

System and Method for Thermally Controlling an Electronic Display

Technical Field

[0001] Exemplary embodiments generally relate to heating/cooling systems for electronic displays.

Background of the Art

[0002] Electronic displays are typically used in indoor, temperature-controlled environments. Although the temperature surrounding the display might be relatively stable (near room temperature), the components of the display may generate a large amount of heat. If not properly removed, this heat could damage the display or shorten its lifetime. Conductive and convective heat transfer systems have traditionally been used to remove heat from the electronic components in a display through as many sidewalls of the display as possible. While such heat transfer systems have enjoyed a measure of success in the past, today's electronic displays require even greater cooling (and in some case heating) capabilities.

[0003] Modern electronic displays are now being used in outdoor environments as well as other situations where the surrounding temperature may extend above and below room temperature. In addition to heat transfer from the surrounding air, radiative heat transfer from the sun through a display surface may also become a major factor. In some applications and locations, 200 Watts or more of power through such a display surface is common. Furthermore, the market is demanding larger and brighter, sometimes high definition displays. With increased electronic display size more heat will be absorbed from the sun and more heat will be transmitted into the displays. To compete with the ambient light from the sun as well as reflections off surrounding surfaces, displays must produce more light, which also typically results in more heat generated by the display and/or its backlight assembly.

[0004] Further, in some applications the temperature may drop well below room temperature. Some components of an electronic display may malfunction or may be permanently destroyed by exposure to such low temperatures. For example, the performance of the liquid crystal material in a liquid crystal display (LCD) may be effected by low temperatures.

Summary of the Exemplary Embodiments

[0005] Exemplary embodiments may contain one or more of the thermal control features disclosed herein. A plurality of thermal control features are disclosed and these features may be utilized alone or in any combination. The precise combination of features would depend upon the particular cooling/heating needs of the display at issue, which would depend upon the type of display, size of the display, and its particular environment. The embodiments may be practiced with any form of electronic display, including but not limited to: LCD, light emitting diode (LED), organic light emitting diode (OLED), field emitting display (FED), cathode ray tube (CRT), plasma, and projection displays. An exemplary embodiment would be practiced with LCD displays.

[0006] One thermal feature relates to an isolated gas cooling system. The gas cooling system is preferably a closed loop which includes a first gas chamber comprising a transparent anterior plate and a second gas chamber comprising a cooling plenum. The first gas chamber is anterior to and coextensive with the viewable face of the electronic display. The transparent anterior plate may be set forward of the electronic display surface, defining the depth of the first gas chamber. A cooling chamber fan, or equivalent means, may be located within the cooling plenum and may be used to propel gas around the isolated gas cooling chamber loop. As the gas traverses the first gas chamber it contacts the electronic display surface, absorbing heat from the display surface. Because the gas and the relevant surfaces of the first gas chamber are transparent, the image quality remains excellent. After the gas has traversed the transparent first gas chamber, the gas may be directed into the rear cooling plenum where it is cooled.

[0007] Another thermal feature may utilize the isolated gas system as a heating device, either instead of or in addition to its cooling abilities. An isolated gas heating system would also be a closed loop system with a first gas chamber anterior to the display surface and a second chamber comprising a heating plenum or cooling/heating plenum. Heating elements may be placed within the plenum in order to heat the gas within the second chamber. As the gas is forced into the first chamber it may transfer its heat to the display surface. The gas may then return to the plenum for another heating cycle. The plenum may function as a cooling plenum only, heating plenum only, or a combination heating/cooling plenum; all depending upon the particular display and its particular operating environment.

[0008] Some embodiments may place electronic components used to operate the electronic display within the plenum of the isolated gas chamber. The electronic components may include, but are not limited to: transformers, circuit boards, processors, resistors, capacitors, batteries, motors, power supplies, illumination devices, wiring and wiring harnesses, and switches. If the plenum is being utilized as a cooling plenum, the cool gas within the plenum can further aid in the cooling of the electronic components, which will naturally generate heat during operation. Further, if the plenum is being utilized as a source of heat for the display, the natural heat from the electronic components can also heat the gas in the plenum, reducing the amount of energy which needs to be applied to the heating elements.

