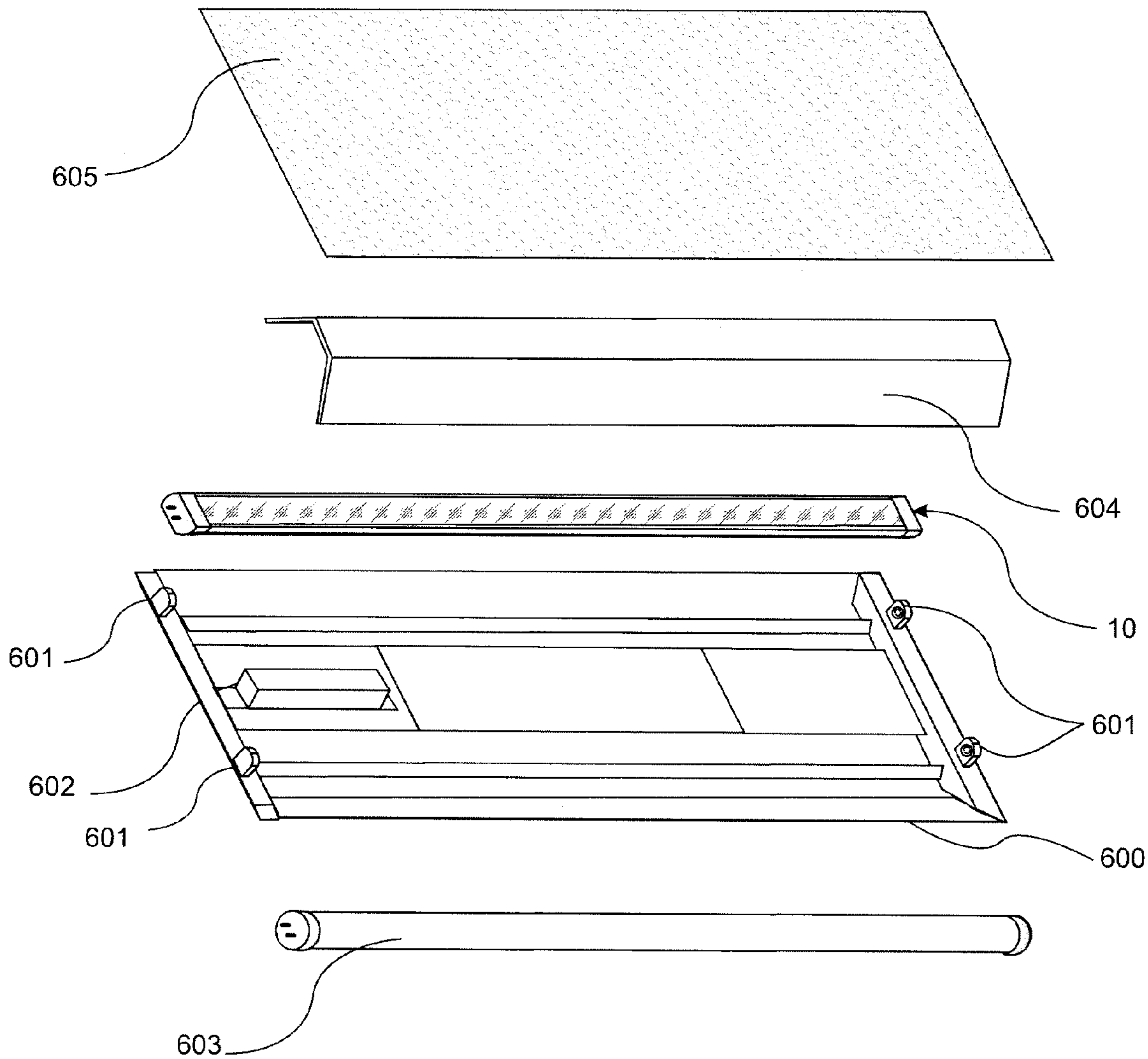


*FIG. 28*



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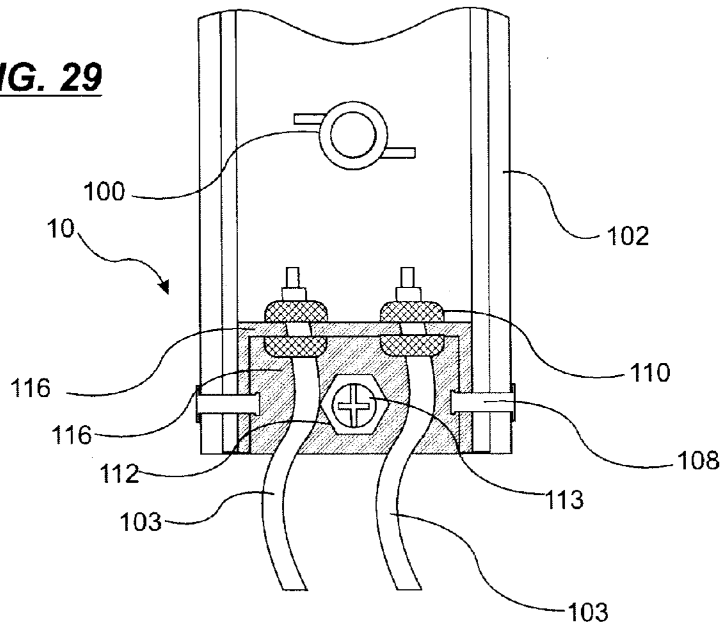


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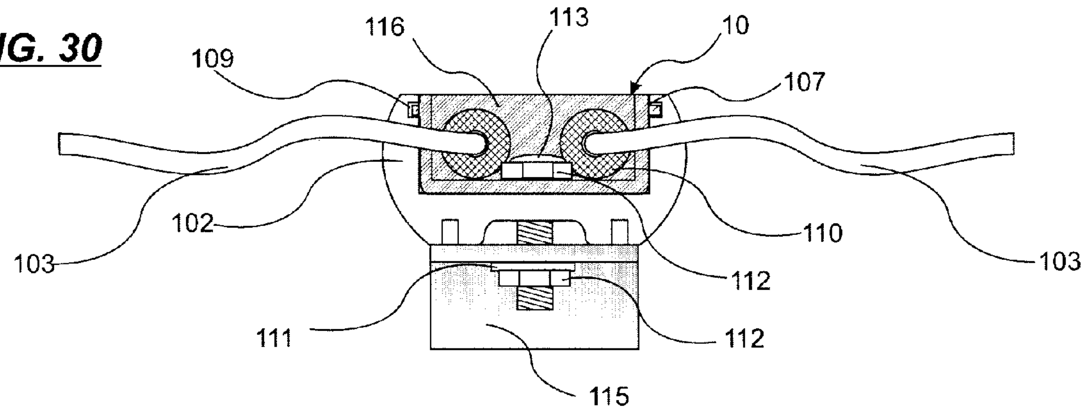


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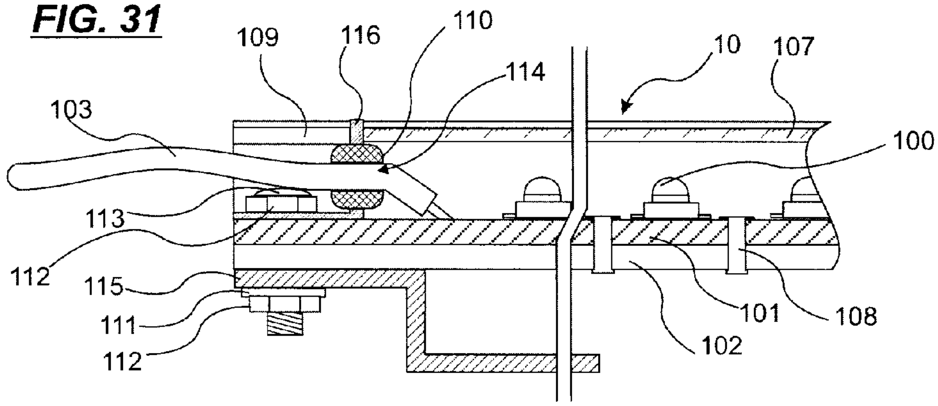

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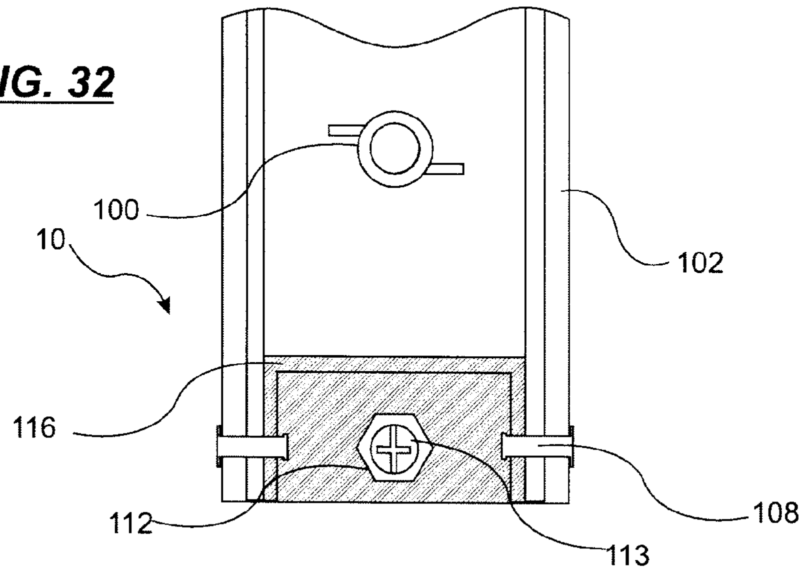


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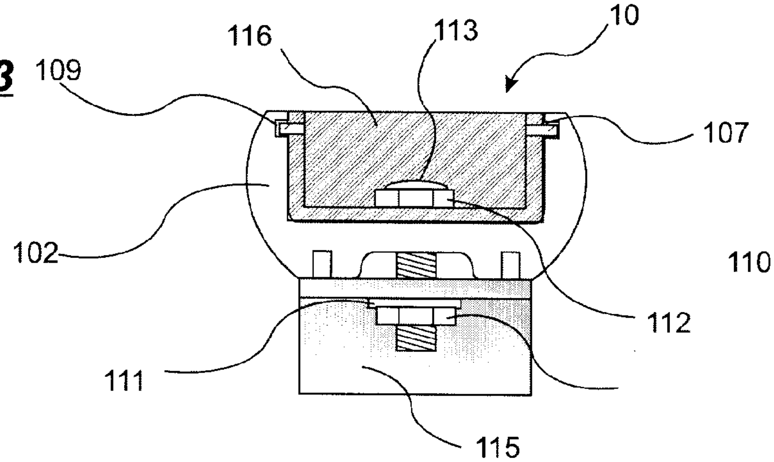


