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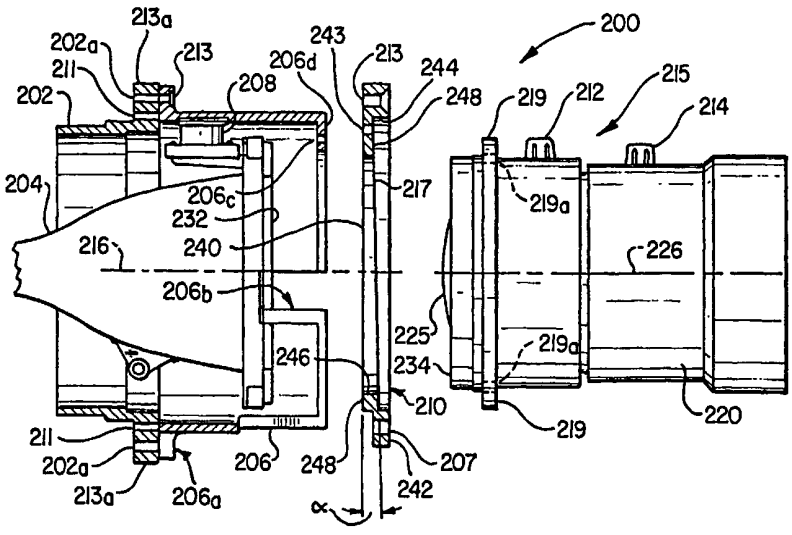
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(71) Applicant: REDIFUN STIMULATION, INC. [US/US]; 260 Bank Street, Southlake, TX 76092 (US).

(72) Inventors: BORDOVSKY, Robert, D.; 710 Rocky Canyon Road, Arlington, TX 76012 (US). HUGHS, Richard, B.; 2960 Kimberly Drive, Grapevine, TX 76051 (US). MEHTA, Amit; 1403 San Marcos Drive, Arlington, TX 76012 (US). WHEATLEY, Neil, M.; 1301 Plantation Drive, Southlake, TX 76092 (US).

(74) Agent: WEATHERFORD, Sidney, L.; Novakov & Davis, P.C., 2000 St. Paul Place, 750 North St. Paul, Dallas, TX 75201-3286 (US).

(54) Title: METHOD AND APPARATUS FOR AN IMPROVED WIDE-ANGLE DISPLAY SYSTEM



(57) Abstract

A wide-angle display system having an image projector, an image generator, and a plurality of CRT assemblies (200). Each CRT assembly includes a CRT member, an adapter housing (206), and a lens assembly. Each CRT member includes a CRT, a CRT cooling element (208), and a CRT housing for coupling to the image projector. The adapter housing has a first surface, and a second surface that forms a selected dihedral angle with the first surface. In an alternate embodiment, an adapter plate is disposed between the adapter housing and the lens assembly. The adapter plate has a first surface, and a second surface that forms the selected dihedral angle with the first surface. The selected dihedral angle between the adapter housing and the lens assembly causes a longitudinal axis of the CRT member to be offset from a longitudinal axis of the lens assembly, thereby correcting image distortion, such as Scheimpflug distortions.

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METHOD AND APPARATUS FOR AN IMPROVED WIDE-ANGLE DISPLAY SYSTEM

Description

Technical Field

The present invention relates in general to wide-angle display systems and, in particular, to projection apparatus utilized in wide-angle collimated universal display systems.

Background Art

Wide-angle collimated universal display systems (hereinafter referred to as wide-angle display systems) are used in training systems as training simulators. These training simulators produce scenes that a viewer, or trainee, would observe if seated in an aircraft cockpit, a helicopter cockpit, a tank hatch, or other such vehicle location. Generally, the scene portrayed to the viewer is representative of "virtual" surroundings, such as terrain or airspace. For example, airlines, government agencies, and private training companies utilize wide-angle display systems in flight simulators used in pilot training programs.

Typical wide-angle display systems utilize large, bulky image projectors to create the virtual surrounding on panoramic display screens. These image projectors are difficult to install and calibrate, because they are designed to either remain in a fixed position, or have minimal movement. Such image projectors typically have three cathode ray tubes, or cathode ray tube assemblies (hereinafter CRT's), each with a corresponding lens. Usually, the three CRT's consist of a first CRT for generating red light, a second CRT for generating green light, and a third CRT for generating blue light. In most instances, the three CRT's are arranged in a triangular fashion with no regard for placement of

to the CRT's, and each lens has a fixed focal length. Thus, to calibrate the image projector, or focus the image on the panoramic display screens, the entire image projector must be moved. These are laborious and time consuming processes, usually requiring a high degree of technical expertise.

In addition to the difficulties associated with installing and calibrating conventional wide-angle display systems, maintenance and repair are extremely time consuming and difficult. Because the CRT's and the corresponding lenses are permanently attached to each other, if a CRT or lens requires repair or replacement, the entire CRT and lens combination must be removed and sent to the manufacturer. In some cases, the entire image projector must be sent to the manufacturer. For these reasons, the owners of these conventional wide-angle display systems typically purchase and maintain backup image projectors in case of a failure of all or part of the primary image projector.

As one might expect, not only are repair and replacement of conventional wide-angle display systems difficult and time consuming, they are also very expensive. Replacement CRT and lens combinations for a typical wide-angle display system installed during the 1980's at a cost of one million dollars or more, may cost hundreds of thousands of dollars.

Referring to **Figure 6** in the drawings, a typical CRT and lens combination **300** for a prior-art wide-angle display system, similar to the system manufactured and sold by Hughes Display Products, Inc. under the product name SUPRALUX®, is shown. CRT and lens combination **300** is one of three such CRT and lens combinations installed on such wide-angle display systems. The three CRT and lens combinations **300** are mounted to an image projector (not shown) in a triangular fashion, as explained above. CRT **301** is typically powered by a 36 Kilovolt power supply (not shown) that

is coupled to CRT **301** at coupling **303**. CRT **301** generates electron beams **302** that pass through focus coils **304**. Focus coils **304** are coupled to a gimbal mounting assembly **305**. Focus coils **304** align electron beams **302** prior to passage through a deflection coil **306**. Deflection coil **306** is controlled by an image generator (not shown) for directing the electron beams **302** to a specific location on a reflective target **308**.

As electron beams **302** impinge upon reflective target **308**, electron beams **302** excite a phosphor coating **310**. Excited phosphor coating **310** generates a particular color of light, usually red, green, or blue. The red, green, or blue light generated as electron beams **302** impinge upon phosphor coating **310** is reflected onto a reflective surface, or mirror, **312**. Reflective surface **312** is typically a concave surface, such that the red, green, or blue light is reflected out of a front portion **313** of CRT **301**. The red, green, or blue light then passes through a corrector lens **314** that is permanently fixed to CRT **301**, usually at front portion **313**. Corrector lens **314** redirects and focuses the red, green, or blue light onto a display screen (not shown). Because corrector lens **314** is fixed to CRT **301**, and because CRT and lens combination **300** are mounted at a fixed angle relative to the image projector, the focal length of CRT and lens combination **300** is fixed. Because corrector lens **313** is fixed to CRT **301**, it is not possible to replace CRT **301** or corrector lens **314** independently with conventional, off- the-shelf (commercially available) replacement parts.

In addition, reflective target **308** is angled slightly relative to mirror **312** to correct Scheimpflug distortions that would result from projecting the image onto the curved and angled panoramic screens. Scheimpflug distortions occur when a lens is not oriented normal to a target. Because reflective target **308**

has been slightly inclined or offset to correct Scheimflug distortions, CRT and lens combination **300** is considerably more expensive than conventional CRT's that do not make such corrections.

The only way to calibrate or alter the focal length of CRT and lens combinations **300** on such wide-angle display systems is to physically move either the entire image projector or all of the panoramic display screens until the projected image is in focus on the display screens. This is a complicated, laborious and time consuming process, usually requiring a high degree of technical expertise. As stated above, if reflective surface **312**, phosphor coating **310**, or corrector lens **314** require repair or replacement, CRT and lens combination **300** must be repaired or replaced in its entirety, which usually involves sending CRT and lens combination **300**, or the entire image projector, back to the manufacturer.

Although the foregoing and other advances have been made with regard to wide-angle display systems, they have not adequately addressed the shortcomings in the art. For example, it would be desirable to have a CRT and lens combination apparatus that could be retrofitted into existing wide-angle display systems to replace existing CRT and lens combinations. It would also be desirable to have a wide-angle display system for which the CRT and lens could be repaired or replaced separately. Further, it would be desirable to have a wide-angle display system for which individual CRT and lens combinations could be calibrated and focused without having to move the entire image projector.

It would be desirable to have a wide-angle display system for which repair and replacement of components, such as CRT's and lenses, could be performed on-site. It would also be desirable to have a wide-angle display system for which individual components, such as CRTs and lenses, could be replaced by off-the-

shelf replacement components. It would be further desirable to have a wide-angle display system that could be calibrated and focused by users without a high degree of technical expertise. It would be further desirable to have a wide-angle display system wherein the projected image is brighter and the life of each CRT is extended.

Disclosure of Invention

Advances in the art of wide-angle display systems have not overcome certain shortcomings and it is an object of the present invention to provide a CRT and lens combination apparatus that can be retrofitted into existing wide-angle projector systems to replace existing CRT and lens combinations.

It is another object of the present invention to provide a wide-angle display system having separate CRT and lens assemblies for which each CRT and each lens assembly can be repaired or replaced independently.

It is yet another object of the present invention to provide a wide-angle display system for which individual CRT and lens combinations can be calibrated and focused independently without having to move an entire image projector or all of the panoramic display screens.

It is yet another object of the present invention to provide a wide-angle display system for which repair and replacement of components, such as CRT's and lens assemblies, can be performed on-site.

It is yet another object of the present invention to provide a wide-angle projector system for which individual components, such as CRT's and lens assemblies, can be replaced by generic

replacement components.

It is yet another object of the present invention to provide a wide angle projector system that can be calibrated and focused by users without a high degree of technical expertise.

It is yet another object of the present invention to provide a wide-angle display system that will provide a brighter image and extend the life of the CRT's.

The foregoing objects are achieved by providing an improved wide-angle display system having three conventional high-definition, monochrome CRT members, or CRTs: a first CRT for generating red light, a second CRT for generating green light and a third CRT for generating blue light. Each CRT has an associated cooling element. The three CRT's are disposed in an equilateral triangular fashion on the face of the wide-angle projector. The green CRT is located at a top position and the red CRT and blue CRT located at bottom positions, thereby providing a clearer, better defined scene with improved edge blending. Each CRT is adapted to be installed into an image projector of either an existing wide-angle display system, or a wide-angle display system of original manufacture. Each CRT is coupled to a separate adapter housing. Each adapter housing is coupled to a separate adapter plate, each of which is configured to receive a conventional lens assembly for focusing the CRT.