[0009] A linear polarizer may be used in some embodiments to further reduce the solar loading on the electronic display. This polarizer can be used in combination with the isolated gas chamber, or may simply be placed anterior to the electronic display with an insulating gap between the polarizer and the display. The insulating gap reduces the amount of heat that is transferred between the polarizer and the display.

[0010] Some electronic displays, such as LCDs for example, require a backlight assembly to produce an image upon the display surface. The backlight assemblies are typically a large source of heat for the display. Thus, some embodiments may utilize a constricted convection system to cool the backlight unit for the display. The constricted convection system may comprise a constricted convection plate which is placed in close proximity to the backlight assembly in order to define a gap. Gas is forced

through the gap in order to facilitate more efficient cooling of the backlight assembly. In some embodiments a wall of the plenum may constitute the constricted convection plate.

[0011] Some embodiments may also utilize an air curtain device which forces air (either warm or cold) over the exterior surface of the display assembly.

[0012] Finally, some embodiments may use a fluid assembly which contacts a fluid against the display surface in order to cool it. The fluid may be a substantially clear form of coolant fluid which is pumped through an anterior cavity which includes the display surface.

Brief Description of the Drawings

[0013] A better understanding of the exemplary embodiments will be obtained from a reading of the following detailed description and the accompanying drawings wherein identical reference characters refer to identical parts and in which:

[0014] **FIGURE 1** is a perspective view of an exemplary embodiment in conjunction with an exemplary electronic display.

[0015] **FIGURE 2** is an exploded perspective view of an exemplary embodiment showing components of the isolated gas cooling system.

[0016] **FIGURE 3** is top plan view of an exemplary embodiment of the cooling chamber.

[0017] **FIGURE 4** is a front perspective view of an embodiment of the isolated cooling chamber, particularly the transparent anterior surface of first gas chamber.

[0018] **FIGURE 5** is a rear perspective view of an embodiment of the isolated cooling chamber, showing optional electrical components placed in the plenum.

[0019] **FIGURE 6** is a rear perspective view of an embodiment of the isolated cooling chamber showing surface features that may be included on the plenum

[0020] **FIGURE 7** is a top plan view of an exemplary embodiment of the cooling chamber showing surface features that may be included on the plenum.

[0021] **FIGURE 8** is a front perspective view of an embodiment of the isolated cooling chamber with included thermoelectric modules.

[0022] **FIGURE 9** is a top plan view of an exemplary embodiment of the cooling chamber with included thermoelectric modules.

[0023] **FIGURE 10** is an exploded perspective view of an exemplary embodiment showing components of the isolated gas cooling system.

[0024] **FIGURE 11** is a top plan view of an exemplary embodiment of the heating chamber.

[0025] **FIGURE 12** is a rear perspective view of an embodiment of the heating chamber, showing optional electrical components and heating elements.

[0026] **FIGURES 13 and 14** are cross-sectional views of exemplary embodiments for utilizing a linear polarizer with the isolated gas system or an insulating gap.

[0027] **FIGURES 15A and 15B** are side views of exemplary embodiments of the constricted convection cooling system with a constricted convection plate.

[0028] **FIGURE 16** is a top plan view of an exemplary embodiment where the cooling plenum is utilized as the constricted convection plate.

[0029] **FIGURES 17A-17C** are cross-sectional views of embodiments where the cooling plenum is utilized as the constricted convection plate.

[0030] **FIGURE 18** is a front plan view of a display utilizing an air curtain device.

[0031] **FIGURE 19** is a cross-sectional view of a display utilizing an air curtain device.

[0032] **FIGURE 20** is an illustration showing the components for a liquid cooled display.

Detailed Description

[0033] It is to be understood that the spirit and scope of the disclosed embodiments includes thermally controlling displays including, but not limited to LCDs. For simple explanation purposes, embodiments may be described with respect to the components for LCD displays. By way of example and not by way of limitation, embodiments may be used in conjunction with displays selected from among LCD, light emitting diode (LED), organic light emitting diode (OLED), field emitting display (FED), cathode ray tube (CRT), plasma, and projection displays. Furthermore, embodiments may be used

with displays of other types including those not yet discovered. In particular, it is contemplated that embodiments may be well suited for use with full color, flat panel OLED displays. Further, it is particularly contemplated that embodiments may be used with relatively large, high definition LCD displays. While the embodiments described herein are well suited for outdoor environments, they may also be appropriate for indoor applications (e.g., factory environments, coolers/freezers, etc.) where thermal stability of the display may be at risk.