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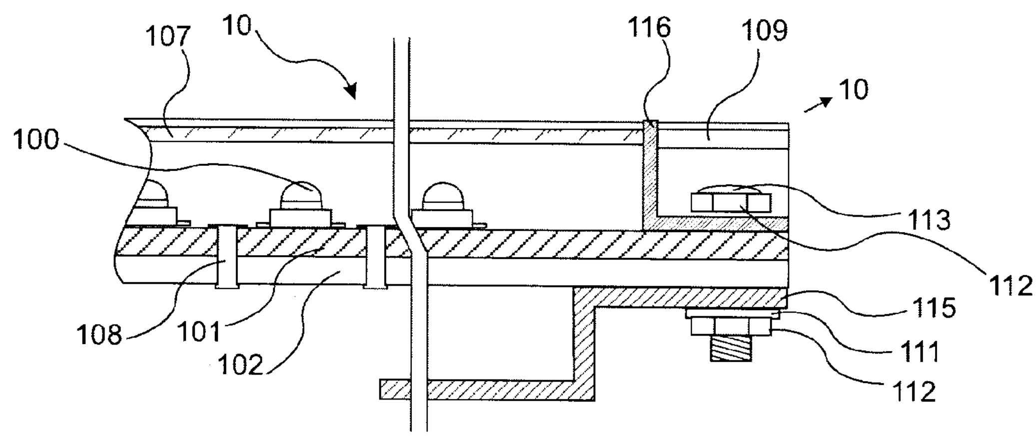

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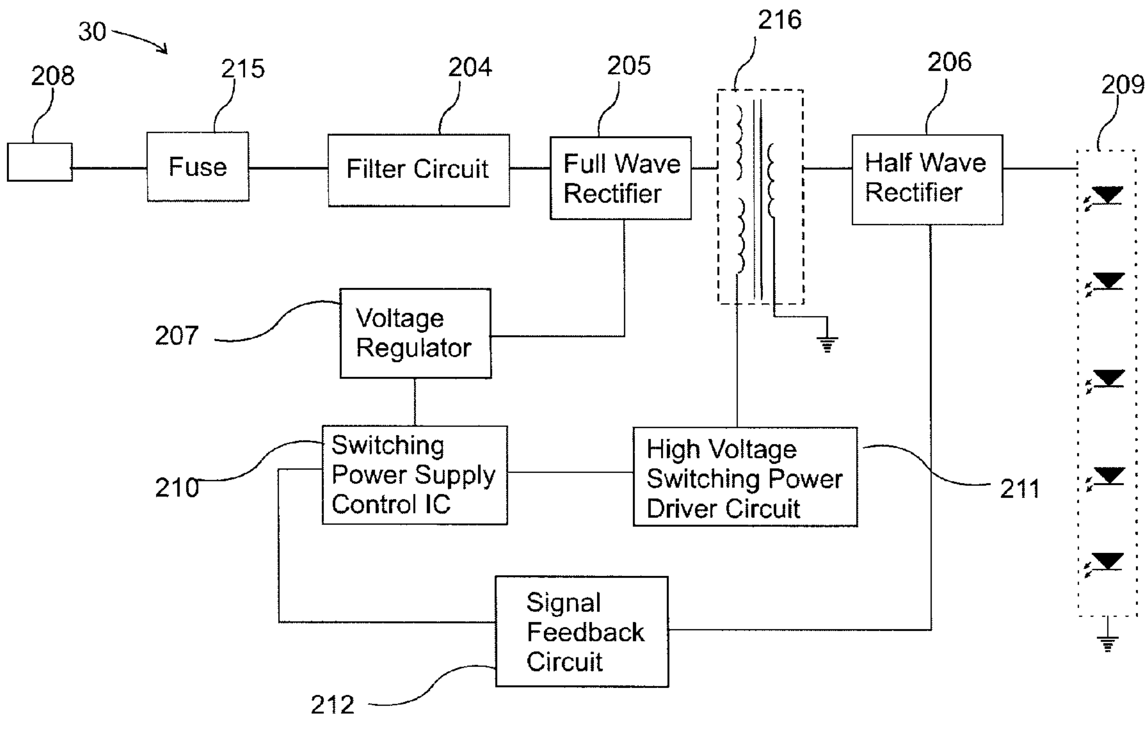
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Fuse
Filter Circuit
Full Wave Rectifier
Half Wave Rectifier
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Voltage Regulator
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Signal Feedback Circuit
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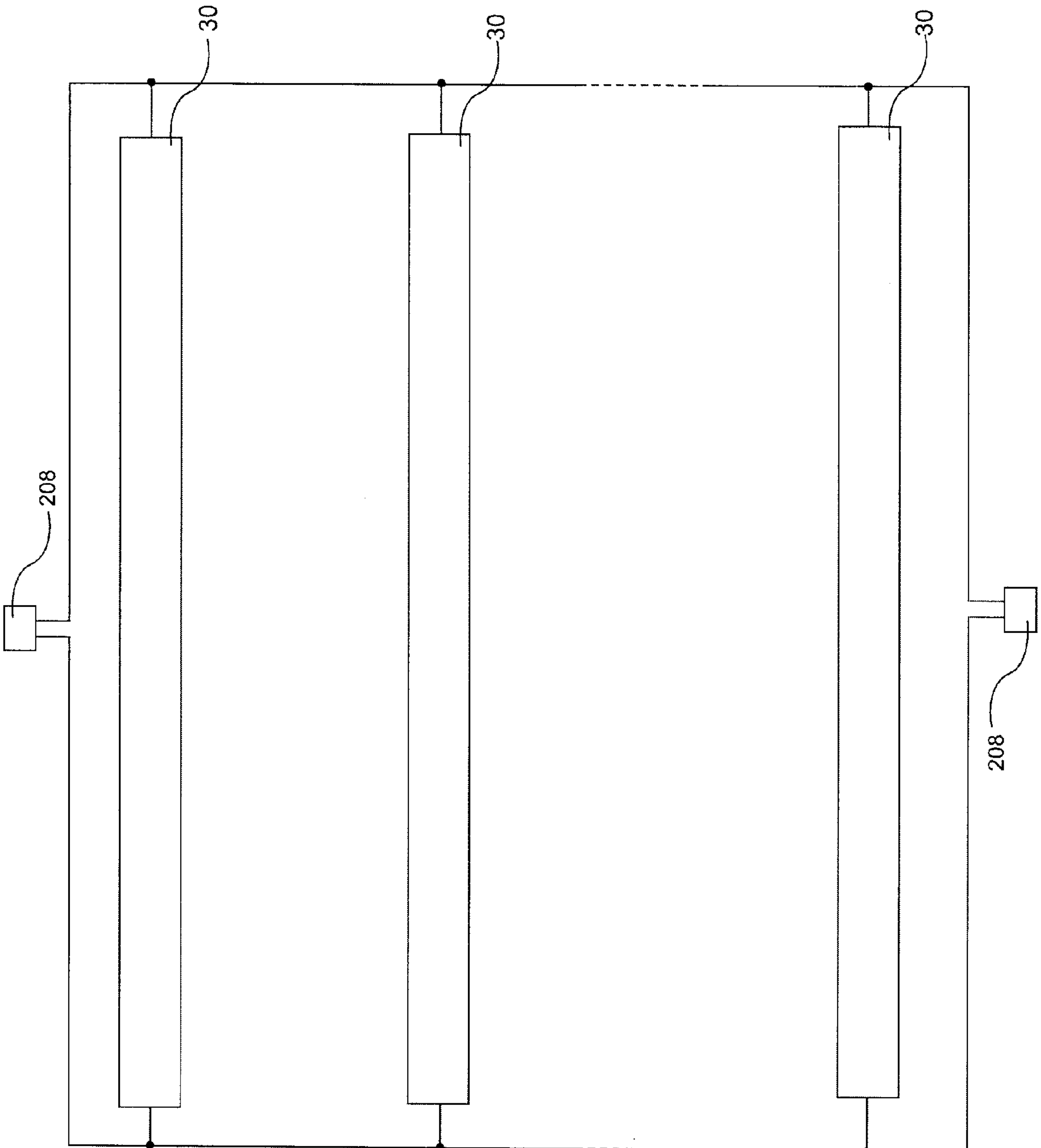


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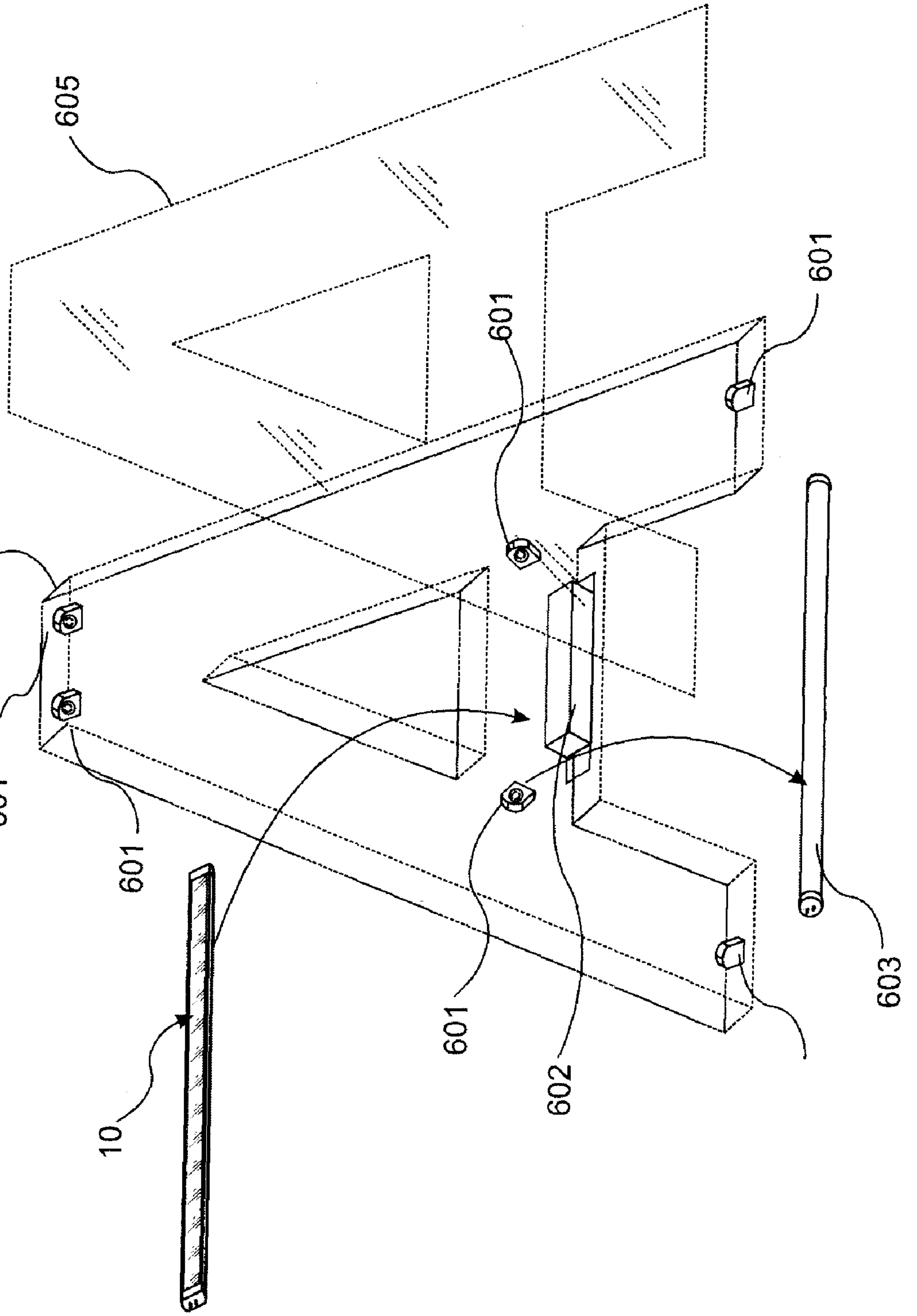