In the preferred embodiment, each adapter housing is configured such that each corresponding lens assembly is oriented at a selected angle relative to the corresponding CRT and the other CRT's. In an alternate embodiment, this selective orientation is accomplished by a modified adapter plate that is configured such that each corresponding lens assembly is oriented at a selected angle relative to the corresponding CRT and the other CRT's. In this alternate embodiment, each adapter plate has

a first mounting surface for attachment to the CRT, and a second mounting surface for attachment to the lens assembly. The selected angle is the dihedral angle between the first mounting surface and the second mounting surface of the adapter plate.

Orienting the lens assembly at the selected angle relative to the CRT eliminates the need for Scheimpflug calibrations. Each lens assembly includes dynamic and static lens adjustment controls to eliminate the need to physically move the image projector in order to calibrate or focus the projected image on the panoramic display screens.

The above, as well as, additional objectives, features, and advantages of the present invention will become apparent in the following detailed description when read in conjunction with the accompanying drawings.

Brief Description of Drawings

The novel features believed characteristic of the invention are set forth in the appended claims. The invention itself however, as well as a preferred mode of use, further objects and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings, wherein:

Figure 1A is a top-view schematic of a wide-angle display system in which a preferred embodiment of the present invention may be implemented;

Figure 1B is a left side view of the wide-angle display system of **Figure 1A**;

Figure 1C is a front view of the wide-angle display system

of **Figure 1A**;

Figure 2A is an exploded side view in partial cross-section of a CRT assembly of the wide-angle display system in accordance with a preferred embodiment of the present invention;

Figure 2B is a top view of the adapter housing for the CRT assembly of **Figure 2A**;

Figure 2C is a cross-sectional view of the adapter housing of **Figure 2B** taken at II-II;

Figure 2D is a perspective view of the adapter housing of **Figure 2A**;

Figure 2E is a top view of the adapter plate for the CRT assembly of **Figure 2A**;

Figure 2F is a side view of the adapter plate of **Figure 2E**;

Figure 3A is a side view in partial cross-section of an assembled CRT assembly of the wide-angle display system of the present invention according to an alternate embodiment;

Figure 3B an exploded side view in partial cross-section of the CRT assembly of **Figure 3A**;

Figure 3C is a front view of an adapter plate for the CRT assembly of **Figures 3A** and **3B**;

Figure 4A is a schematic of a CRT connector/mounting printed circuit board (PCB) in accordance with a preferred embodiment of the present invention;

Figure 4B is a schematic of a power supply circuit for the wide-angle display system according to the present invention;

Figure 5 is a perspective view of a wide-angle display system depicted in a airplane cockpit simulator application in accordance with a preferred embodiment of the present invention; and

Figure 6 is a side view of a prior-art CRT and lens combination.

Best Mode for Carrying Out the Invention

With reference now to the figures, and in particular, with reference to **Figures 1A-1C**, a preferred embodiment of a wide-angle display system **100** according to the present invention is depicted. In **Figure 1A**, wide-angle display system **100** is shown in a top-view schematic. Wide-angle display system **100** includes at least one image projector **102** and at least one panoramic display screen **104**. It is not uncommon for a large installation to include a plurality of image projectors **102** generating images on a plurality of panoramic display screens **104**. An example of such a large installation would be one for a flight simulator for a large commercial aircraft (see **Figure 5**). When using multiple image projectors **102**, it is necessary that image projectors **102** be calibrated. Calibrating is a process whereby multiple displayed images are adjusted so that the displayed images appear on the panoramic display screens as an uninterrupted, continuous scene.

Image projector **102** houses a plurality of, preferably three, CRT assemblies **106**, **108**, and **110**. CRT assemblies **106**, **108**, and **110** are also represented by reference letters **R** for red, **G** for green, and **B** for blue, respectively. As is shown in **Figures 1A** and **1B**, it may be necessary for CRT assemblies **106**, **108**, and **110**

to protrude out from a front surface **101** of image projector **102**. Image projector **102** includes a housing, a conventional power source (not shown), electronic circuits and assemblies for controlling and generating images (see **Figures 4A** and **4B**), and three monochrome CRT members operably associated with three lens assemblies (see **Figures 2A**, **3A**, and **3B**). CRT assembly **106** generates green light; CRT assembly **108** generates red light; and CRT assembly **110** generates blue light. As is shown in **Figure 1C**, CRT assemblies **106**, **108**, and **110** are preferably arranged in an equilateral triangular shape, with CRT assembly **106** at the top position, and CRT assemblies **108** and **110** at the base positions. The significance of such an arrangement will be explained in detail below.

Each CRT assembly **106**, **108**, and **110**, is adapted to generate images over a predetermined range, as indicated by the dashed lines in **Figure 1A**. CRT assembly **106** has an image range **106a**, CRT assembly **108** has an image range **108a**, and CRT assembly **110** has an image range **110a**. Each CRT assembly **106**, **108**, and **110** has a projection center line **106b**, **108b**, and **110b**, respectively. Projection center lines **106b**, **108b**, and **110b** intersect at a focal point **111**, preferably located on panoramic display screen **104**. It should be understood that **Figure 1A** is not drawn to scale, and that, in reality, center lines **106b**, **108b**, and **110b** are nearly parallel. Focal point **111** is generally defined by the distance from front surface **101** to panoramic screen display **104**. It is preferred that focal point **111** be in the range of about 110 to 122 inches. As will be explained below, the present invention allows for minor adjustments to focal point **111** to be made quickly and easily.

In conventional wide-angle display systems, blue CRT assembly **110** is located in the top position of the triangular arrangement.

However, according to the present invention, green CRT assembly **106** is located in the top position of the triangular arrangement. Significant advantages are achieved by locating green CRT assembly **106** in the top position. Image projector **102** is usually located directly above the user. By locating green CRT assembly in the top center position, the brightest light of the wide-angle display system is along the same axis as the user's line of sight. This means increased overall brightness to the user, and a clearer, better-defined image display. In addition, by always placing green CRT assembly **106** in the top center location, particularly with installations having multiple image projectors **102**, there is less brightness variation across the field of view; and soft edge blanking. Soft edge blanking, the process of blending the border resulting between adjacent images projected by each projector in the simulator, is improved greatly, thereby providing the appearance of more uniform edge blending between adjacent images.

Because green CRT assembly **106** supplies the majority of the brightness of image projector **102**, green CRT assembly usually requires replacement more often. Another advantage of placing green CRT assembly **106** in the top position is that maintenance and replacement are easier.

Referring now to Figures **2A-2F** in the drawings, a CRT assembly **150** according to the preferred embodiment of the present invention is illustrated. In **Figure 2A**, CRT assembly **150** is illustrated in an exploded view in partial cross-section. CRT assembly **150** is representative of CRT assemblies **106**, **108**, and **110**. CRT assembly **150** includes a conventional CRT housing **152**, conventional CRT **154** having a conventional cooling element **156**, adapter housing **158** coupled to CRT housing **152**, adapter plate **160** coupled to adapter housing **158**, and conventional adjustable lens assembly **162** coupled to adapter plate **160**. CRT **154** and cooling element **156** generally define a "CRT member," which, for purposes

of the present invention, may be used interchangeably with the phrase "CRT." CRT **154** is preferably a 9-inch high-definition monochrome color projection tube having an attached cooling element **156**, similar to the CRT manufactured and sold by the Sony Corporation under model number 09MEX2. When assembled, CRT housing **152**, CRT **154**, and adapter housing **158** share a common longitudinal CRT axis **164**. CRT **154** is connected to power and electronics (not shown) via conventional cables and connectors (not shown).

CRT housing **152** is adapted to be releasably coupled to front surface **101** of image projector **102** (see **Figures 1A-1C**) by conventional fastening means (not shown), preferably by the provision of a plurality of mounting apertures **166**. CRT housing **152** may be integral with front surface **101** of image projector **102**. CRT **154** is adapted to utilize the electronics and electrical connectors from existing image projectors. Thus, CRT housing **152** and CRT **154** may be components of image projector **102** as originally manufactured, or may be retrofitted into an existing image projector. Such retrofitting will be discussed in more detail below. Adapter housing **158** is releasably coupled to CRT housing **152** by conventional fastening means (not shown), preferably by the provision of a plurality of mounting apertures **168** that pass longitudinally through a plurality of radially extending flange members **169**. Mounting apertures **168** align with a plurality of mounting apertures **173** in CRT housing **152**. As seen in **Figure 2D**, flange members **169** include recessed portions **169a** that allow access to mounting apertures **166**.

Adapter housing **158** has a flat rear surface **171** and a plurality of opposing integral protrusions **172** that extend longitudinally away from flat rear surface **171**. Protrusions **172** terminate in flat surfaces **174**. Protrusions **172** provide recessed,

open areas **172a** that allow clearance of CRT **154**. Flat surfaces **174** define a plane that forms a dihedral angle **α** with rear surface **171**. Dihedral angle **α** is preferably about 1° and may be in the range of 0.75° to 1.75° depending on the mounting arrangement. Each flat surface **174** includes at least one longitudinal mounting aperture **175**. Mounting apertures **175** are not parallel with CRT axis **164**; rather, mounting apertures **175** are offset from CRT axis **164** by angle **α**. As explained above, when a lens is not pointed normal to a target, a distortion condition called the Scheimpflug distortion is created. Angle **α** substantially eliminates any Scheimpflug distortion present as a result of projecting images onto panoramic display screens **104**.

Referring particularly to **Figures 2B**, **2C**, and **2D** in the drawings, adapter housing **158** includes a plurality of flange members **177** that extend radially outward from adapter housing **158**. Flange members **177** are generally parallel to rear surface **171**; therefore, flat surfaces **174** also form dihedral angle **α** with flange members **177**, and consequently, CRT **154**. Flange members **177** are preferably located in the recessed, open areas **172a** of protrusions **172**. Flange members **177** include mounting apertures **179** so that CRT **154** may be releasably coupled to and carried by adapter housing **158**.

Adapter plate **160** is releasably coupled flushly against flat surfaces **174** of adapter housing **158** by a plurality of conventional fastening means (not shown) that pass through a plurality of apertures **170** in adapter plate **160**. As such, adapter plate **160** forms dihedral angle **α** with rear surface **171** of adapter housing **158**.

Adapter plate **160**, is preferably an annular ring having a front surface **176** and an opposing parallel rear surface **178**. In

Figure 2A, adapter plate **160** is shown in a cross-sectional view taken at III-III of **Figure 2E**. A circular aperture **180** passes concentrically through the center of adapter plate **160**. It should be understood that adapter housing **158** and adapter plate **160** may be integrated into a single component.