Isolated Gas Cooling System

[0034] As shown in FIGURE 1, when the display 10 is exposed to outdoor elements, the temperatures inside the display 10 may vary greatly without some kind of cooling device. As such, the display 10 may not function properly or may have a greatly reduced life span. Direct sunlight is especially problematic in causing increases in the internal temperature of the display 10.

[0035] In Figure 1, the display area of the electronic display shown includes a narrow gas chamber that is anterior to and coextensive with the electronic display surface. The display shown is also equipped with an optional air curtain device 114. The air curtain device 114 is discussed in detail below. Optionally, the display may have a reflection shield 119, to mitigate reflection of the sunlight on the display surface. Additionally, in outdoor environments, housing 70 is preferably a color which reflects sunlight.

[0036] As shown in FIGURE 2, an exemplary embodiment of the electronic display 10 includes an isolated gas cooling chamber 20 contained within a display housing 70. A transparent first gas chamber is defined by spacers 100 and transparent front plate 90. A second transparent front plate 130 may be laminated to front plate 90 to help prevent breakage of front plate 90 and protect the interior of the display. Cooling chamber 20 surrounds a display stack 80 and associated backlight assembly 140.

[0037] The display 10 may include means for cooling gas contained within the second gas chamber. This means may include one or more fans 60 which may be positioned at the base of the display housing 70. The fans 60 may ingest cool air and force the cooler ingested air over at least one external surface of a posterior cooling plenum 45. If desired, an air conditioner (not shown) may also be utilized to cool the air which

contacts the external surface of plenum 45. Alternatively, the fans 60 may simply ingest ambient air.

[0038] Referring to FIGURE 3, embodiments of the isolated gas cooling chamber 20 may comprise a closed loop which includes a first gas chamber 30 and a second gas chamber 40. The first gas chamber includes a transparent plate 90. The second gas chamber comprises a cooling plenum 45. The term "isolated gas" refers to the fact that the gas within the isolated gas cooling chamber 20 is essentially isolated from external air in the housing of the display. Because the first gas chamber 30 is positioned in front of the electronic display surface 85, the gas should be substantially free of dust or other contaminants that might negatively affect the display image. An optional filter (not shown) may be utilized to assist in preventing contaminants and dust from entering the first gas chamber 30.

[0039] The isolated gas may be almost any transparent gas, for example, normal air, nitrogen, helium, or any other transparent gas. The gas is preferably colorless so as not to affect the image quality. Furthermore, the isolated gas cooling chamber 20 need not necessarily be hermetically sealed from the external air. It is sufficient that the gas in the chamber is isolated to the extent that dust and contaminants may not substantially enter the first gas chamber.

[0040] In the closed loop configuration shown in Fig. 3, the first gas chamber 30 is in gaseous communication with the second gas chamber 40. A cooling chamber fan 50 may be provided within the cooling plenum 45 and utilized to propel gas around the isolated gas cooling chamber 20. The first gas chamber 30 includes at least one front glass 90 mounted in front of an electronic display surface 85.

[0041] Referring to FIGURE 4, the front plate 90 may be set forward from the electronic display surface 85 by spacing members 100. The spacing members 100 define the depth of the narrow channel passing in front of the electronic display surface 85. The spacing members 100 may be independent or alternatively may be integral with some other component of the device (e.g., integral with the front plate 90). The electronic display surface 85, the spacing members 100, and the transparent front plate 90 define a first gas chamber 30. The chamber 30 is in gaseous communication with plenum 45 through entrance opening 110 and exit opening 120.

[0042] As shown in Fig. 3, a posterior surface of the first gas chamber 30 preferably comprises the electronic display surface 85 of the display stack 80. As the isolated gas in the first gas chamber 30 traverses the display it contacts the electronic display surface 85. Contacting the cooling gas directly to the electronic display surface 85 enhances the convective heat transfer away from the electronic display surface 85. In exemplary embodiments the electronic display surface 85 comprises the posterior surface of the first gas chamber 30. Accordingly, the term “electronic display surface” refers to the front surface of a typical electronic display (in the absence of the embodiments disclosed herein).