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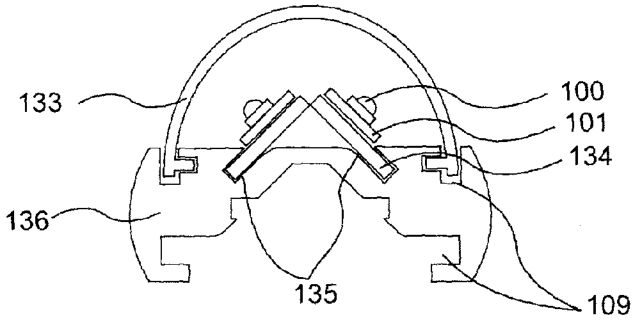


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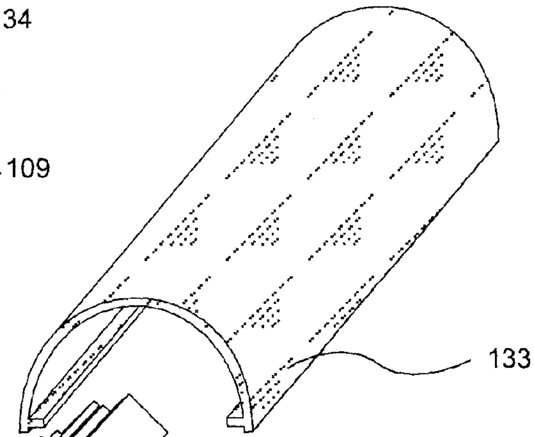
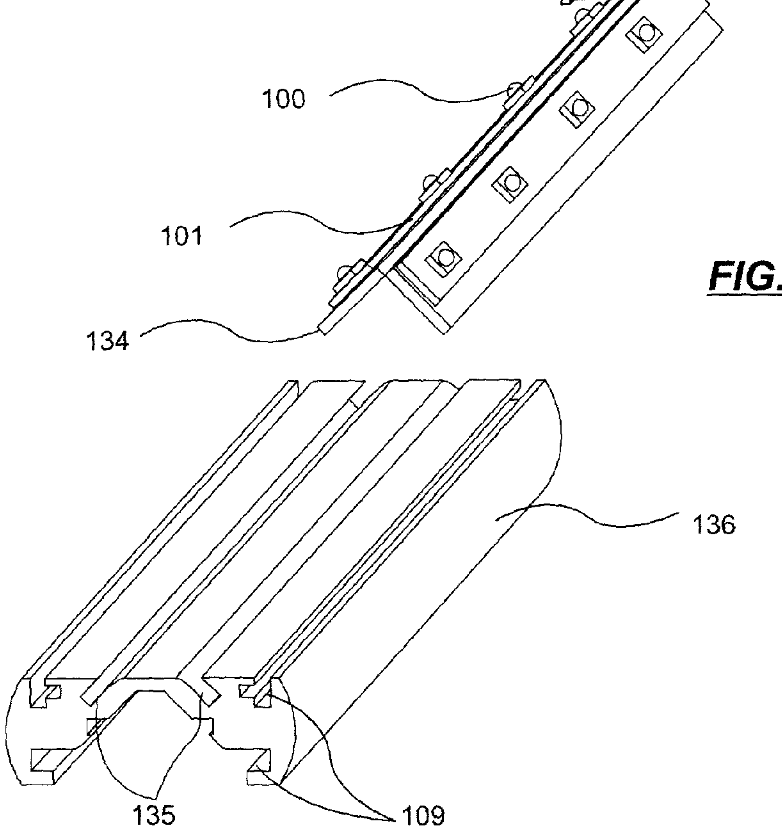
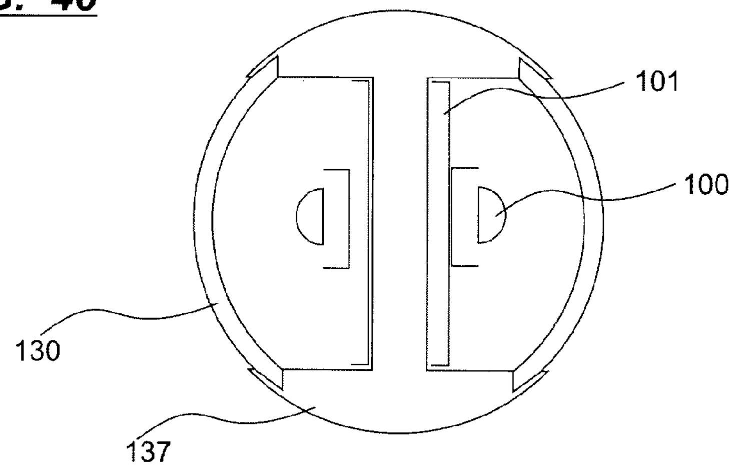




FIG. 39

FIG. 40

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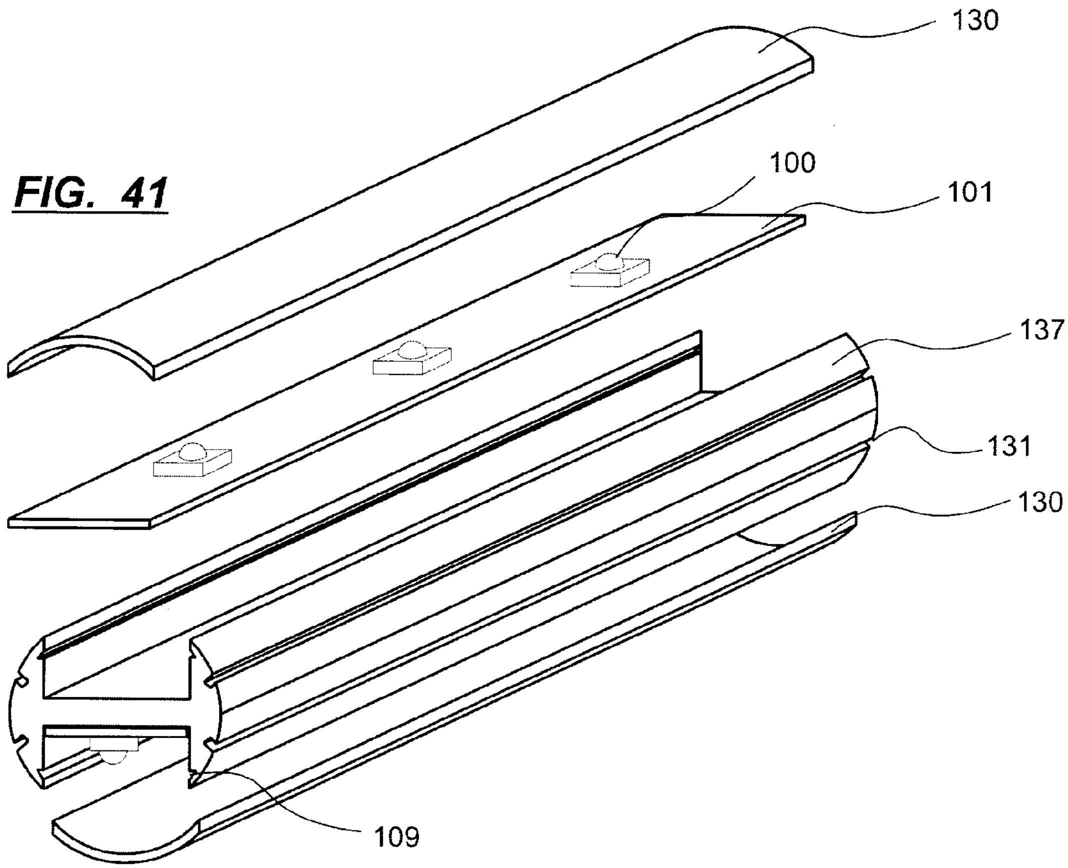

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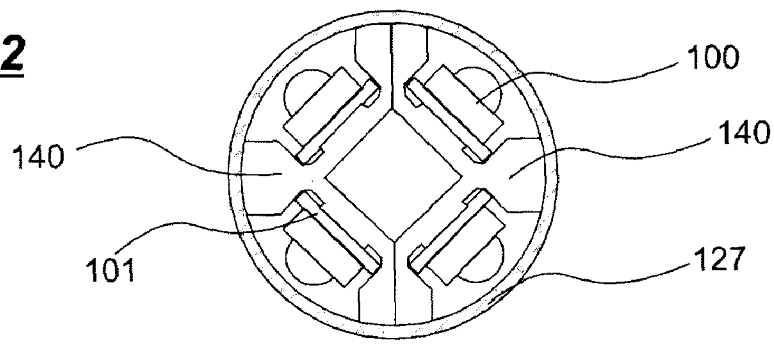


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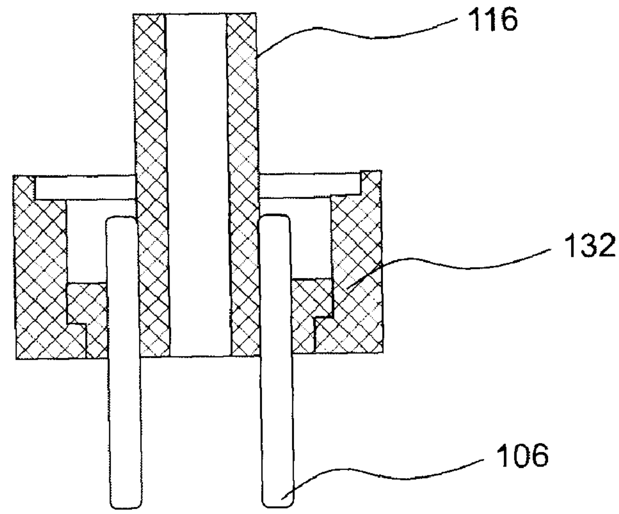