Lens assembly **162** includes a plurality of lenses, such as lens **182**, and is preferably similar to the lens assembly manufactured and sold by U.S. Precision Lens under the model name Condor. Lens assembly **162** includes a static focus adjustment **184** for focusing interior portions of the displayed image on panoramic display screen **104**, and a dynamic focus adjustment **186** for focusing perimeter portions of the displayed image on panoramic display screens **104**. Lens assembly **162** includes a mounting flange **188** having a plurality of mounting apertures **190**.

Lens assembly **162** is releasably coupled flush against adapter plate **160** by conventional fastening means (not shown) that pass through mounting apertures **190** in mounting flange **188** and a plurality of aligned mounting apertures **192** (see **Figure 2E**) that pass through adapter plate **160**. As mentioned above, mounting apertures **170** in adapter plate **160** are aligned with mounting apertures **175** in flat surfaces **174** of adapter housing **158**. In this manner, lens assembly **162** is offset from rear surface **171** of adapter housing **158** by dihedral angle α.

Lens assembly **162** has a longitudinal lens axis **192**. When installed, rear surface **178** of adapter plate **160** flushly contacts flat surfaces **174** of adapter housing **158**; and mounting flange **188** of lens assembly **162** flushly contacts front surface **176** of adapter plate **160**. Thus, when CRT assembly **150** is assembled, lens axis **192** and CRT axis **164** are not parallel; rather, CRT axis **164** and lens axis **192** are offset by angle α, such that lens assembly **162**

angles inwardly toward the center of front surface **101** of image projector **102**. Focal point **111** is created at the intersection of the lens axis **192** of each lens assembly **215** of CRT assemblies **106**, **108**, and **110** of image projector **102**. Focal point **111**, though set by angle **α** of adapter housing **158**, may be further adjusted utilizing static focus adjustment **184** and dynamic focus adjustment **186**.

Adapter housing **158** and adapter plate **160** allow the unique combination of conventional CRT **154** and conventional CRT housing **152** with conventional lens assembly **162**. Using this unique combination, off-the-shelf components can be used in a retrofit application on existing image projectors, thus greatly reducing the cost of repair and replacement of CRT assemblies, such as prior-art CRT assembly **300** (see **Figure 6**). The present invention corrects Scheimpflug distortions without the need for an expensive CRT having a reflective target **308** that must be angled slightly relative to a mirror **312** (see **Figure 6**) as is employed in the prior art.

Prior-art wide-angle display systems have a focal point located about 112 inches from the panoramic display screens. Focal length **111** for the present invention is preferably about 115 inches. As such, minor modifications to mounting assemblies (not shown) of image projector **102** may be necessary during initial installations when the present invention is used in a retrofit application. However, fine tuning of focal length **111** may be accomplished utilizing static focus adjustment **184** and dynamic focus adjustment **186**.

Referring now to **Figures 3A-3C** in the drawings, a CRT assembly **200** according to an alternate embodiment of the present invention is illustrated. CRT assembly **200** is representative of

CRT assemblies **106**, **108**, and **110**. As best seen in **Figure 3B**, CRT assembly **200** includes a conventional CRT housing **202**, a conventional CRT **204** having a conventional cooling element **208**, an adapter housing **206** coupled to CRT housing **202**, an adapter plate **210** coupled to adapter housing **206**, and a conventional adjustable lens assembly **215** coupled to adapter plate **210**. CRT **204** and cooling element **208** generally define a CRT member. As in the preferred embodiment, CRT **204** is preferably a 9-inch high-definition monochrome color projection tube having an attached liquid coupled cooling element **208**, similar to the CRT manufactured and sold by the Sony Corporation under model number 09MEX2. CRT housing **202**, CRT **204**, adapter housing **206**, and adapter plate have a common longitudinal CRT axis **216**. CRT **204** is connected to power and electronics (not shown) via appropriate cables and connectors (not shown). CRT **204** is adapted to utilize the electronics and electrical connectors from existing image projectors.

CRT housing **202** is adapted to be releasably coupled to front surface **101** of image projector **102** (see **Figures 1A-1C**) by conventional fastening means (not shown), preferably by the provision of aligned apertures **211**. CRT housing **202** may be integral with front surface **101** of image projector **102**. Thus, CRT housing **202** may be a component of image projector **102** as originally manufactured, or may be retrofitted into an existing image projector. Such retrofitting will be discussed in more detail below. Adapter housing **206** is releasably coupled to CRT housing **202** by conventional fastening means (not shown), preferably by the provision of a plurality of mounting apertures **213** that pass longitudinally through a plurality of radially extending flange members **213a**. Mounting apertures **213** align with a plurality of mounting apertures **202a** in CRT housing **202**. As seen in **Figure 3B**, flange members **213a** include recessed portions

206a that allow access to mounting apertures 202a.

Adapter plate 210 is releasably coupled to adapter housing 206 by a plurality of fastener means, preferably screws 210a that pass through a plurality of mounting apertures 207 in adapter plate 210 and through aligned apertures 206c that pass through inwardly extending flanges 206d located at the end of adapter housing 206. Screws 210a are matingly received by a plurality of spacing fasteners 209 having a threaded male end 209a, a head 209b, and internal female threads 209c inset within head 209b. Female threads 209c of spacing fasteners 209 matingly receive screws 210a. In this manner, adapter plate 210 is flushly mounted against flange 206d of adapter housing 206. Screws 210a, spacing fasteners 209, and mounting apertures 213 are parallel to CRT axis 216.

Threaded male ends 209a extend through mounting apertures 204a in CRT 204 and are secured by nuts 204b. In this manner, CRT 204 and cooling element 208 are releasably coupled to adapter plate 210. Thus, CRT 204 is not directly coupled to adapter housing 206. Spacing fasteners 209 maintain a selected clearance between CRT 204 and adapter plate 210. A plurality of longitudinal cut-outs 206b in adapter housing 206 provide clearance for screws 210a, spacing fasteners 209, and the corners of CRT 204.

Adapter plate 210 has a generally square-shaped rear surface 240, and a generally octagonal-shaped front surface 242. Rear surface 240 and front surface 242 are preferably parallel to each other. A generally octagonal-shaped recessed portion 244 extends inward from front surface 242, and a longitudinal circular aperture 246 passes through adapter plate 210. Aperture 246 is smaller in diameter than recessed portion 244 such that a flange

248 extends radially inward around adapter plate 210. Recessed portion 244 and flange 248 are created by precision grinding such that a front machined surface 217 exists. Front machined surface 217 forms a predetermined dihedral angle α with rear surface 240. Angle α is preferably about 1°.

Lens assembly 215 includes a plurality of lenses, such as lens 225, and is preferably similar to the lens assembly manufactured and sold by U.S. Precision Lens under model name Condor. Lens assembly 215 includes a static focus adjustment 212 for focusing interior portions of the displayed image on panoramic display screen 104, and a dynamic focus adjustment 214 for focusing perimeter portions of the displayed image on panoramic display screens 104. Lens assembly 215 includes a mounting flange 219 having mounting apertures 219a. Recessed portion 244 is octagonally shaped to accommodate mounting flange 219 of lens assembly 215. It should be understood that recessed portion 244 may be of different shapes depending upon the shape of mounting flange 219 of lens assembly 215.

Lens assembly 215 is coupled to adapter housing 206 via adapter plate 210. In **Figure 3B**, adapter plate 210 is shown in cross-section along section lines B-B of **Figure 3C**. Lens assembly 215 is releasably coupled to adapter plate 210 by conventional fasteners (not shown) that pass through mounting apertures 219a and apertures 243 that pass through flange 248 in adapter plate 210. Apertures 243 in flange 248 are perpendicular to front machined surface 217. Thus, apertures 243 are offset by angle α from CRT axis 216. In this manner, lens assembly 215 is offset from CRT housing 202, CRT 204, and adapter housing 206 by angle α.

Lens assembly 215 has a longitudinal lens axis 226. When

installed, rear surface **240** flushly contacts adapter housing **206**, as shown in **Figure 3A**. Also, when installed, mounting flange **219** of lens assembly **215** flushly contacts front machined surface **217**. Thus, when CRT assembly **200** is assembled, as shown in **Figure 3A**, lens axis **226** and CRT axis **216** are not parallel; rather, CRT axis **216** and lens axis **226** form angle **α** such that lens assembly **215** angles inwardly toward the center of front surface **101** of image projector **102**. It is preferable that CRT axis **216** and lens axis **226** intersect at a point of intersection **230** located between a front surface **232** of CRT **204** and a rear surface **234** of lens assembly **215**. Focal point **111** is created at the intersection of the lens axes **226** of each lens assembly **215** of the three CRT assemblies **106**, **108**, and **110** of image projector **102**.

Angle **α** substantially eliminates any Scheimpflug distortion present as a result of projecting images onto panoramic display screens **104**. Focal point **111**, though set by angle **α** of adapter plate **210**, may be further adjusted utilizing static focus adjustment **212** and dynamic focus adjustment **214**.

Adapter housing **206** and adapter plate **210** allow the unique combination of conventional CRT **204** and conventional CRT housing **202** with conventional lens assembly **215**. Using this unique combination, off-the-shelf components can be used in a retrofit application on existing image projectors, thus greatly reducing the cost of repair and replacement of CRT assemblies, such as prior-art CRT assembly **300** (see **Figure 6**). It should be understood that adapter housing **206**, adapter plate **210**, and front machined surface **217** may be integrated into a single component.

Prior-art wide-angle display systems have a focal point located about 112 inches from the panoramic display screens. Focal point **111** for the present invention is preferably in the

range of about 110 to 122 inches. As such, minor modifications to mounting assemblies (not shown) of image projector **102** may be necessary during initial installations when the present invention is used in a retrofit application. However, fine tuning of focal length **111** may be accomplished utilizing static focus adjustment **212** and dynamic focus adjustment **214**.

Referring now to **Figure 4A** in the drawings, a schematic of a connector/mounting printed circuit board (PCB) **400** for CRT **154** or CRT **204** according to the present invention is illustrated. Connector/mounting PCB **400** is adapted to replace existing connector/mounting PCB's in retrofit applications. In connector/mounting PCB **400**, the connector (not shown) for CRT **204** is mounted directly on connector/mounting PCB **400**, thereby providing a quick and easy connection to the existing CRT support assembly (not shown). By using connector/mounting PCB **400**, all electrical and most mechanical connections from an existing image projector to CRT assemblies **106**, **108**, and **110** require little or no additional modification.

Referring now to **Figure 4B** in the drawings, a schematic of a power supply circuit **410** for the wide-angle display system **100** of the present invention is illustrated. Power supply circuit **410** is utilized in a retrofit application. As such, an existing power supply **412**, usually a 36 Kilovolt power supply, is controlled by existing controls and connectors **414**. In a preferred embodiment, existing power supply **412** is adjusted, utilizing a high voltage potentiometer integral to existing power supply **412**, so that voltage available at CRT assemblies **106**, **108**, **110** is 32KV.