[0043] In an exemplary embodiment, the electronic display surface 85, front plate 90, and optional second front plate 130 may be comprised of a glass substrate. However, neither display surface 85, nor transparent front plate 90, nor optional second transparent front plate 130 need necessarily be glass. Thus, the term “glass” may be used herein interchangeably with the term plate, but a glass material is by no means required. Further, electronic display surface 85 does not have to comprise the posterior surface wall of the front gas compartment 30. An additional plate may be used. However, by utilizing the electronic display surface 85 as the posterior surface wall of the gas compartment 30, there may be fewer surfaces to impact the visible light traveling through the display. Furthermore, the device will be lighter and cheaper to manufacture.

[0044] Although the embodiment shown utilizes the electronic display surface 85, certain modifications and/or coatings (e.g., anti-reflective coatings) may be added to the electronic display surface 85, or to other components of the system in order to accommodate the coolant gas or to improve the optical performance of the device. In the embodiment shown, the electronic display surface 85 may be the front glass plate of a liquid crystal display (LCD) stack. However, almost any display surface may be suitable for embodiments of the present cooling system. Although not required, it is preferable to allow the cooling gas in the first gas chamber 30 to contact the electronic display surface 85 directly. In this way, the convective transfer of heat from the display components to the circulating gas will be maximized.

[0045] Referring to Fig. 4, the front plate 90 of the first gas chamber 30 is transparent and is positioned anterior to the electronic display surface 85. The arrows shown represent the movement of the isolated gas through the first gas chamber 30. As shown, the isolated gas traverses the first gas chamber 30 in a horizontal direction. Although cooling system 20 may be designed to move the gas in either a horizontal or a vertical direction, it is preferable to propel the gas in a horizontal direction. In this way, if dust or contaminants do enter the first gas chamber 30, they will tend to fall to the bottom of chamber 30 outside of the viewable area of the display. The system may move air left to right, or alternatively, right to left. After the gas traverses the first gas chamber 30 it exits through exit opening 120. Exit opening 120 defines the entrance junction into the rear cooling plenum 45.

[0046] FIGURE 5 shows a schematic of the rear cooling plenum (illustrated as transparent for explanation). One or more fans 50 within the plenum may provide the force necessary to move the isolated gas through the isolated gas cooling chamber. Whereas the first gas chamber 30 was designed to collect heat from the surface 85 of the display, the second gas chamber 40 is designed to extract the heat from the gas and remove the heat from the cooling chamber 20. The second chamber 40 may have various contours and features to accommodate the internal structures within a given electronic display application.

[0047] If desired, various electronic components 200 can be placed anywhere throughout the second gas chamber 40. The electronic components 200 may include, but are not limited to: transformers, circuit boards, processors, resistors, capacitors, batteries, motors, power supplies, illumination devices, wiring and wiring harnesses, and switches. These components can be mounted directly on the walls of the chamber or supported on rods or posts 209. Thus, the cooling plenum can be designed to not only extract heat from the first gas chamber 30 but also to cool these various electronic components 200. (Additionally, as discussed below, if the isolated gas system is used to heat the display, the electronic components can assist in heating the isolated gas.)

[0048] Referring now to FIGURES 6 and 7, various surface features 150 may be added to improve heat dissipation from the plenum 45. These surface features 150 provide more surface area to radiate heat away from the gas within the second gas

chamber 40. These features 150 may be positioned at numerous locations on the surface of the plenum 45.

[0049] Referring now to FIGURES 8 and 9, one or more thermoelectric modules 160 may be positioned on at least one surface of the plenum 45 to further cool the gas contained in the second gas chamber 40. The thermoelectric modules 160 may be used independently or in conjunction with surface features 150. Alternatively, thermoelectric modules 160 may be used to heat the gas in the plenum if the isolated gas system is utilized to heat a display in a cold environment.