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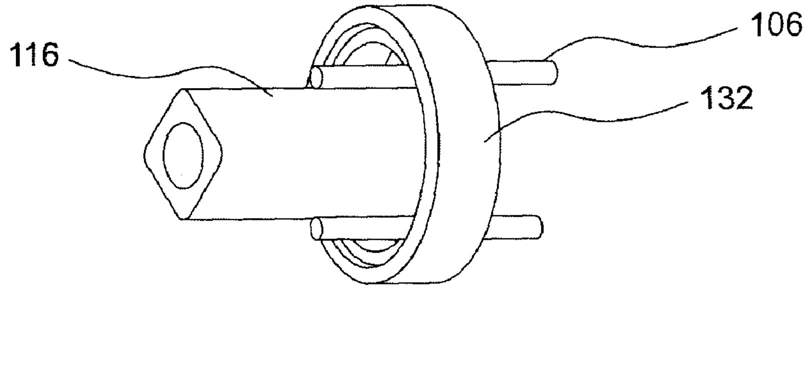
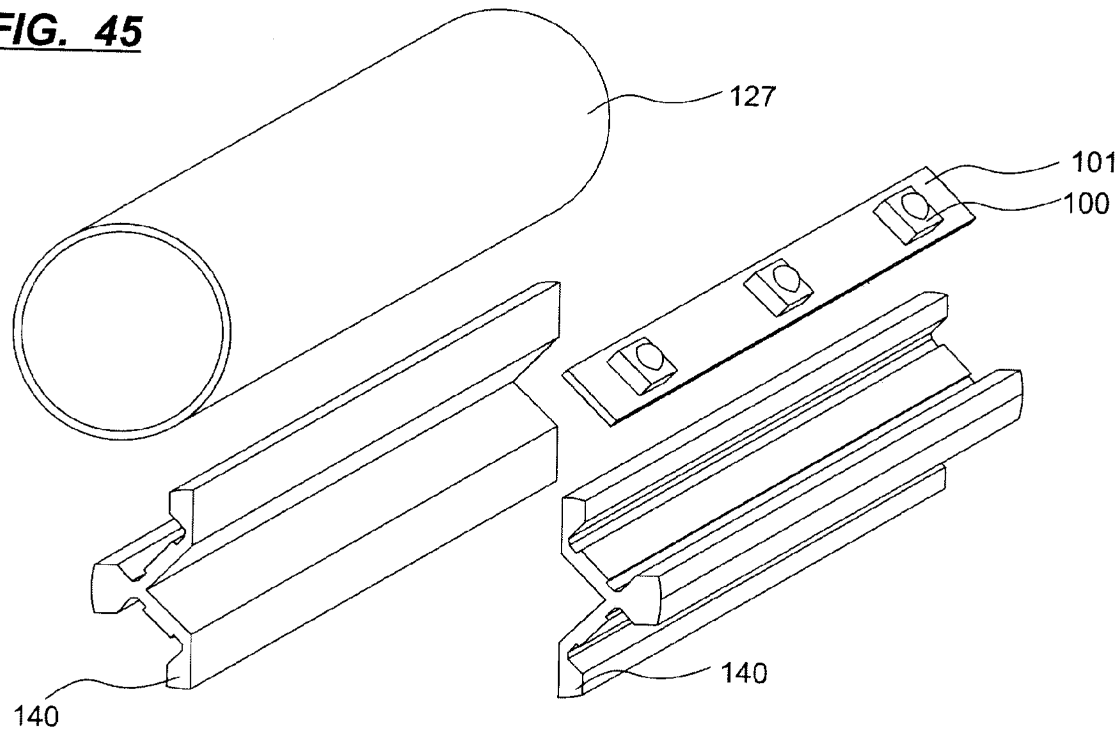


*FIG. 45*



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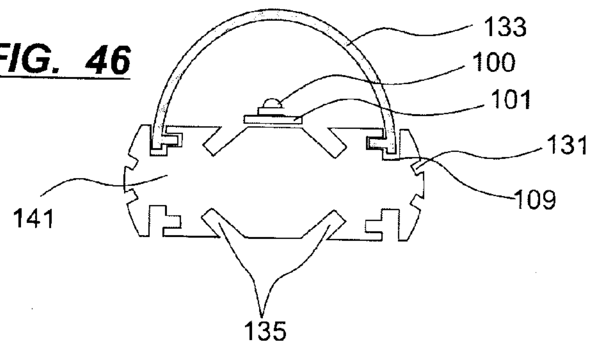


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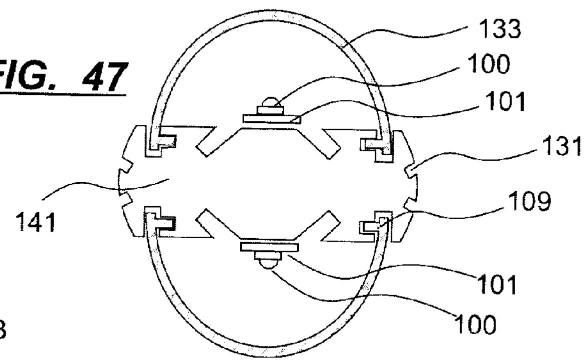


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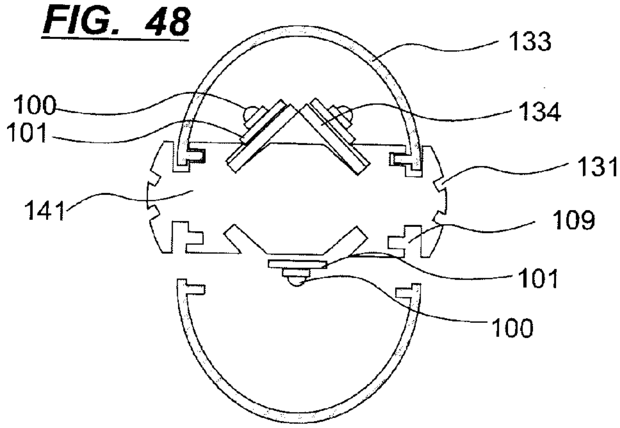


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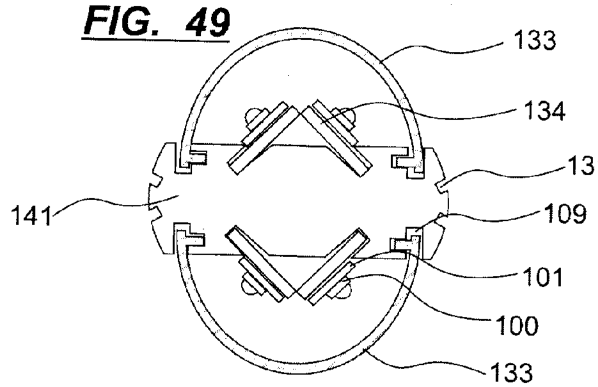

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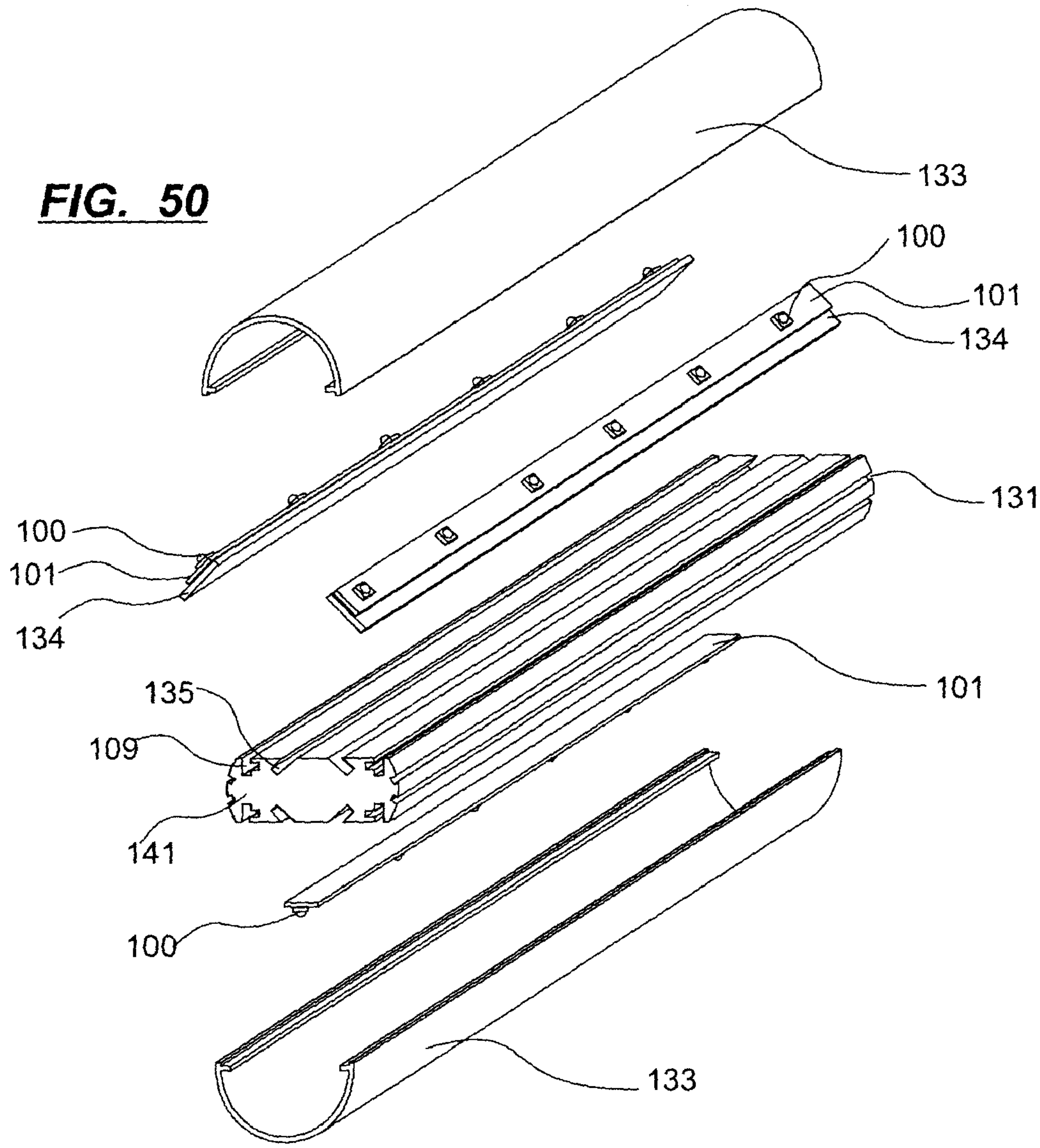
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FIG. 51

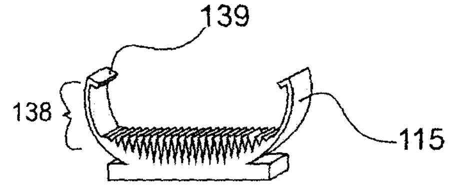
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FIG. 52