In another, less desirable embodiment, at least one dropping resistor and connector interchange unit (not shown) is electrically coupled between power supply **412** and each CRT

assembly **106**, **108**, and **110**. Dropping resistor and connector interchange unit (not shown) can reduce the voltage to CRT assemblies **106**, **108**, and **110** to about 32 Kilovolts. In this manner, existing power supply **412** in an existing image projector does not have to be replaced or adjusted to allow CRT assemblies **106**, **108**, and **110** to be retrofitted into the existing image projector.

Referring now to **Figure 5** in the drawings, a perspective view of a wide-angle display system **500** according to the present invention is illustrated being used in an airplane cockpit simulator application. An image projector **502**, similar to image projector **102**, is shown installed directly above and behind pilot's consoles **503**. It would not be uncommon in such an application to have a plurality of image projectors **502**. Image projector **502** projects synchronized images onto panoramic display screens **504**. It should be apparent wide-angle display system **500** could be easily modified for use in a helicopter cockpit simulator application by modifying the size and placement of panoramic display screens **504** and changing the arrangement of pilot's consoles **503**.

In its retrofit application, the wide-angle display system **100** of the present invention functions without any change in the calibration procedures of the existing image projector. No additional changes are necessary for correction of distortion. Existing power supplies do not need to be replaced, and there is no need for image generator calibration. Consequently, modifications to the image projector may be made in the field. Because improved CRT assemblies **106**, **108**, and **110** are used, the time from power off to a training picture is shortened and CRT life expectancy is nearly doubled.

Although the present invention describes correction of image

distortions by employing a selected dihedral α between surfaces of either adapter housing **158** or adapter plate **210**, it should be understood that dihedral angle α may also be integrated into lens assembly **162** or **215**. In addition, it should be understood that the use of surfaces forming selected dihedral angle α is only one of several means of correcting image distortions. Other means of correcting image distortions include incorporating one or more inserts, washers, and spacers to offset a lens assembly from a CRT assembly.

The wide-angle display system of the present invention provides a significant improvement in convergence and color balance stability over the prior-art systems. By positioning the green CRT assembly **106** in the top position, improved brightness of the displayed image is provided. In addition, this arrangement provides improved definition of the displayed image, a reduced need for green CRT brightness, and easier access to green CRT assembly **106**. The inherently brighter green CRT projected image provides a reduction in intensity which lengthens the life of green CRT assembly **106**.

A further advantage of the wide-angle display system of the present invention is that the cost of maintaining and replacing CRT and lens elements is greatly reduced. In addition, maintenance and calibration time for image projector **102** is reduced. CRT assemblies **106**, **108**, and **110** substitute directly for existing CRT and lens assemblies in existing image projectors, and provide better edge match, improved contrast ratio, and improved light-point profile.

While the invention has been particularly shown and described with reference to a preferred embodiment, it should be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the spirit and

scope of the invention.

Claims

1. A wide-angle display system comprising:

an image projector for projecting an image onto a panoramic display screen;

a plurality of adapter housings, each adapter housing having a front surface and a rear surface, said front surface and said rear surface being configured to form a selected dihedral angle, each said rear surface being flushly coupled to said image projector;

a plurality of CRT members, each CRT member being coupled to a corresponding said adapter housing;

a plurality of lens assemblies, each lens assembly being coupled to a corresponding said front surface;

and

at least one image generator for controlling said CRT members.

2. The wide-angle display system according to claim 1, wherein said plurality of CRT members comprises:

a high-intensity monochrome green CRT member;

a high-intensity monochrome red CRT member; and

a high-intensity monochrome blue CRT member.

3. The wide-angle display system according to claim 2, wherein said high-intensity monochrome green CRT member is located above said high-intensity monochrome red CRT member and said high-intensity monochrome blue CRT member.

4. The wide-angle display system according to claim 2, wherein said plurality of coupled adapter housings form an equilateral triangle with said high-intensity monochrome green CRT member being disposed in a top position, and said high-intensity monochrome red CRT member and said high-intensity monochrome blue CRT member each being disposed in a bottom position.

5. The wide-angle display system according to claim 1, wherein each said CRT member comprises:

a CRT housing;

a high-intensity monochrome CRT carried by said CRT housing; and

a cooling element.

6. The wide-angle display system according to claim 1, wherein said selected dihedral angle is within a range of 0.75° to 1.75°.

7. The wide-angle display system according to claim 6, wherein said dihedral angle is appropriate for correcting any Scheimpflug image distortions.

8. The wide-angle display system according to claim 1, wherein said lens assembly comprises:

at least one lens;

at least one static focus adjustment; and

at least one dynamic focus adjustment.

9. The wide-angle display system according to claim 1, further comprising:

an adapter plate being disposed between each said adapter housing and each said corresponding lens assembly.

10. A method for displaying a wide-angle image on at least one panoramic display screen, the method comprising the steps of:

providing an image projector for projecting said wide-angle image;

coupling a plurality of CRT members to said image projector;

disposing an adapter plate between each said CRT member and a corresponding lens assembly;

utilizing said adapter plate for inducing said CRT member and said corresponding lens assembly to form a selected dihedral angle with a centerline of said CRT member in the range of 0.75° to 1.75°; and

adjusting voltage to each said CRT member.

11. The method according to claim 10, wherein the step of coupling a plurality of CRT members to said image projector further comprises:

coupling a high-intensity monochrome green CRT member to said image projector;

coupling a high-intensity monochrome red CRT member to said image projector; and

coupling a high-intensity monochrome blue CRT member to said image projector

adjusting said voltage to each said CRT Member to 32 kilovolts.

12. The method according to claim 11, wherein said high-intensity monochrome green CRT member is coupled to said image projector in a superior position above said high-intensity monochrome red CRT member and said high-intensity monochrome blue CRT member.

13. The method according to claim 11, further comprising:

providing a plurality of CRT housings;

coupling a high-intensity monochrome CRT to each said CRT housing; and

coupling an adapter housing to each said CRT housing.

14. The method according to claim 11, further comprising:

forming a selected angle between a longitudinal axis of each said lens assembly and a longitudinal axis of each corresponding said CRT member.

15. The method according to claim 14, wherein said selected angle is within a range of 0.75^0 to 1^0.

16. An apparatus for retrofitting into an existing wide-angle display system having an existing power supply, existing control circuitry, at least one existing image projector for projecting an image onto at least one existing wide angle display screen wherein said image projector comprises at least one existing CRT member and an existing lens assembly coupled to said at least one existing CRT member, further comprising:

at least one replacement CRT assembly adapted to replace said existing CRT member and said existing lens assembly; and

instructions for adjusting voltage to each said CRT member.

17. The apparatus according to claim 16, wherein said at least one replacement CRT assembly comprises:

a replacement CRT housing;

a replacement CRT member coupled to said replacement CRT housing, said replacement CRT member being adapted to be controlled by said at least one existing image generator;

an adapter housing coupled to said replacement CRT housing; and

a replacement lens assembly coupled to said adapter housing.

18. The apparatus according to claim 17, wherein a selected angle is formed between said adapter housing and said lens assembly.

19. The apparatus according to claim 18, wherein the selected angle is within a range of 0.75° to 1.75°.

20. The apparatus according to claim 17, further comprising:

replacement voltage control circuitry configured to replace said existing voltage control circuitry.

21. The apparatus according to claim 20, wherein said replacement control circuitry comprises:

at least one dropping resistor and connector interchange unit for adjusting an existing power output from said existing power supply to match a power requirement for said replacement CRT member.

22. The apparatus according to claim 21, wherein said at least one dropping resistor and connector interchange unit changes said existing power output to 32 kilovolts.

23. A wide-angle display system comprising:

an image projector for projecting an image onto a panoramic display screen;

a plurality of adapter housings coupled to said image projector;

a plurality of adapter plates, each adapter plate having a front surface and a rear surface, said front surface and said rear surface being configured to form a selected dihedral angle, each said rear surface being flushly coupled to a corresponding said adapter housing;

a plurality of lens assemblies, each lens assembly being coupled to a corresponding said front surface;

a plurality of CRT members, each CRT member being coupled to a corresponding said adapter plate; and

at least one image generator for controlling said CRT members.

24. The wide-angle display system according to claim 23, wherein said plurality of CRT members comprises:

a high-intensity monochrome green CRT member;

a high-intensity monochrome red CRT member; and

a high-intensity monochrome blue CRT member.

25. The wide-angle display system according to claim 24, wherein said high-intensity monochrome green CRT member is located above said high-intensity monochrome red CRT member and said high-intensity monochrome blue CRT member.

26. The wide-angle display system according to claim 24, wherein said plurality of CRT members are arranged in the shape of an equilateral triangle with said high-intensity monochrome green CRT member being disposed in a top position, and sais high-intensity monochrome red CRT member and said high-intensity monochrome blue CRT member each being disposed in a bottom position.

27. The wide-angle display system according to claim 23, wherein each said CRT member comprises:

a CRT housing;

a high-intensity monochrome CRT carried by said CRT housing; and

a cooling element.

28. The wide-angle display system according to claim 23, wherein the selected dihedral angle is between 0.75° to 1.75°.

29. The wide-angle display system according to claim 23, wherein said lens assembly comprises:

at least one lens;

at least one static focus adjustment; and

at least one dynamic focus adjustment.

30. The wide-angle display system according to claim 28, wherein image distortions are corrected.

31. A method of displaying a wide-angle image on at least one panoramic display screen, the method comprising the steps of:

providing an image projector for projecting said wide-angle image;

coupling a plurality of CRT members to said image projector;

controlling the plurality of CRT members with at least one image generator;

coupling a lens assembly to each said CRT member; and

disposing an adapter plate between each said CRT member and each said lens assembly.

32. The method according to claim 31, wherein the step of coupling a plurality of CRT members to said image projector comprises the steps of:

coupling a high-intensity monochrome green CRT member to said image projector;

coupling a high-intensity monochrome red CRT member to said image projector; and

coupling a high-intensity monochrome blue CRT member to said image projector.

33. The method according to claim 32, wherein said high-intensity monochrome green CRT member is coupled to said image projector above said high-intensity monochrome red CRT member and said high-intensity monochrome blue CRT member.

34. The method according to claim 31, wherein the step of coupling a plurality of CRT members to said image projector comprises the steps of:

providing a CRT housing;

coupling a monochrome CRT to said CRT housing; and

coupling an adapter housing to said CRT housing.

35. The method according to claim 31, wherein the step of disposing an adapter plate between each said CRT member and each said lens assembly comprises the steps of:

forming a first surface on said adapter plate; and

forming a second surface on said adapter plate at a selected angle to said first surface such that a longitudinal axis of said lens assembly forms said selected angle with a longitudinal axis of said CRT member.