[0050] FIGURE 10 shows an exemplary method for removing heat in the gas contained in the rear plenum 45. Fan 60 may be positioned to ingest air and blow that air across the anterior and posterior surfaces of the plenum 45. Again, fan 60 may ingest air conditioned air into the display housing 70 or may simply ingest ambient surrounding air. Furthermore, in this configuration, fan 60 may also force air past the heat generating components of the electronic display (e.g., the display stack 80 and the backlight assembly 140) to further improve the ability to cool the entire display. It should be noted that this embodiment can be combined with the constricted convection cooling method discussed in detail below. The heated exhaust air may exit through one or more apertures 179 located on the display housing 70.

Isolated Gas Heating System

[0051] As mentioned above, the isolated gas system can be utilized to also heat the electronic display. Referring to FIGURES 11 and 12, heating elements 220 may be located within the second gas chamber 40 and operate to warm the gas as it passes through the second gas chamber 40. These heating elements can be any one of the many commonly available heating elements or thermoelectric modules. Many times, these elements are simply a material which contains a high electrical resistance, and thus generates heat when current flows through it. The heating elements can be, but are not limited to, any one of the following: nichrome wire or ribbon, screen printed metal/ceramic tracks deposited on ceramic insulated metal (generally steel) plates, CalRod (typically a fine coil of nichrome wire in a ceramic binder, sealed inside a tough metal shell), heat lamp, and Positive Thermal Coefficient (PTC) of resistance ceramic.

[0052] As discussed above, the plenum 45 may contain electrical components 200 which power and control the electronic display. The electrical components may be any one of the following: transformers, microprocessors, printed circuit boards, power supplies, resistors, capacitors, motors, wiring harnesses, and connectors. The electrical connections for the electrical components 200 may pass through a wall of the plenum 45. The electrical components 200 can be located anywhere within the plenum 45. The electrical components 200 may be mounted on the posterior or anterior surface of the plenum and may be mounted directly on the surface of the plenum or may be suspended by mounting posts so that gas may pass all around the component.

[0053] While the display is operational, the isolated gas cooling system may run continuously. However, if desired, a temperature sensor (not shown) and a switch (not shown) may be incorporated within the electronic display. Thus, a thermostat may be used to detect when temperatures have reached a predetermined threshold value and the isolated gas system may be selectively engaged when the temperature in the display reaches a predetermined value. Predetermined temperature thresholds may be selected and the system may be configured to heat, cool, or both heat and cool the display to advantageously keep the display within an acceptable temperature range.

Linear Polarizer with Optional Insulator Gap

[0054] FIGURE 13 is a cross-sectional view of another exemplary embodiment for another thermal control feature. In the arrangement shown, the front plate 90 and a second front plate 130 may be comprised of glass and may be laminated together. The first and second front panels 130 and 90 may be fixed to one another with a layer of index matched optical adhesive 201 to form a front glass unit 206. The display stack 80 may comprise a liquid crystal assembly 212 interposed between a front polarizer 216 and a rear polarizer 214. In other embodiments, the display stack 80 may be any other type of assembly for any other type of electronic display. The space between the display stack 80 and the front glass unit 206 defines an insulator gap 300. The insulator gap 300 serves to thermally separate the front glass unit 206 from the LCD stack 80. This thermal separation localizes the heat on the front glass unit rather than allowing solar loading of the LCD stack. If used in combination with the isolated gas system, the insulator gap 300 may comprise the first gas chamber 30. In other

embodiments, the insulator gap 300 may be used without the isolated gas system simply as a layer of insulation from both the ambient air as well as solar loading.

[0055] The second front panel may have a first surface 202 and a second surface 208. The first surface 202 may be exposed to the elements; while the second surface 208 may be fixed to the first front plate 90 by the index matched optical adhesive 201. The first front plate 90 may have a third surface 209 and a fourth surface 204. The third surface 209 may be fixed to the second front plate 130 by the index matched optical adhesive 201; while the fourth surface may be directly adjacent to the insulator gap 300. In some embodiments, to decrease the solar loading of the display stack 80 and improve the viewable image quality, an anti-reflective coating may be applied to the first surface 202 and the fourth surface 204. In other embodiments, the anti-reflective coating may only be applied to at least one of the first, second, third, or fourth surface 202, 208, 209, and 204, respectively.