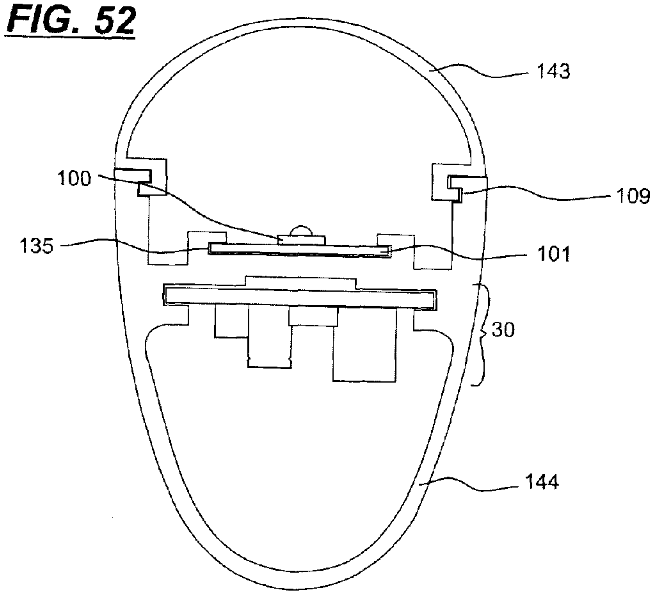



FIG. 53

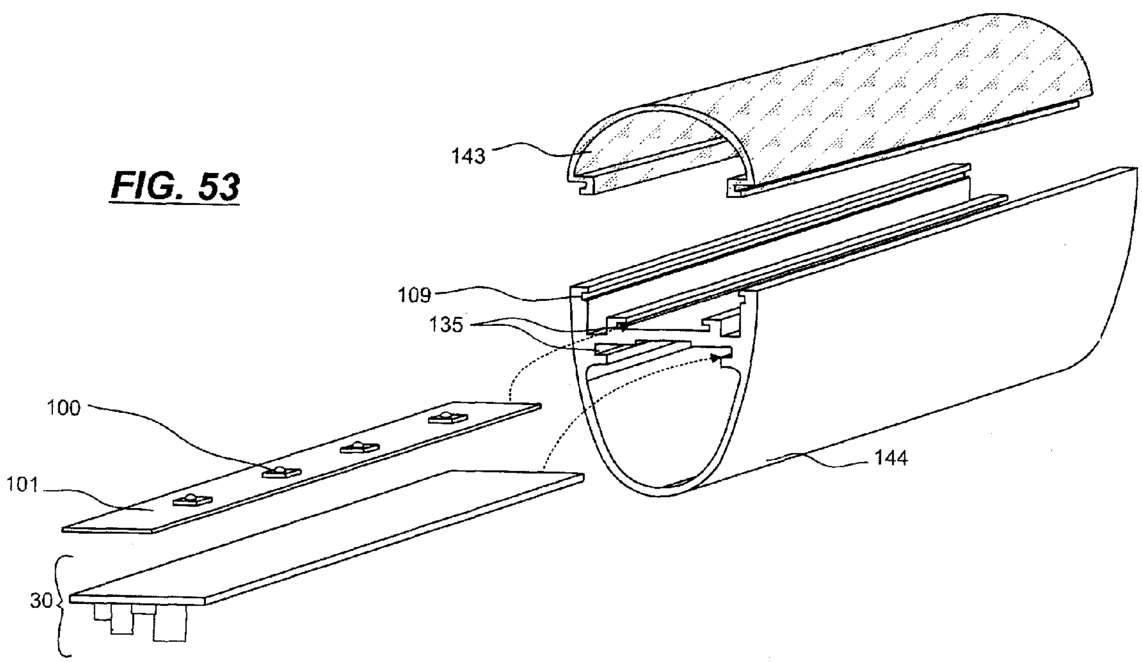


FIG. 54

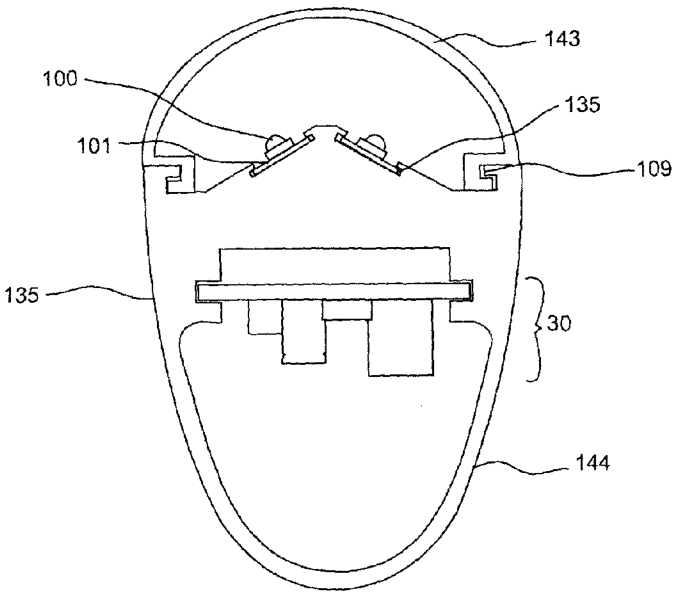
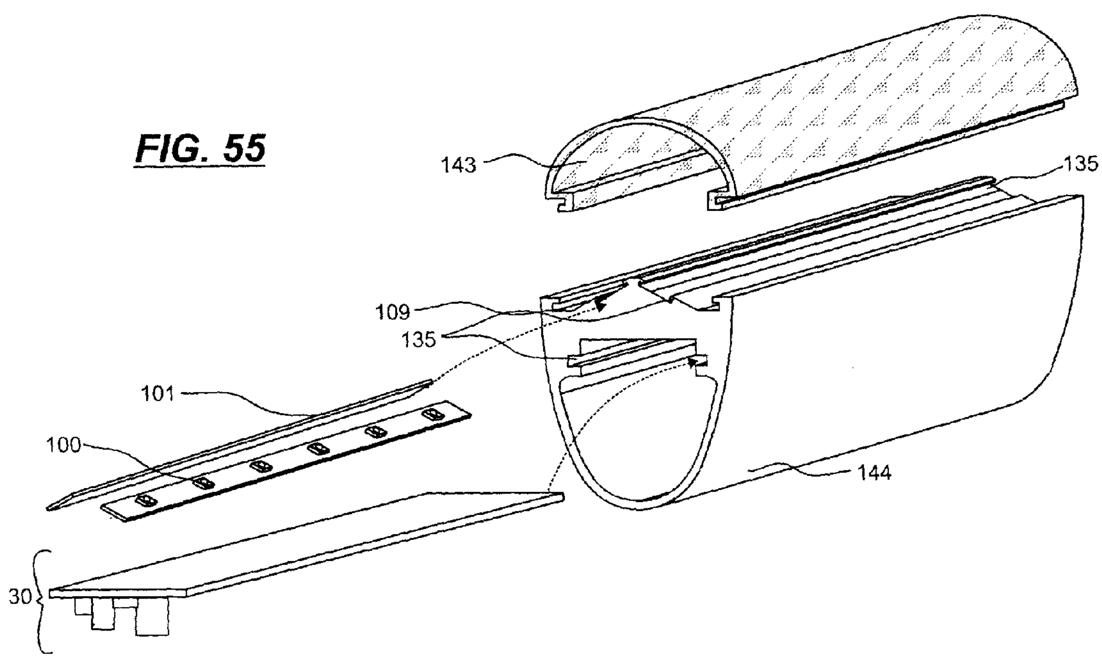



FIG. 55



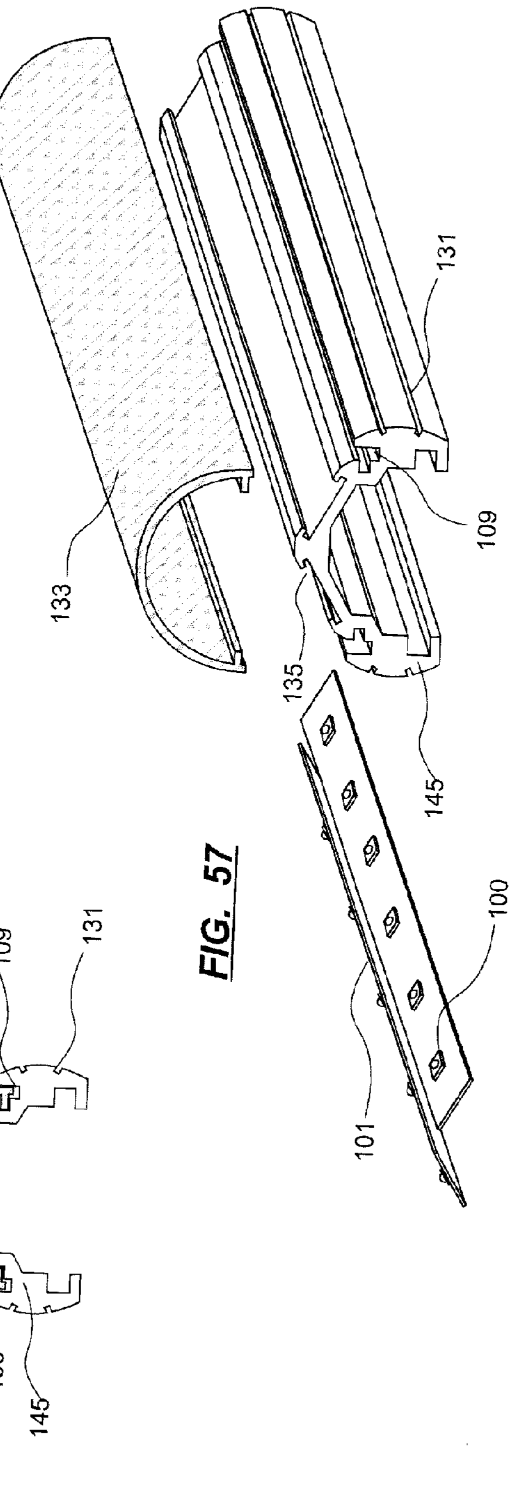



FIG. 57

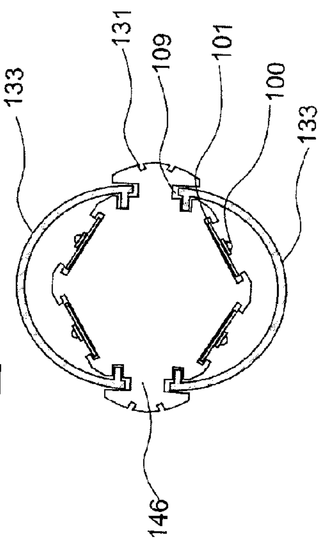



FIG. 58

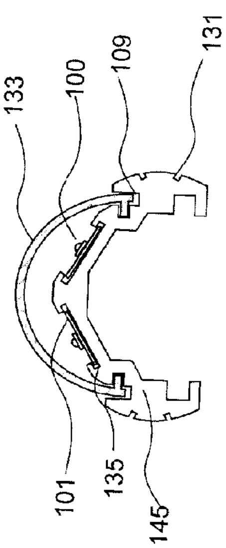



FIG. 56

FIG. 59

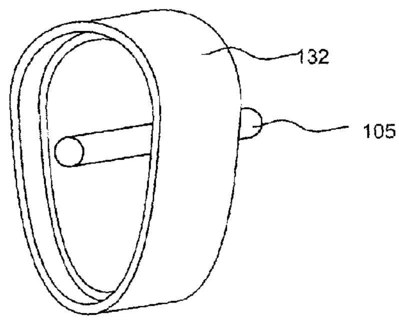



FIG. 60

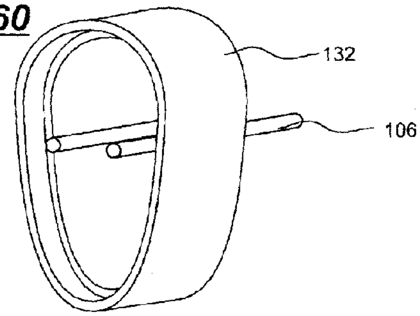



FIG. 61

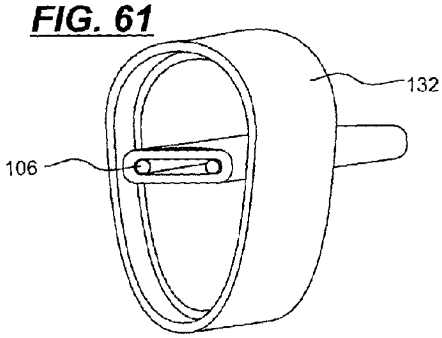



FIG. 62

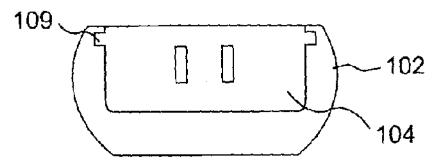



FIG. 63

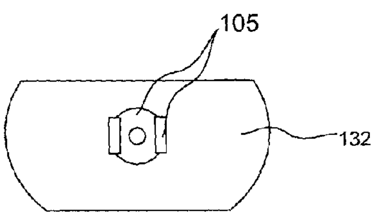



FIG. 64

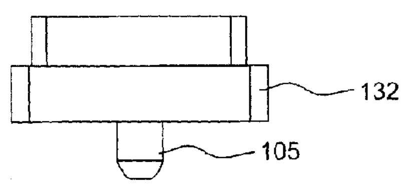
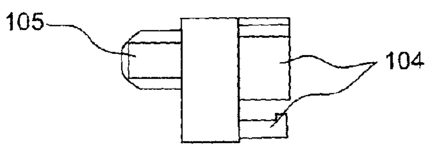