36. The method according to claim 35, wherein said selected angle is in a range of 0.75° to 1.75°.

37. An apparatus for retrofitting into an existing wide-angle display system having an existing power supply, existing control circuitry, at least one existing image projector for projecting an image onto at least one existing panoramic display screen, at least one existing CRT member, an existing lens assembly coupled to said at least one existing CRT member, and at least one image generator for controlling said at least one CRT member, the apparatus comprising:

at least one replacement CRT assembly including a means for correcting image distortions, said CRT assembly being adapted to replace said at least one existing CRT member and said existing lens assembly.

38. The apparatus according to claim 37, wherein said at least one replacement CRT assembly comprises:

a replacement CRT housing;

a replacement CRT member carried by said replacement CRT housing, said replacement CRT member being adapted to be controlled by said at least one existing image generator;

an adapter housing coupled to said replacement CRT housing; and

a replacement lens assembly coupled to said adapter housing;

said means for correcting image distortions being an adapter plate disposed between said replacement CRT housing and said replacement lens assembly, said adapter plate having a first surface being configured for coupling to said adapter housing, and a second surface disposed at a selected angle to said first surface, said second surface being configured for coupling to said replacement lens assembly.

39. The apparatus according to claim 38, wherein said selected angle is in a range of 0.75° to 1.75° such that said adapter plate provides correction for image distortion.

40. The apparatus according to claim 37, further comprising:

replacement control circuitry configured to replace said existing control circuitry.

41. The apparatus according to claim 40, wherein said replacement control circuitry comprises:

at least one dropping resistor and connector interchange unit for adjusting an existing power output from said existing power supply to match a power requirement for said replacement CRT member.

42. The apparatus according to claim 41, wherein said at least one dropping resistor and connector interchange unit reduces said existing power output.