[0056] FIGURE 14 is a cross-sectional view of another exemplary embodiment of the front glass unit 206. In the arrangement shown, the front glass unit 206 comprises a second front plate 130, a layer of index matched optical adhesive 201, a linear polarizer 400, and a first front plate 90. The linear polarizer 400 may be bonded to at least one of the first, second, third or fourth surfaces 202, 208, 209, and 204, respectively. Again, anti-reflective layers may be applied to at least one of the first, second, third or fourth surfaces 202, 208, 209, and 204, respectively. The linear polarizer 400 may be aligned with the front polarizer 209 found in the LCD stack 85. The inclusion of a linear polarizer 400 in the front glass unit 206, further decreases the solar load on the display stack 80. The reduction in solar loading may significantly reduce the internal temperature of the electronic display. The linear polarizer 300 may also cause a reduction in specular reflection of the front glass unit 206 and the display stack 80. As discussed above, if used in combination with the isolated gas system, the insulator gap 300 may comprise the first gas chamber 30. In other embodiments, the insulator gap 300 may be used without the isolated gas system simply as a layer of insulation from both the ambient air as well as solar loading. Again, it should be noted that the display stack 80 may be an LCD stack, but it can also be any other type of electronic display.

[0057] It should also be noted that the second front plate 130 is not required. Embodiments may utilize only the first front plate 90 with a linear polarizer attached to either the posterior or anterior surface of the front plate 90. An anti-reflective layer may also be attached to either the anterior or posterior surface of the front plate 90. The front plate 90 may be tempered for additional strength if using only the front plate 90 without the second front plate 130.

Constricted Convection

[0058] Some types of electronic displays require a backlight assembly in order to generate an image upon a viewable screen. LCDs are one type of display that requires a backlight assembly. Other types of displays, such as plasma displays and OLEDs, do not require a backlight assembly as they generate light themselves. However, these types of displays still generate a significant amount of heat. Thus, in the foregoing description, the constricted convection system will be described with regard to a backlight assembly, but it should be noted that the embodiments can be practiced with other types of displays. Therefore, when a backlight or backlight assemblies are discussed, these assemblies could also be the rear surfaces of other heat-generating displays and the constricted convection system would facilitate more efficient cooling of these alternate displays. It should also be noted that Figures 15A-15B and Figures 17A-17C are not necessarily drawn to scale. The relationship between the elements may be exaggerated for explanatory purposes.

[0059] FIGURE 15A shows a cross-sectional view of the backlight 140 with the constricted convection plate 300, the space between the two features defines a narrow gap 305. The dimensions of the gap may vary depending on several factors including the size of the display, its operating conditions, the type of backlight assembly and its posterior surface material, and the number and power applied to the various constricted convection fans. Some exemplary embodiments may utilize a gap distance of approximately 0.25-3.5 inches. Other embodiments may utilize a slightly larger gap. It has been found that forcing air through this gap 305 increases the ability to cool the backlight 140. One or more constricted convection fans 310 may be used to pull air through the gap 305. FIGURE 15B shows a cross-sectional view of another

embodiment for the constricted convection system where one or more constricted convection fans 310 push air through the gap 305.

[0060] FIGURE 16 shows a top view of the isolated gas system as discussed above. The cross-section line 17-17 is shown passing through the isolated gas system.

[0061] FIGURES 17A-17C show cross-sectional views of the 17-17 section that is shown in Figure 16. Referring first to Figure 17A, towards the front of the display is the first gas chamber 30 which abuts against the electronic display 80. Anterior to the first gas chamber 30 is the front plate 90. Towards the rear of the display, the backlight 140 is placed in close proximity to the second gas chamber 40. In this arrangement, the outer wall of the second gas chamber 40 may function as the constricted convection plate. This embodiment does not utilize a constrictive convection fan, but instead uses the fan 60 which ingest air from outside the display housing and forces it over the surfaces of the second gas chamber 40. As noted above, this air may simply be ambient air or alternatively this air may come from a conditioning unit (not shown). To facilitate the flow of air between the backlight 140 and the cooling chamber 40, a guiding device 320 may be used.

[0062] Referring now to Figure 17B, the cooling chamber 40 contains a guiding feature 41, which is used in combination with the guiding device 320 to facilitate the flow of air between the backlight and the cooling chamber. Figure 17C shows another embodiment, where both the external fan 60 and the constrictive convection fan 310 is used. This embodiment could also utilize a version of the guiding devices shown in Figures 17A and 17B.