FIG. 65



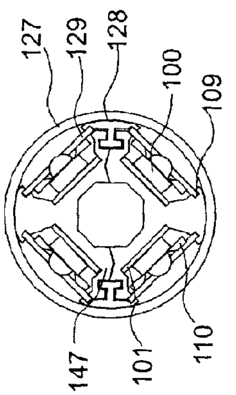

127
129
128
100
109
147
101
110

FIG. 66

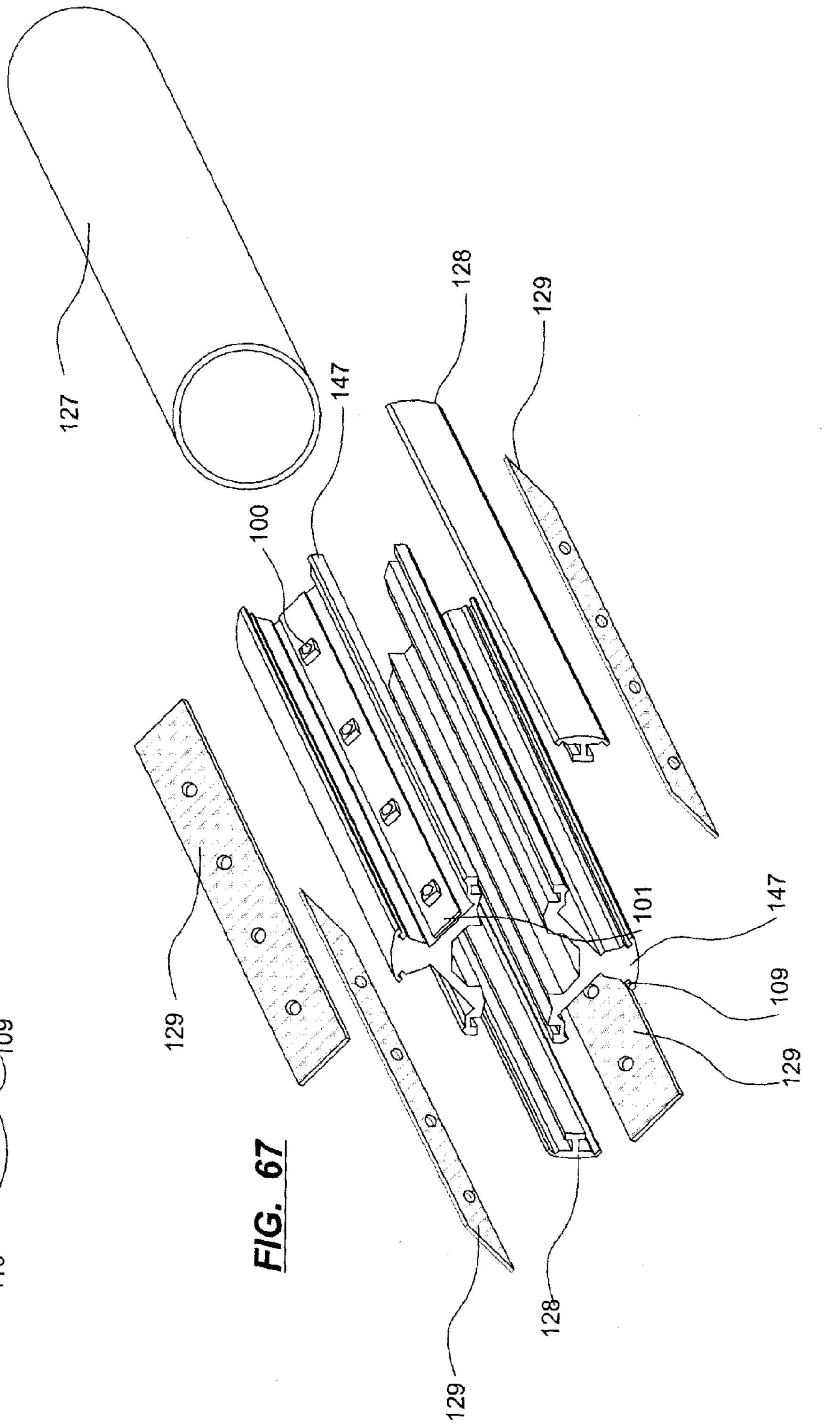

127
128
129
147
100
101
147
109
129
129
128
129

FIG. 67

# LED LIGHTING SYSTEM

## BACKGROUND

The presented LED lighting system relates in part to a retrofit and direct replacement of conventional fluorescent lighting tubes with light emitting diode (LED) lighting devices for usage in vehicles, including mass-transit vehicles such as buses, trains, subway trains, also for lighting watercrafts, aircrafts, signage, furniture, equipment or buildings using LEDs.

For many years the lighting of interiors of vehicles, aircraft, buildings, signage, and watercraft, and more recently the lighting of exteriors of vehicles, and signage have use the cold cathode lamp; more commonly known as the fluorescent lamp or a fluorescent system. The fluorescent lamp however has limitations on its capabilities and usages. The fluorescent lamp has disadvantages to the consumer. The disadvantages of the fluorescent lamp are the short life, easily broken, low durability, high costs of replacement, high costs of specialty lights, limited color selection, electromagnetic interference (EMI) which may be harmful to other electronic equipment. The manufacturing of fluorescent lamps and debris from replaced lamps have a high environmental risks, as the chemicals inside of a fluorescent lamp are toxic. Also the flicker effect of dying or improperly installed fluorescent lamps may be extremely harmful to individuals with certain medical conditions. The constant inconsistency of fluorescent lighting colors is often a complaint of consumers who have to replace lamps on a regular basis. A fluorescent system cannot be used effectively in extreme low or high ambient temperatures.

To attempt to avoid difficulties with fluorescent lighting, proposals have been made to use LEDs as replacements for fluorescent lighting, as for example described in U.S. Pat. No. 6,860,628 issued Mar. 1, 2005 and U.S. Pat. No. 6,583,550 issued Jun. 24, 2003. While these devices do provide some of the advantages of LEDs, there remains a need for lighting systems that can supply sufficient illumination to meet lighting requirements in vehicles, including mass-transit vehicles such as buses, trains, subway trains, also for lighting watercrafts, aircrafts, buildings and signage without excessive heat build up, while reducing the amount of lamps, wiring, ballasts, power consumption and maintenance that fluorescent systems require.

## SUMMARY

There is therefore provided a variety of light emitting diode lighting devices and systems that can be used for illuminating the interior and/or exterior of vehicles, aircraft, watercraft, signage or buildings is provided. The system in one embodiment may include a voltage feedback constant current power supply circuitry and high power LEDs. In one embodiment, the power supply circuitry is provided on printed circuit assemblies firmly mounted onto a continuous or semi-continuous mounting channel case that also works as a heat sink. By this means, it not only increases the reliability of the LED lighting tube but also it provides sufficient heat dissipation capability for the heat generated by the LEDs. Since the operating temperature of the LEDs is controlled and stays in cool condition, it dramatically increases the LED's lifetime and efficiency. The end caps and pins of this LED lighting device are in some embodiments fully compatible with existing conventional fluorescent light fixtures and can directly replace those fluorescent lighting tubes in vehicles, mass-transit, watercrafts, aircrafts, signage or buildings with minimal modifications.



In various embodiments of the LED lighting systems described here, there may for example be a support structure forming a channel and being heat conductive and rigid, with one or both ends of the support structure having electrical connectors for connection to a power source. An LED array in some embodiments extends along the support structure for example within the channel, and in some embodiments supported in slots, each LED in the LED array may have in some embodiments a power rating of greater than 0.1 watt. The power supply circuitry in some embodiments is provided by current control circuitry, for example onboard circuitry, carried by the support structure, in some embodiments within the channel, and may provide current control for individual sets of LEDs. The current control allows careful control of the forward current passing through the LED array so that it controls the brightness and heat production by the LEDs. Devices with full 360 degree illumination are disclosed, along with devices with LEDs having differently angled illumination fields. Various electrical power supplies, structural support configurations and shapes, lens configurations, and overall structural configurations are also disclosed.

## BRIEF DESCRIPTION OF THE DRAWINGS

There will now be described embodiments of an LED lighting system, with reference to the drawings, by way of illustration only, in which like numerals denote like elements and in which:

FIG. **1** is a cross cut view from inside of single pin type LED lighting system;

FIG. **2** is a cross cut view from inside of 'bi-pin'—two pin type LED lighting system;

FIG. **3** is a cross cut view from inside single or 'bi-pin'—two pin type of LED lighting system showing permanent, for example, rivet or screw, mounting;

FIG. **4** is an end view of single pin type of LED lighting system;

FIG. **5** is an end view of recessed double contact base, two pin type LED lighting system;

FIG. **6** is an end view of 'bi-pin', two pin type LED Lighting Tube;

FIG. **7** is a top view of single pin design, one end cross cut, to view interior configuration;

FIG. **8** is a top view of single pin design, with lens;

FIG. **9** is a top view of recessed double contact base-two pin design, one end cross cut, to view interior configuration;

FIG. **10** is a top view of recessed double contact base-two pin design, with lens;

FIG. **11** is a top view of 'bi-pin'—two pin design, one end cross cut, to view interior configuration;

FIG. **12** is a top view of 'bi-pin'—two pin design, with lens;

FIG. **13** is a block diagram of single series of electronics (1.5V~72V) for onboard current control;

FIG. **14** is a block diagram of multi series of electronic configuration (1.5V~72V) for onboard current control;

FIG. **15** is a 3-D view of the LED Lighting tube, without end fittings;

FIG. **16** is a 3-D side view of the LED Lighting tube, without end fittings;

FIG. **17** shows an LED lighting system in a mass-transit application, bus shown here for reference purposes, new or retrofit application;

FIG. **18** shows an LED lighting system in a vehicle application, taxi side view, for taxi advertisement sign;

FIG. **19** shows an LED lighting system in a vehicle application, taxi top view, for taxi advertisement sign;

FIG. **20** shows an LED lighting system in a vehicle application, taxi front view, for taxi advertisement sign;

FIG. **21** shows an LED lighting system in a vehicle application, taxi side view, for taxi 'on-duty' sign;

FIG. **22** shows an LED lighting system in a vehicle application, taxi top view, for taxi 'on-duty' sign;

FIG. **23** shows an LED lighting system in a vehicle application, taxi front view, for taxi 'on-duty' sign;

FIG. **24** shows an LED lighting system in an airplane application, cross cut view of fuselage;

FIG. **25** shows an LED lighting system in an airplane application, bottom view of fuselage;

FIG. **26** shows an LED lighting system in a mass-transit application, cross cut view of bus;

FIG. **27** shows some examples of lenses for the LED lighting system;

FIG. **28** shows an LED lighting system in a fluorescent lamp, replacement, retrofit, or new installation;

FIG. **29** is a top view of vehicle application LED lighting system, powered end;

FIG. **30** is an end view of vehicle application LED lighting system, powered end;

FIG. **31** is a cross cut view of vehicle application LED lighting system, powered end;

FIG. **32** is a Top view of vehicle application LED lighting system;

FIG. **33** is an End view of vehicle application LED lighting system;

FIG. **34** is a cross cut view of vehicle application of LED lighting system;

FIG. **35** is a block diagram of current control electronics for a high voltage application, single series (73V~240V);

FIG. **36** is a block diagram of current control electronics for high voltage application, multiple series (73V~240V);

FIG. **37** is a signage application, with a view of replacement of fluorescent lamps in signage;

FIG. **38** is a cross cut view of an LED lighting system with LED arrays facing different directions;

FIG. **39** is a view of multiple sections of an LED lighting system with LED arrays facing different directions;

FIG. **40** is a section through a embodiment of an LED lighting system with 360 degree coverage;

FIG. **41** is an exploded view of the embodiment of FIG. **40**;

FIG. **42** is a section through a further embodiment of an LED lighting system with 360 degree coverage;

FIG. **43** is a section of an end socket for use with an LED lighting system;

FIG. **44** is a perspective view of the embodiment of FIG. **43**;

FIG. **45** is an exploded view of the embodiment of FIG. **42**;

FIGS. **46-49** are a series of sections of an LED lighting system showing how various configurations of LED arrays may be carried by a support structure;

FIG. **50** is an exploded view of the embodiment of FIG. **48**;

FIG. **51** is a perspective view of a mounting bracket that may be used with the embodiments of for example FIGS. **46-49**;

FIG. **52** is a section through an embodiment of an LED lighting system with a domed support structure;

FIG. **53** is an exploded view of the embodiment of FIG. **52**;

FIG. **54** is a section through a further embodiment of an LED lighting system with a domed support structure;

FIG. **55** is an exploded view of the embodiment of FIG. **54**;

FIG. **56** is a section through a further embodiment of an LED lighting system with differently angled LED arrays;

FIG. **57** is an exploded view of FIG. **56**;



FIG. **58** is a section through a further embodiment of an LED lighting system with differently angled LED arrays;

FIGS. **59-65** show a variety of end sockets for use with LED lighting systems;

FIG. **66** is a section through a further embodiment of an LED lighting system with 360 degree coverage; and

FIG. **67** is an exploded view of the embodiment of FIG. **66**.