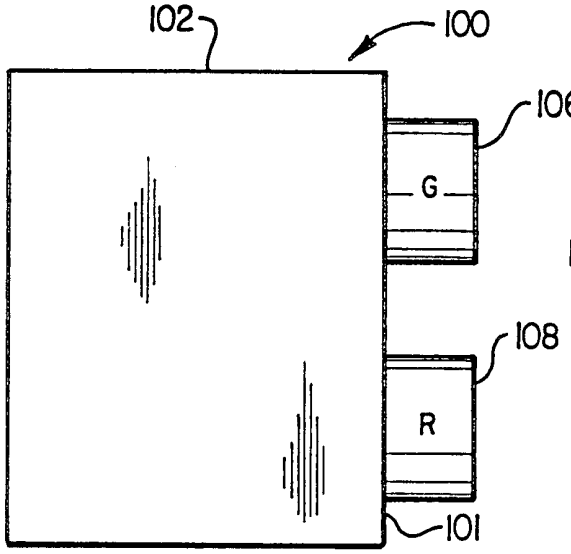


FIG. 1B

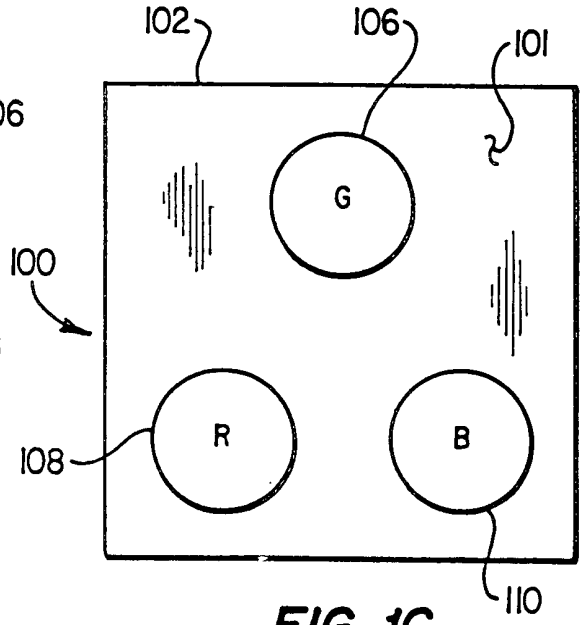


FIG. 1C

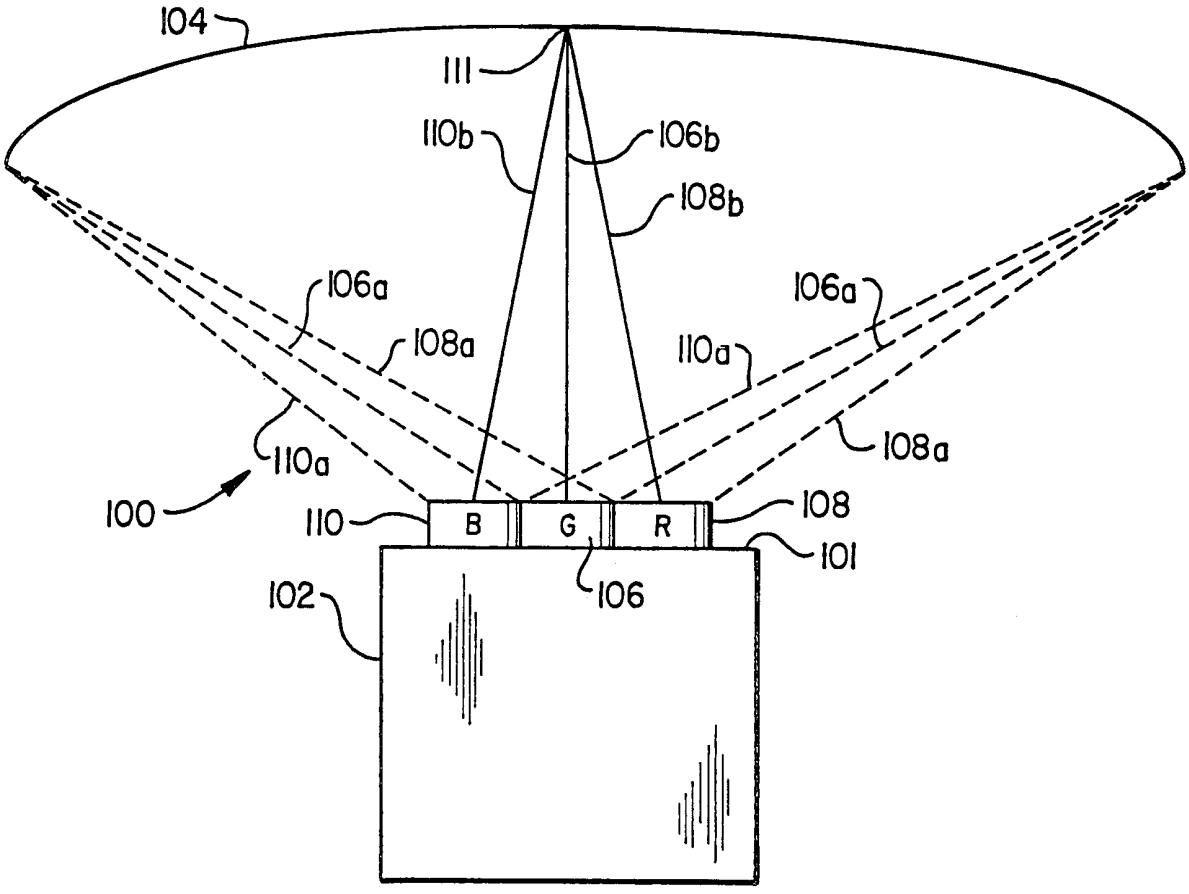


FIG. 1A

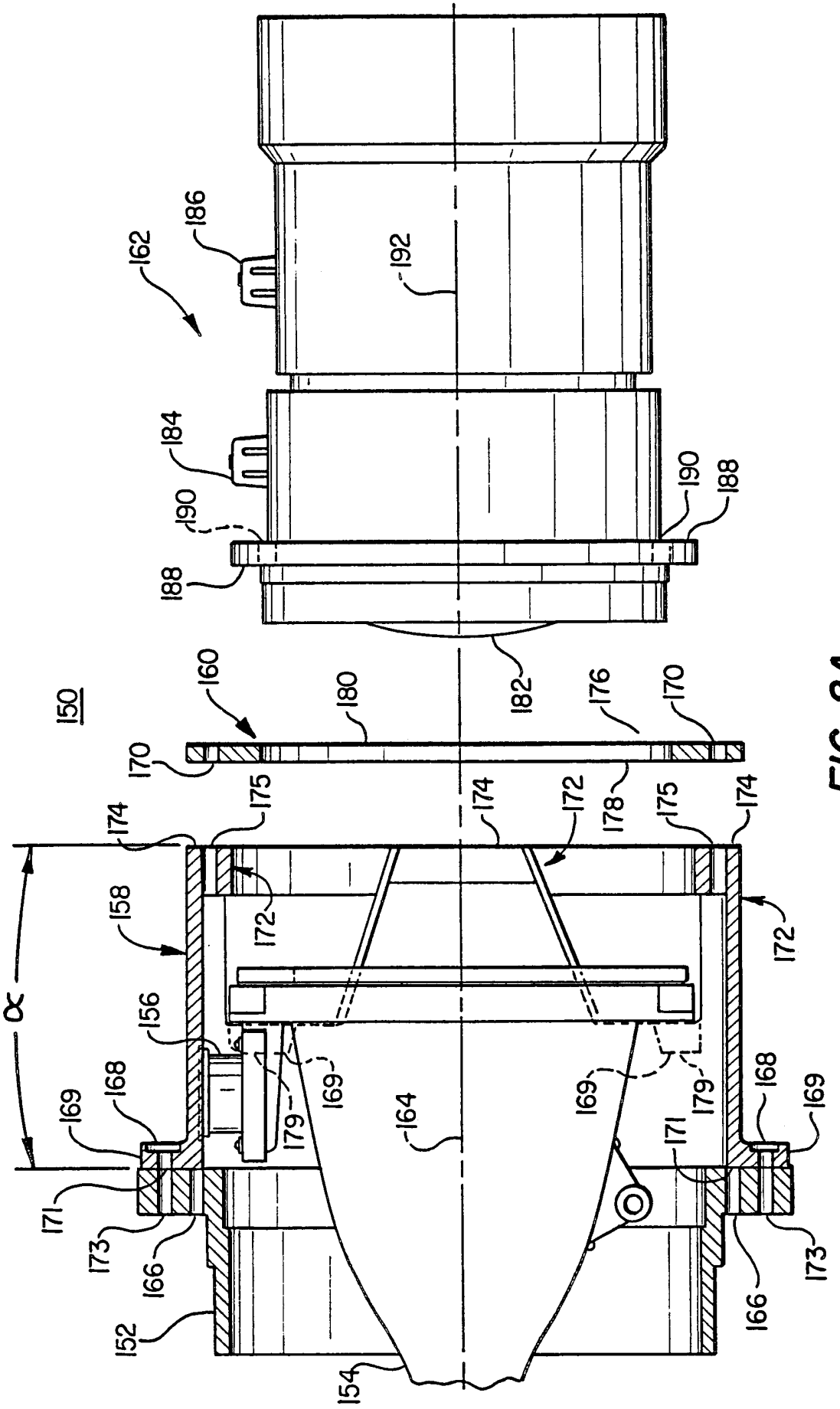

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FIG. 2A

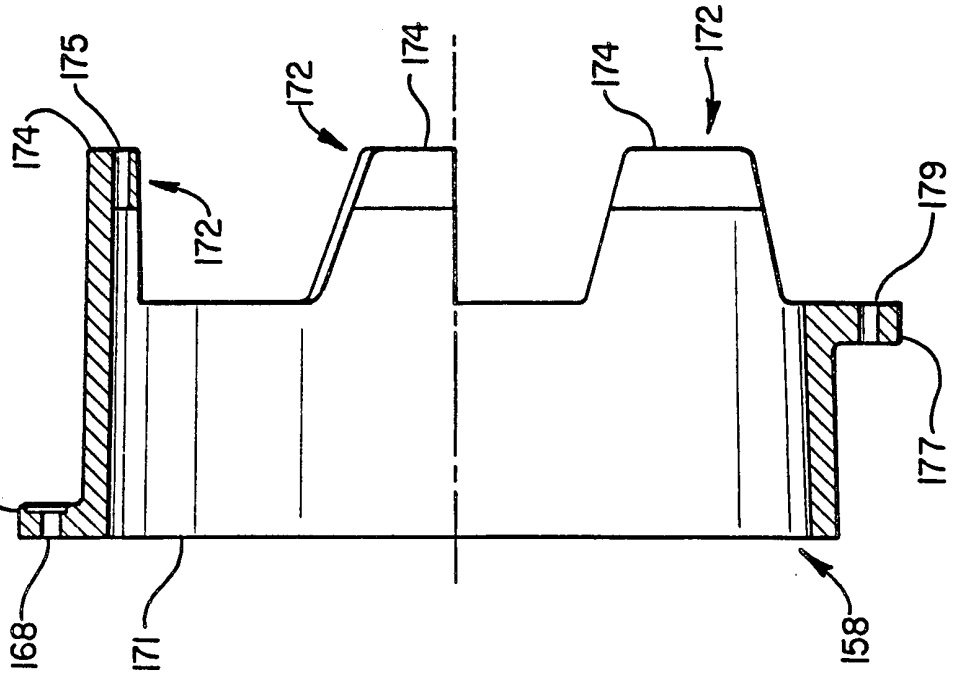

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FIG. 2C

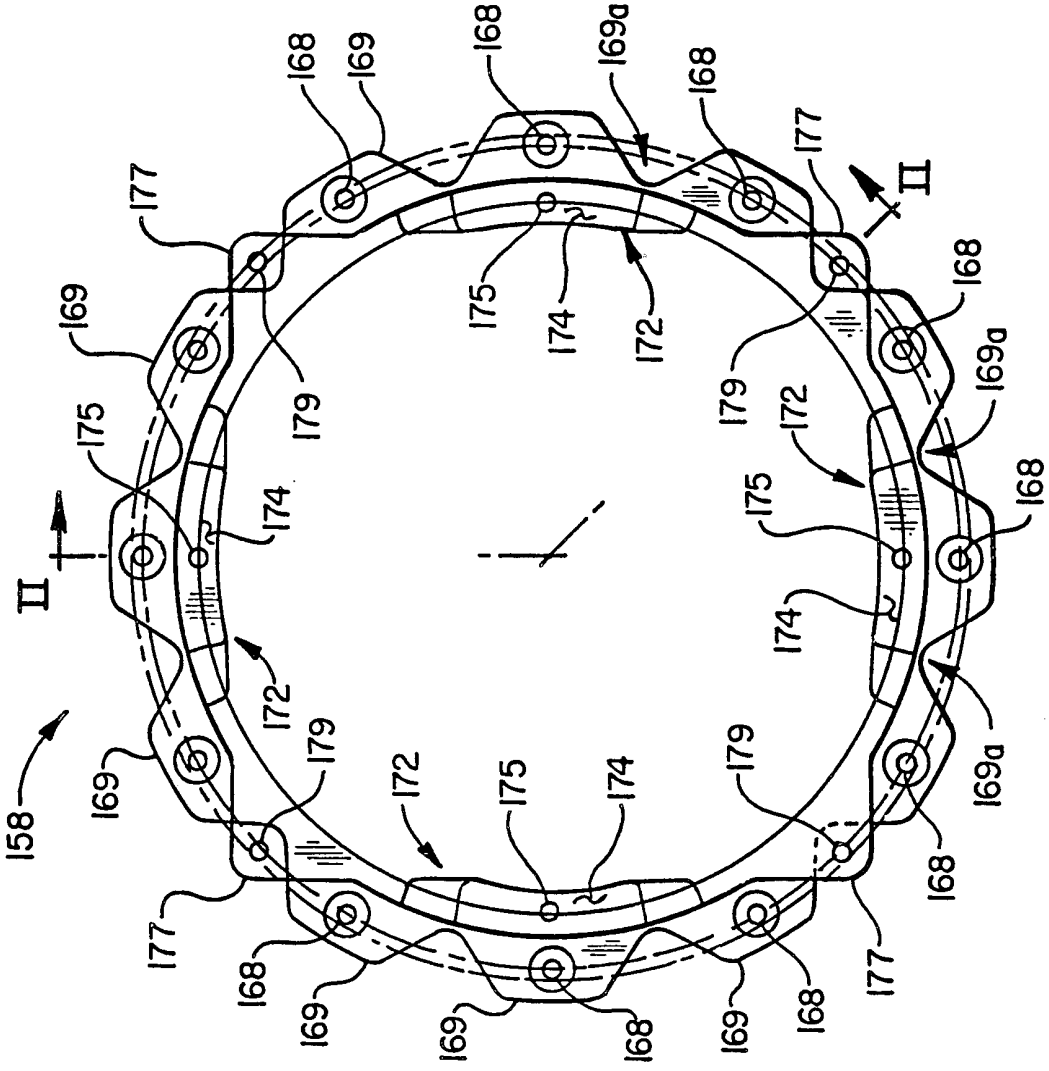

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FIG. 2B

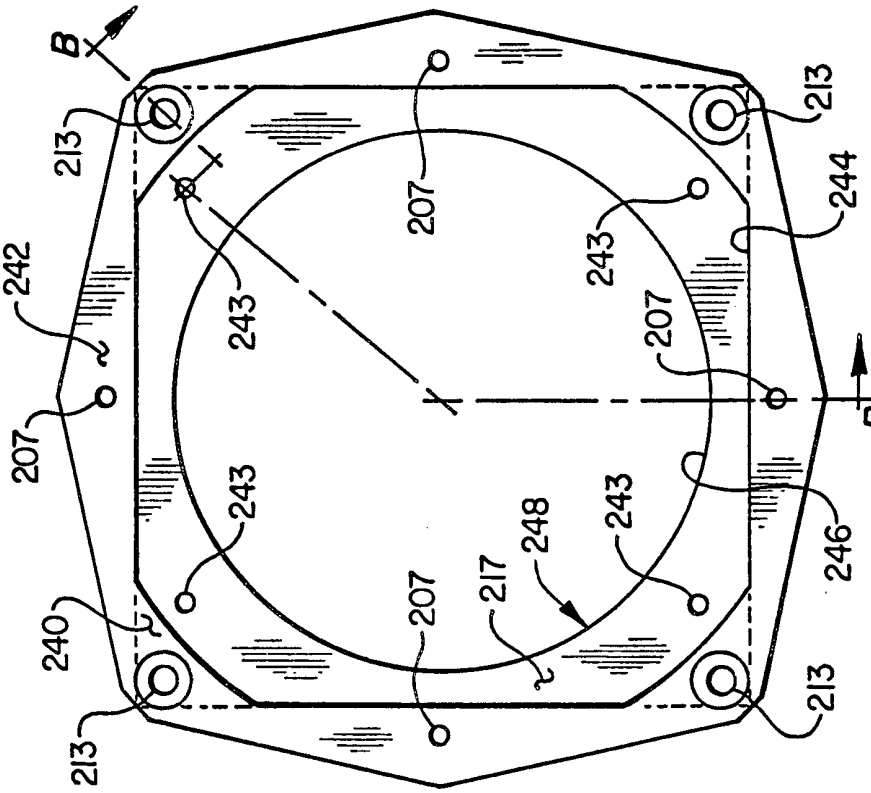

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FIG. 3C

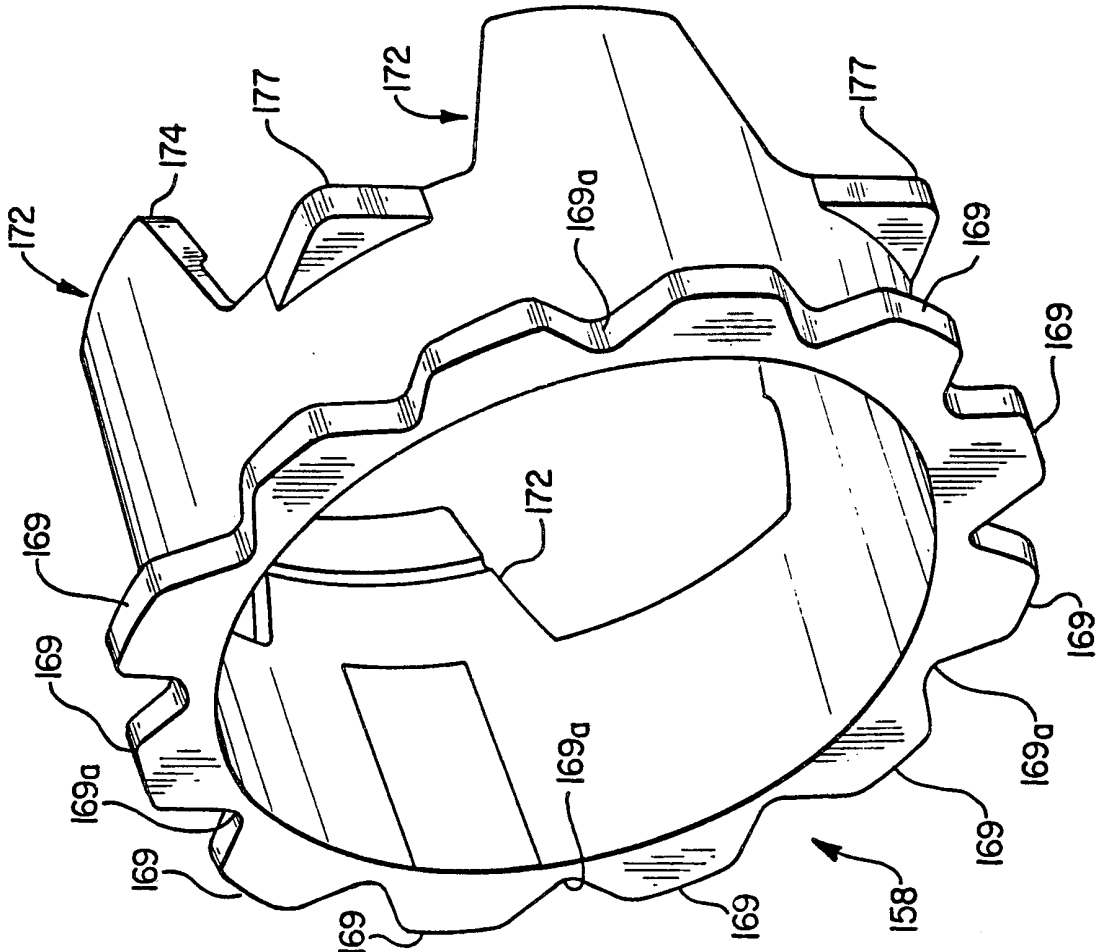

172
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169a
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FIG. 2D