## DETAILED DESCRIPTION

In this patent document, "comprising" means "including". In addition, a reference to an element by the indefinite article "a" does not exclude the possibility that more than one of the element is present. Each one of the individual features described here may be used in one or more embodiments and is not, by virtue only of being described here, to be construed as essential to all embodiments as defined by the claims.

In FIGS. **1-3**, **7-12**, there is shown an exemplary LED lighting system **10** that includes a plurality of LEDs **100**, each LED **100** being supplied power from a circuit board **101** supported by support structure **102**. Support structure **102** in one embodiment forms a channel and is made of a heat conductive and rigid material, such as aluminum, ceramic or any thermally conductive formable material. In one embodiment, the support structure **102** is both heat conductive and rigid and is made of a unitary piece of material. The support structure **102** is rigid and extends from end to end of the LED lighting system **10**. The heat sink capability may be continuous from end to end or may be semi-continuous. In the case of being semi-continuous, the material providing the heat sink function may have breaks, in which case additional connector material is required to provide the channel with sufficient rigidity so that the lighting system **10** does not collapse or sag under its own weight. The circuitry **20** or **30** provide current control for the LED lighting system **10** and are attached to the support structure **102** permanently such as by fasteners **108** (FIG. **3**), which may be rivets or screws, so they do not allow for vibration to loosen the connection between the circuit board **101** and the support structure **102** over time. The support structure **102** does not require adhesive, or thermally conductive substance to connect to the circuit board **101**. The support structure **102** provides a rigid backbone structure to the LED lighting system **10**, and is sufficiently rigid to prevent the LED lighting system **10** to resist or prevent breakage during normal use, or bending, unless the product design requires it. The support structure **102** may be provided with a cover **107** secured in a groove **109** that runs along the inside edge of the support structure walls. The cover **107** is transparent or translucent and may be formed as a lens.

At one or both ends of the support structure **102** there are provided electrical connectors **103**, **105**, and **106** for connection of the lighting system **10** to a power source. When LED lighting system **10** is configured as a bulb, rather than as tube, it will typically have connectors only at one end. In the embodiment of FIGS. **1**, **4**, **7** and **8**, a single connector **105** of Pin Type 1 is formed in end caps of the support structure **102**. In the embodiment of FIGS. **2**, **5**, **6**, and **9-12** double connectors **106** of Pin Type 2, either in the bi-pin format (FIGS. **6**, **11** and **12**) or the recessed double contact type (FIGS. **5**, **9** and **10**) are formed in end caps **104** of the support structure **102**. These connectors **105**, **106** are of conventional design. The end caps **104** may be any suitable material such as plastic, Lexan™, polycarbonate, acrylic, ABS, metal such as aluminum, copper, brass, stainless steel, metal alloy, combination of metal and plastic, or fiberglass. The end caps **104** may be manufactured in different shapes and sizes, all able to connect to the circuit boards **101** within the support structure **102**. The end caps **104** encase the channel, are secured against movement and do not break with vibration. The end caps **104** also secure and prevent movement of the lens **107**, **118-127**. As with the other components of the lighting system **10**, the end caps **104** should be made to withstand high ambient temperatures (up to 125° C.+) and low ambient temperatures (as low as −40° C.). In the case of use of the LED lighting system **10** as a fluorescent light fixture replacement, the connectors **105**, **106** are conventional pins for attached to fluorescent light fixture receptacles. In other embodiments, such as when the LED lighting system **10** is used in a single socket fixture, the connectors **106** may be provided at one end only of the support structure **102**.

An LED array formed of LEDs **100** extends along the support structure within the channel formed by the support structure **102**. To provide sufficient power to provide light, particularly in an industrial or commercial environment, each LED **100** in the LED array should have a power rating sufficient to provide the desired degree of light, including in the case of vehicles used for transportation a sufficient degree of light to meet regulatory requirements. For example, such requirements may be met by LEDs having a power rating of greater than 0.1 watt, depending on the efficiency of the LED in converting power to light energy. The LEDs may also be organic LEDs or any other suitable LED now known or later developed.

The circuit boards **101** provide in one embodiment onboard current control circuitry for the LED array. The circuit boards **101** are carried by the support structure **102** and are in electrical communication with the electrical connectors **103**, **105**, **106**. The LEDs **100** are preferably organized in groups of LEDs, either in series, or parallel. The LEDs may be surface mounted (SMT) or through hole mounted (TH). The colour of the LEDs can be any available colour such as white, blue, green, red, yellow, amber, purple, pink, or orange.

FIGS. **13** and **14** show circuit diagrams with an example circuit **20** for onboard current control. The circuits of FIGS. **13**, **14**, **35**, **36** may all be placed on the circuit board or boards **101**. FIG. **13** illustrates a single circuit **20** connected to a conventional power source **208**, while FIG. **14** shows multiple circuits **20** in parallel connected to a conventional power source **208**. The circuit boards **101** for the circuits **20** may be made of fiberglass based printed circuit board (PCB) or metal based (for example Aluminum) PCB or any other suitable PCB material now known or later developed. The circuit boards **101** may be TH type or SMT type. Preferably, the surface of the circuit boards **101** have a white solder mask and exposed areas of tinned plane so as to efficiently reflect the majority of LED light. The circuit boards **101** may be flexible to accommodate mounting channels and lighting fixtures in different shapes and curves. As shown in FIGS. **13** and **14**, the LED array is divided into sets **209** of LEDs, with for example five LEDs per set. As shown in FIG. **14**, the onboard current control circuitry is formed of multiple circuits **20**. Each circuit **20** provides current control for a corresponding set **209** of LEDs in the LED array.

The onboard current control circuitry **20** is configured to provide constant current to the LEDs **100** of the LED array **209**. A polarity protection circuit **201** of conventional design safeguards against the user installing the product in the wrong polarity. Current control is provided by current control circuit **202**, also of conventional design. As an example, the current control circuit **202** may be use pulse width modulation (PWM) to control the current supplied to the LEDs. The circuit **202** supplies constant, controlled, current to unit for the entire LED set **209** with information from voltage sensor **203**. The voltage sensor **203** receives current information from LEDs **209** and feeds back information to the current control circuitry **202**. For example, in the use of PWM, the voltage sensor **203** converts the current of LED array **209** to voltage signal and supplies the voltage signal to the current control circuit **202**. The current control circuit **202** senses how much the detected voltage varies from the desired level, and by varying the pulse width or frequency, changes the current supplied to the LEDs towards the desired level. The power supply **208** may be AC or DC, although in the example shown it is DC. Current control provides constant brightness and prevents overheating. A typical pulse frequency for the current control may be 200 kHz to 4 MHz. This low voltage application shown here provides voltage for applications below about 72 volts.

The organization of the circuit boards **101** is shown in FIGS. **15** and **16**. FIG. **15** shows a single set of five LEDs **100** with circuit components **201**, **202** and **203**. FIG. **16** shows an exploded side view of an LED lighting system **10**, with support structure **102**, cover **107** and with LEDs **100**, which LEDs may be for example secured or joined to a circuit board **101** by any suitable means as for example soldering or heat sink compound **117**.

FIG. **17** is an example of an LED lighting system or tube **10** in a mass transit application. A transit vehicle has a body or hull **303** with a windshield **300**. The break away shows floor **304**, with seating **306** and partitions **305**. Lighting tubes **10** may be installed in pre-existing fluorescent light sockets or receptacles **309**, with bypassing or removal of the fluorescent light ballasts **308**. FIG. **26** is another view of the mass transit application, showing also passengers **310** and a reading plane **311** and floor plane **313**, which acts as a test zone for establishing whether the LEDs are providing sufficient illumination. FIGS. **18**, **19** and **20** illustrate an application in which the LED lighting system **10** is used as part of an advertising sign **401** for a taxi **400**. FIGS. **21**, **22** and **23** illustrate an application in which the LED lighting system **10** is used as part of an on duty sign **404** for a taxi **400**. FIGS. **24** and **25** illustrate installation of the LED lighting system **10** in new or pre-existing fluorescent light fixtures of an aircraft with a fuselage **500**, seating **501**, windows **502**, upper luggage compartment **503**, cargo area **504** and floor **505**.

In FIGS. **27A-27K**, various shapes of cover lens **107** are shown including moderate convex **124**, straight **107**, straight raised **118**, asymmetrically peaked **119** and **120**, symmetrically peaked **121**, raised dome **122**, low dome **123**, convex **124**, depressed low dome **125** raised convex **126**, and low dome with channel enclosing **127**. FIG. **28** shows a fluorescent lamp fixture **600** with power receptacles or sockets **601**, conventional ballast **602** for lamp **603**, replacement LED lighting tube **10**, ballast cover **604** and diffuser panel **605**. While the lens **107** is not required for the final assembly it can be added to act as a guard against vandalism, as a dust/dirt guard, as a light enhancing device, as a light directing/focusing device, as a moisture/waterproofing device (sealing unit completely with the addition of sealant) or as a light diffuser. In FIG. **28**, only the lighting tube **10** is new. FIG. **37** shows replacement of a fluorescent lamp **603** in a display sign application with an LED lighting tube **10** that fits between power receptacles **601**. The ballast **602** may be removed or bypassed.

In FIGS. **29-31**, powered end of an LED lighting tube for a vehicle application includes LED **100** (one of several in the array), support structure **102**, connecting wires **103** that connect to the circuit board **101** and rivets **108** for securing the circuit board **101** on the support structure **102**. The connecting wires **103** pass through the holes **114** in O-rings **110** that are secured to the upstanding flange of an inner mounting bracket **116**. The mounting bracket **116** is secured to the support structure **102** by a bolt **113** secured with nuts **112** and washer **111**. Bolt **113** and nuts **112** also secure outer mounting bracket **115** to the support structure **102**. Rivets **108** also secure the side walls of the mounting bracket **116** to the channel walls of the support structure **102**. Mounting bracket **115** is used to connect the LED lighting tube of this embodiment to a structural portion of a vehicle. FIGS. **32-34** show the non-powered end of the LED lighting system for a vehicle, which is the same as the powered end except that there are no power connections.