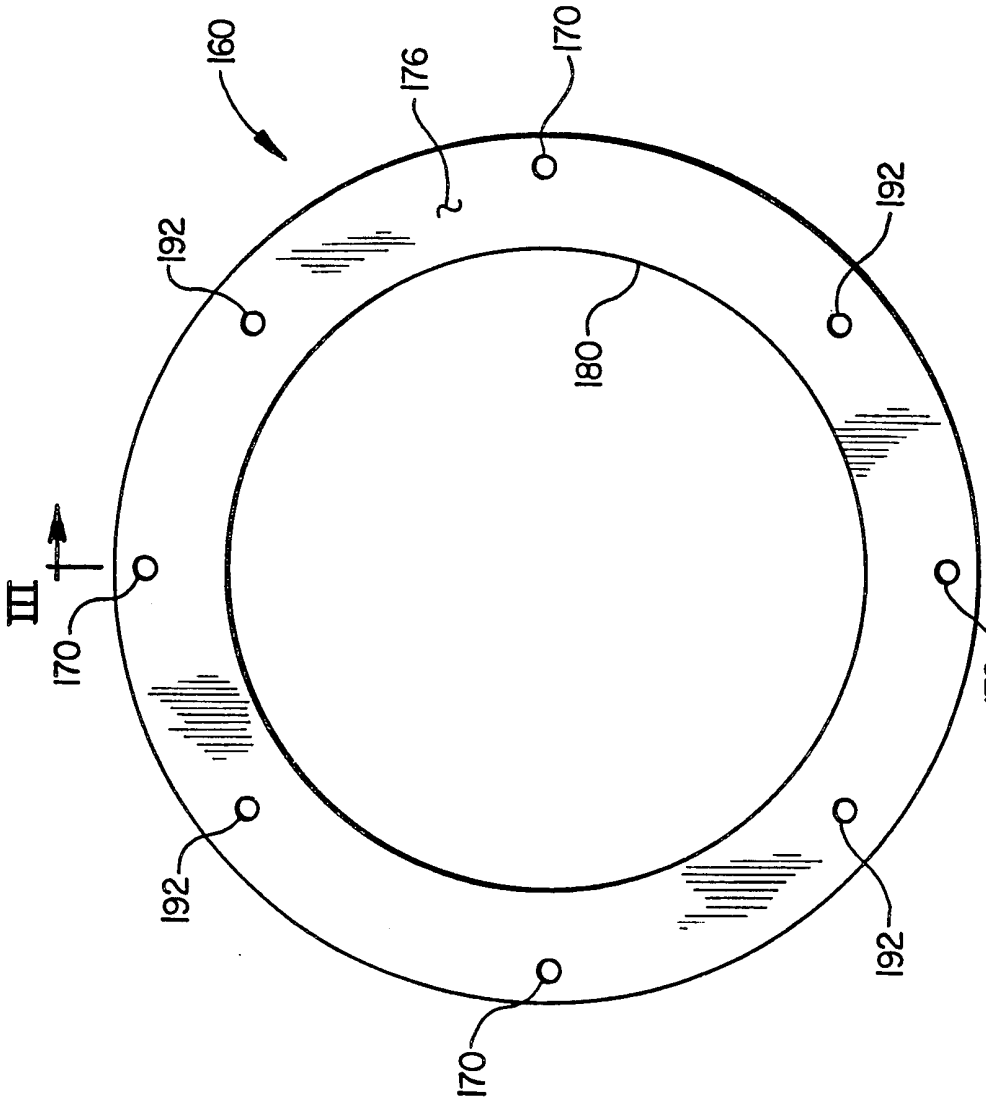


FIG. 2E

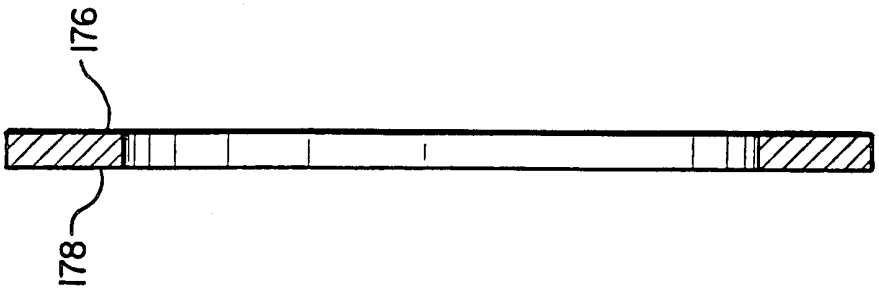


FIG. 2F

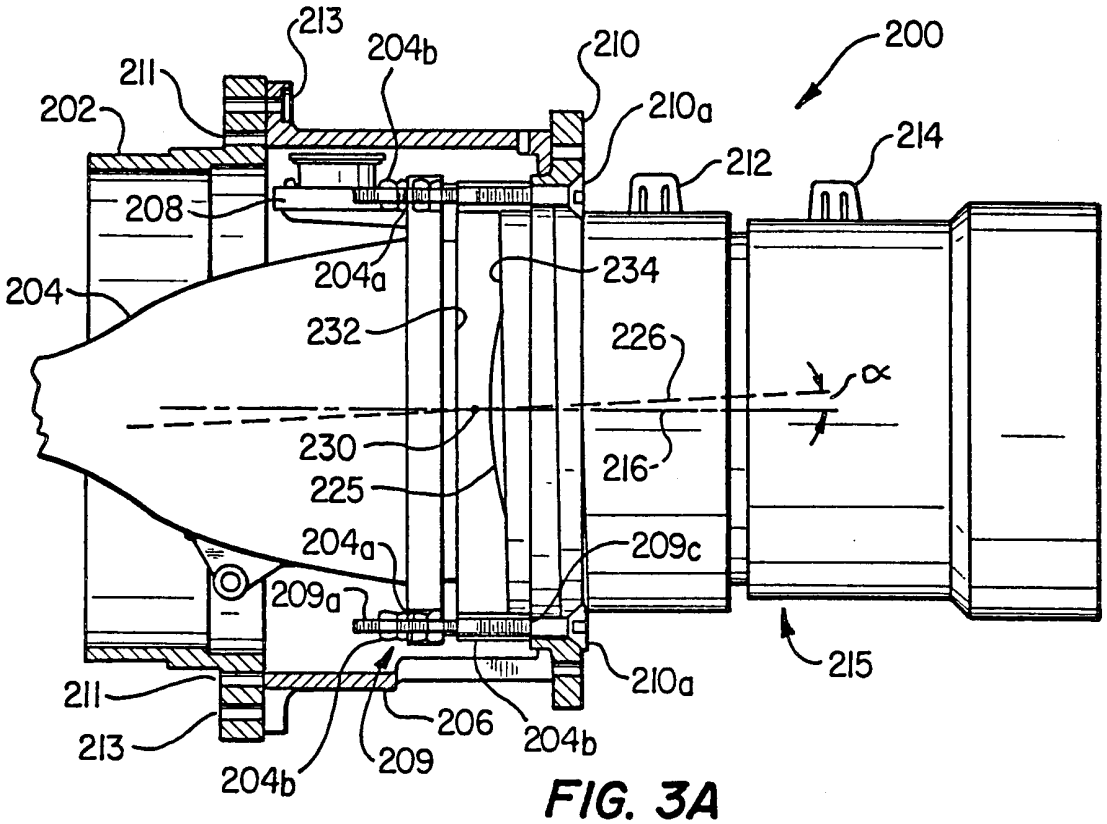

213
204b
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200
211
202
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214
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234
204
232
226
α
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216
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209c
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209a
215
210a
211
206
204b
213
209
204b

FIG. 3A

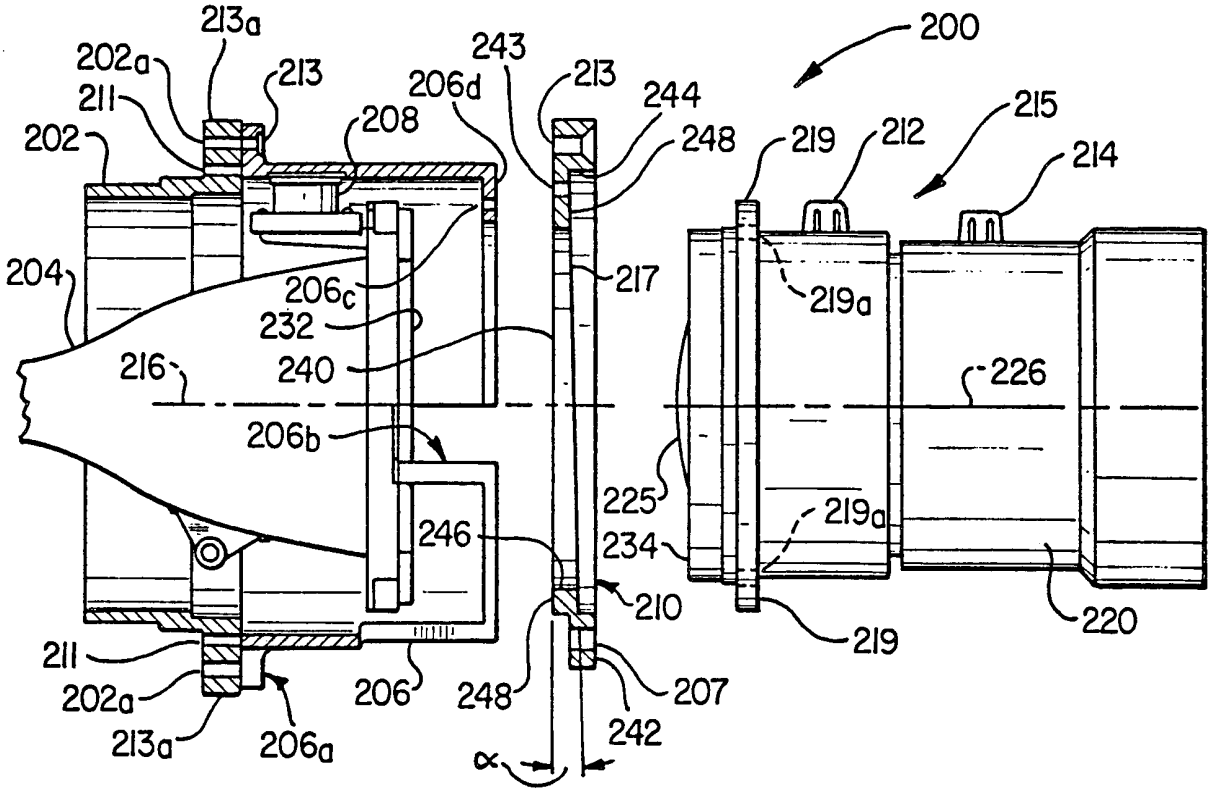

213a
200
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243
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248
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204
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219a
232
240
226
216
206b
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219a
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210
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211
202a
206
248
207
213a
206a
242
α