FIG. **35** shows electrical circuitry **30** of an current circuit, and FIG. **36** shows several such boards connected in parallel between respective power buses. FIGS. **35** and **36** show circuitry for a high voltage power source, above 72 volts, for example 120 volts to 240 volts, either AC or DC. The example shown here is for AC power supply. Fuse **215** protects the circuitry of the board from power surges. The fuse can be permanent or be a resettable fuse. Bi-directional filter circuit **204** filters out noise. Full wave rectifier **205** transforms AC current from the power bus (left side of figure) to DC current. The DC current from the full wave rectifier **205** is supplied to voltage regulator **207** to step the voltage down to a low level, for example 5 volts, to power switching power supply control IC **210**. The switching power supply control IC **210** provides a modulated signal at about 250 kHz or more that determines the switching frequency or pulse width of a high voltage switching power driver circuit **211**. The switching signal from driver **211** drives a primary coil of transformer **216**, and causes DC voltage supplied by the full wave rectifier **205** to switch at the switching frequency or pulse width determined by the control IC **210**. Transformer **216** couples this switching voltage through half-wave rectifier **206** which also filters the high frequency signal from the transformer **216** to the LED array **209** on the right side of FIG. **35**. The half-wave rectifier **206** provides the switching frequency or pulse width of the current from the secondary of the transformer **216** and supplies a isolated feedback signal through a signal feedback circuit **212** to control IC **210**. Depending on whether the sensed signal is above or below the desired current level, the control IC **210** varies the pulse width or pulse frequency of the signal driven by the driver circuit **211** to ensure a constant average current supplied to the LEDs. The transformer **216** both isolates input from the output, which drives the LEDs, and provides a voltage step down from high voltage above 72 volts, to low voltage required by the LED array **209**. The control IC **210** may also be configured to vary the average current supplied to the LEDs, by suitable controlling the pulse width or frequency of the drive signal to the circuit **211**, and thus provide a dimmable controller that can be used to control the brightness of the lighting devices. The switching power supply circuit **30** may be mounted on each circuit board **101**, or shared by each of several circuit boards **101** and located at one end of the lighting device **10**.

The switching power supply circuit **30** is integrated with the LEDs **100** on each section of printed circuit board **101**, so that any defect of each power supply circuits or LEDs **100** would not affect the lighting device **10** as a whole. The other circuit boards **101** of the lighting device are still active. The LED lighting device **10** can be installed in polarity or no polarity, and may have any required length. The LED lighting device **10** may use voltages from 1.5V~240V in both DC and AC, and may fit retroactively into existing fluorescent lighting fixtures after removing or bypassing the ballast. This LED lighting device **10** can be a replacement or retrofit for all existing fluorescent lighting tubes larger than the size of T5.

FIG. **38** and FIG. **39** show two different views of an embodiment of an LED lighting system in which the LEDs **100** lie on flat PCB heat sinks **134**. The LED arrays are attached to the flat PCB heat sinks with each of the LED arrays facing in a different direction. Each LED array contains a series of LEDs, each with a conical beam, that together create an illumination field. The orientation of the illumination fields of the LED arrays shown in FIGS. **38** and **39** are angularly offset from each other by 90 degrees. In other embodiments, this angle may change, and/or individual LEDs may have conical beams that are angularly offset from each other. Additional LED arrays may also be provided, with each LED array having a differently oriented illumination field. In one embodiment, the illumination fields of three or more LED arrays may together make up a 360 degree pattern. In the embodiment of FIGS. **38** and **39**, an 180 degree lens **133** with guides is attached to the support structure **136** in channel **109**, and may slide into place along the channel **109**. In FIG. **39**, two PCB heat sink slots **135** are formed in the support structure **136**. The heat sinks **134** fit in the slots **135**. Heat from the heat sinks **134** is in part conducted to the support structure **136** to assist in heat dissipation. A suitable heat conductive material such as aluminum may be used for the heat sinks **134** and support structure **136**.

FIGS. **40** and **41** show a further embodiment of an LED lighting system with 360 degree coverage in which the support structure **137** defines two channels and the LEDs **100** of two LED arrays on circuit boards **101** have illumination fields at 180 degrees to each other. A double sided lens **130** is received in channel **109** in the support structure **137**. Grooves **131** on the outside of the support structure are provided for receiving a mounting clip such as mounting clip **115** shown in FIG. **51**. Mounting clip **115** has arms **138** with hooks **139** that insert into the grooves **131**. The clip **115** may be secured by any suitable means to the structure **137** such as a part of the surface to which it is mounted.

FIGS. **42** and **45** show a further embodiment of an LED lighting system with 360 degree coverage similar to the design of FIG. **66**, but the lens covers **129** are omitted, and the locking elements **128** are also omitted, the cylindrical lens **127** being used to secure the elements together.

FIGS. **43** and **44** shows an end socket for use with an LED lighting system **10** which uses two pins **106** secured within an inner mounting channel **116** inside an end cap channel **132**. This end socket may be used with the designs of hollow support structures (or at least partially hollow) such as those of FIGS. **42**, **45**, **66** and **67** with the channel **116** protruding into the hollow support structure **140** or **147**.

FIGS. **46-50** show how various configurations of LED arrays may be carried by a support structure **141**. In these figures, the support structure **141** is the same in each case, and may be provided with one or two semi-cylindrical lenses **133** received in slots **109** running along the length of the support structure **141**. Mounting clip grooves **131** are provided on the outer sides of the support structure **141**. There may be one (FIG. **46**), two (FIG. **47**), three (FIG. **48**) or four (FIG. **49**) circuit boards **101** carrying LEDs **100** in linear arrays that may be directly secured to the support structure **141** or placed on flat PCB heat sinks **134** that are received in angled slots **135** running along the length of the support structure **141**. In this way, the orientation and number of the LED arrays can be selected according to the application.

FIGS. **52-55** show a variety of LED lighting systems with a domed support structure **142** and **144**. A 180 degree lens **143** has guides that are received in grooves **109** in the support structure **142** and **144**. An LED array formed of LEDs **100** on circuit boards **101** in one 180 degree embodiment (FIG. **52**) is received in slots **135** on the front side of the support structure, and on the opposite rear side a power supply **30** may be secured by any suitable means within the domed portion of the support structure **142** and **144**. In another embodiment (FIG. **54**), the LEDs of respective circuit boards **101** have illumination fields that are oriented at different angles, though both illumination fields are perpendicular to the direction of elongation of the support structure. The direction of the illumination field is the direction perpendicular to the light emitting surface of the LEDs **100**. The embodiments of FIGS. **52-55** may be connected to fixtures by end cap channels **132** as for example shown in FIGS. **59-61**.

FIGS. **56** and **57** show further embodiments of an LED lighting system with differently angled LED arrays. In this embodiment, the support structure **145** may be mounted by clips with lips that are received in grooves **131**. The embodiment of FIG. **58** is an example of an LED lighting system with 360 degree illumination field generated by four LED arrays at angles to each other, with semi-cylindrical lenses **133**, and also that may be mounted on a mounting clip.

FIGS. **62-65** show a variety of end sockets for use with LED lighting systems, showing support structure **102**, end cap **104**, pin connector Type 1 **105**, and end cap channel **132**.

FIGS. **66** and **67** show an embodiment of an LED lighting system with 360 degree coverage. In this embodiment, there are four LED arrays each secured to one piece of a two piece hollow support structure **147**. In this example, the support structure **147** forms four channels at the base of which circuit boards **101** holding the LEDs **100** are fixed by any suitable means. The four channels are defined by four arms of the support structure **147**. Lens covers **129** are received in slots running the length of the arms and are provided with openings for the LEDs. The LEDs protrude into the openings. A cylindrical lens **127** surrounds the support structure **147**. The two pieces of the support structure **147** are held together by locking elements **128**.

Immaterial modifications may be made to the embodiments described here without departing from what is claimed.

What is claimed is:

**1**. An LED lighting system, comprising:

a support structure spanning between a first end and a second end, the support structure being heat conductive and rigid;

at least the first end of the support structure carrying electrical connectors for connection to a power source;

at least one LED array extending along the support structure; and

power control circuitry for the at least one LED array, the power control circuitry being carried by the support structure and being in electrical communication with the electrical connectors,

wherein:

the power control circuitry is configured to provide current control for the LED array;

the at least one LED array is supported by a circuit board and the corresponding power control circuitry is provided on the circuit board;

the at least one LED array is divided into sets of LEDs; and

the power control circuitry is formed of multiple current controllers, each current controller of the multiple current controllers providing current control for a corresponding set of LEDs in the LED array.

**2**. The LED lighting system of claim **1** in which the support structure forms a channel, and the at least one LED array is located in the channel.

**3**. The LED lighting system of claim **1** in which each LED of the at least one LED array has a power rating of greater than 0.1 watts.

**4**. The LED lighting system of claim **1** further comprising:

the support structure being generally elongated in a first direction;

the at least one LED array having a first illumination field directed perpendicularly to the first direction; and

at least one other LED array carried by the support structure, the at least one other LED array having a second illumination field directed perpendicularly to the first direction, the second illumination field being oriented at a non-zero angle to the first illumination field.

**5**. The LED lighting system of claim **4** in which the first illumination field and the second illumination field are oriented at 180 degrees to each other.

**6**. The LED lighting system of claim **1** further comprising:

the support structure being generally elongated in a first direction; and

plural other LED arrays carried by the support structure, the plural other LED arrays being oriented to provide an illumination field that extends 360 degrees around the support structure at a given distance outward from the support structure.

**7**. The LED lighting system of claim **1** in which the support structure has a front side on which the at least one LED array is carried and a rear side on which the power control circuitry is carried.

**8**. The LED lighting system of claim **1** in which the support structure incorporates electrical connectors at a second end of the support structure.

**9**. The LED lighting system of claim **8** in which the electrical connectors at each of the first end and the second end of the support structure are compatible with a fluorescent light receptacle attachment pins.

**10**. The LED lighting system of claim **1** in which the power control circuitry is configured to provide constant current to the LEDs of the at least one LED array.

**11**. The LED lighting system of claim **1** in which the support structure is made of a unitary piece of material that is both heat conductive and rigid.

**12**. The LED lighting system of claim **1** further comprising an optically transparent or translucent cover secured to the support structure over the at least one LED array.

**13**. The LED lighting system of claim **1** in which the support structure is hollow.

**14**. The LED lighting system of claim **1** in which support structure is provided with at least one slot, and the at least one LED array is carried on at least one board inserted in the at least one slot.

**15**. The LED lighting system of claim **1** in which the at least one LED array is provided on a front side of the support structure and the support structure has a domed shaped rear side.

**16**. The LED lighting system of claim **12** in which the combination of the support structure and the optically transparent or translucent cover has an egg shaped cross-section.

**17**. The LED system of claim **16** in which the power control circuitry is carried inside the support structure.

**18**. A lighting system comprising multiple LED lighting systems according to claim **1** installed in a vehicle.

**19**. The lighting system of claim **18** in which the vehicle is a watercraft, aircraft or land vehicle.

**20**. A lighting system comprising multiple LED lighting systems according to claim **1** installed in a building or in signage.

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