FIG. 3B

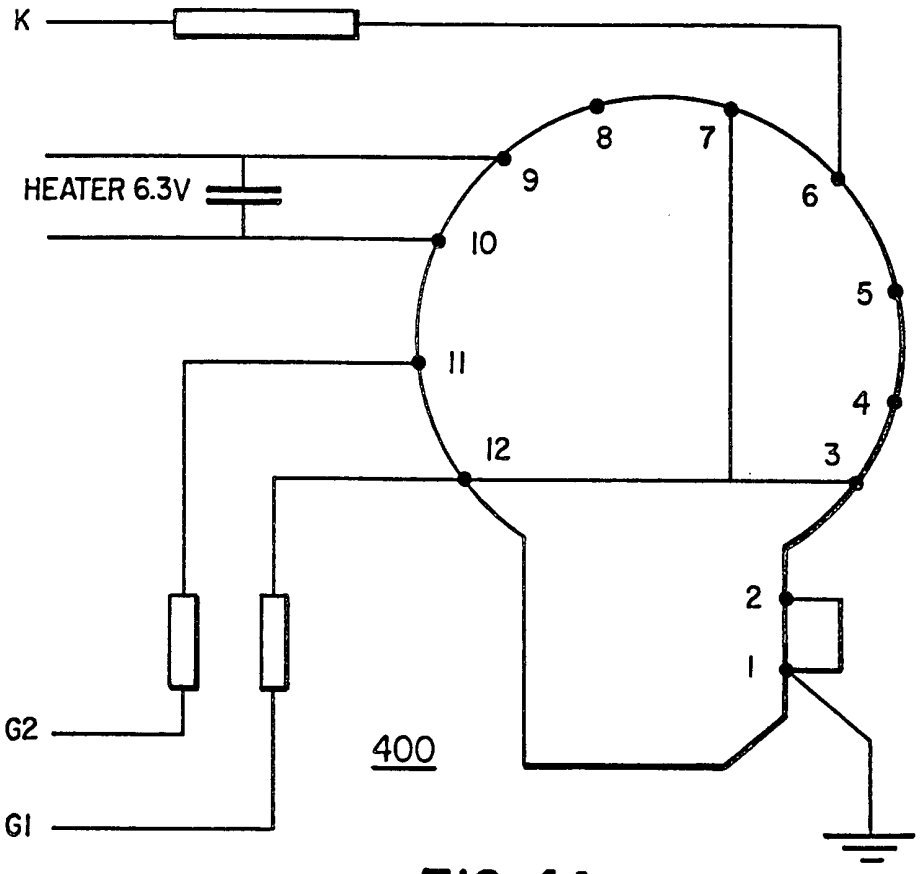

K
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FIG. 4A

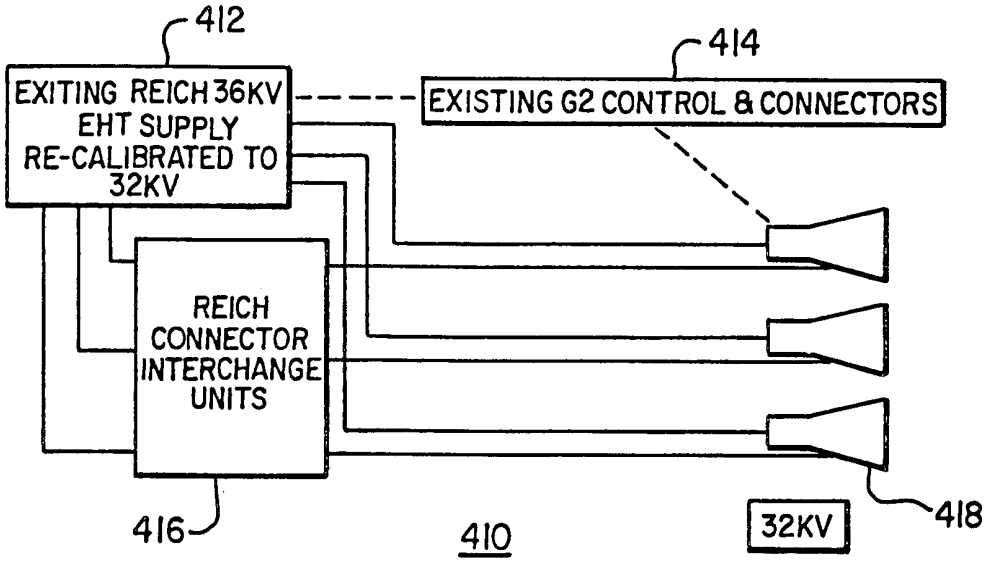

412
414
EXITING REICH 36KV EHT SUPPLY RE-CALIBRATED TO 32KV
EXISTING G2 CONTROL & CONNECTORS
REICH CONNECTOR INTERCHANGE UNITS
416
410
32KV
418

FIG. 4B

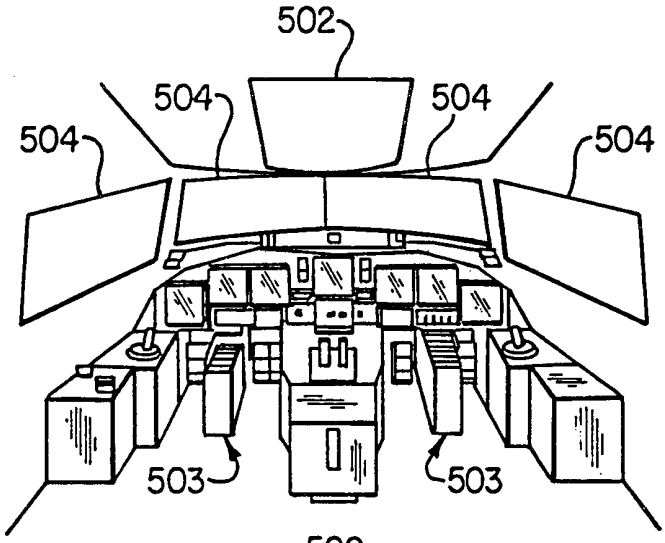


FIG. 5

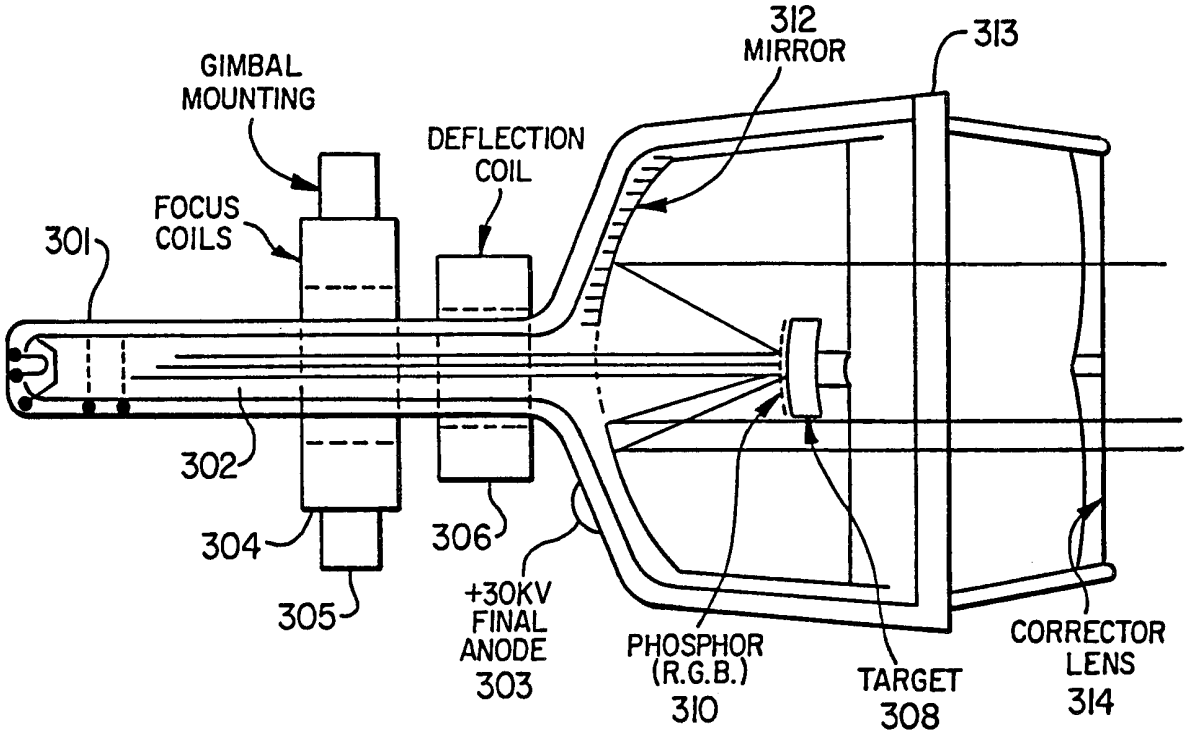


FIG. 6
(PRIOR ART)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/11330

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : HO4N 7/18
US CL : 348/825

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 348/825, 827; 434/29

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

None

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

None

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,275,565 A (MONCRIEF) 04 January 1994, figs. 2 and 4, col. 5, ln. 30 - col. 6, ln. 33 and col. 8, ln. 14 - col. 9, ln. 50.	1-42
Y	US 4,656,506 A (RITCHEY) 07 April 1987, fig. 3.	1, 10
Y	US 5,795,430 A (BEETESON et al) 18 August 1998, figs. 4-6, col. 7, ln. 25 - col. 9, ln. 63.	1-42

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

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Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer NHON T. DIEP Telephone No. (703) 305-4648

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