[0063] The backlight 140 may comprise a printed circuit board (PCB) with a plurality of lights mounted to the side facing the electronic display 80. The lights in the backlight may be any one of the following: LED's, organic light emitting diodes (OLED), field emitting display (FED), light emitting polymer (LEP), or organic electro-luminescence (OEL) lights. In an exemplary embodiment, the backlight 140 would ideally have a low level of thermal resistance between the side facing the electronic display 80 and the side facing the second gas chamber. To accomplish this low level of thermal resistance, the backlight 140 may be built using metal printed circuit board (PCB) technology to further transfer heat away from the lights. The rear surface of the

backlight 140 may also be metallic, or some other thermally conductive material, to further enhance the convective heat transferring properties. The surface may even have a plurality of surface features such as fins to further enhance the convective heat transferring properties. The constrictive convective fan 310 may then send the warm air out of an exhaust 179 (shown in Figure 2) so that it may exit the display housing entirely.

[0064] While the display is operational, the external fan 60 and the constrictive convection fan 310 may run continuously. However, if desired, a temperature sensor (not shown) and a switch (not shown) may be incorporated within the electronic display. This effective thermostat may be used to detect when temperatures have reached a predetermined threshold value. In such a case, the various fans may be selectively engaged when the temperature in the display reaches a predetermined value. Predetermined thresholds may be selected and the system may be configured with a thermostat (not shown) to advantageously keep the display within an acceptable temperature range. This would save on both energy costs as well as the useful lifetime of the devices.

Air Curtain

[0065] In addition to the various thermal control features discussed above, an air curtain device can also be used. The air curtain device may be used alone, or in combination with any of the other thermal control features discussed above.

[0066] FIGURE 18 shows an electronic display 10, having a housing 70 and a front plate 90. The air baffles 114 for the air curtain can be seen as a broken line in the figure. Cross-section line 19-19 can also be seen in this figure.

[0067] FIGURE 19 shows the cross-sectional view from the line 19-19 shown in Figure 18. This figure shows the circulation of air through the housing 70 when fans 60 are actuated. As discussed above, fans 60 ingest air into the housing 70 through entrance 51. This air may be ambient air or alternatively may be air conditioned air. The flow of ingested air is shown as arrow 111. Once inside the display housing 70, the air may flow upwards along flow arrow 121. This air may be utilized with any of the above mentioned thermal control features. For example, this air may be used to cool

the isolated gas within the second chamber (plenum) or may be used with the constricted convection system described above.

[0068] For explanatory purposes, the details of the internal components of the display have been omitted from this figure and only a cavity 61 is shown. It should be noted, that the air curtain can be practiced with any type of electronic display and with any combination of the thermal control features described above. Various internal features (not shown) may be placed within the cavity 61 to direct the air towards the baffles 114. The ingested air may continue through the cavity 61 along arrow 121 until it reaches the baffles 114 which may direct the air against the exterior display surface. This exterior surface may be the first front plate 90, or alternatively, any of the additional front plates which are described in detail above (ex. second front plate 130).

[0069] Thus, the air curtain can be used as an exhaust for the cooling of internal components of the display. Alternatively, the cool air from the air curtain can be used to further cool the exterior front surface of the display which may be subjected to significant solar loading or heat transfer from ambient hot air.

Fluid Cooling System

[0070] FIGURE 20 is an explanatory schematic illustrating another thermal control feature. As may be appreciated from the drawing, the cooling system 22 includes various components in fluid communication. Preferably, this may be accomplished by connecting the components with a series of tubes or pipes (illustrated conceptually as dotted lines). The cooling system 22 components include a reservoir tank 37, a pump 47, and a cooling chamber 4 in fluid communication. Preferably, the system also includes a filter 83 and a radiator 72, also in fluid communication. Optionally, the system may also include a fan unit 94. However, the optional fan unit is preferably not in fluid communication with the other components.

[0071] Reservoir tank 37 holds the primary volume of coolant fluid and provides surface area to conduct heat away from the fluid while it is contained in the tank 37. The tank has at least two openings, an exit port 13 and a return port 14. Optionally, the reservoir tank includes a ventilation port 66. Pump 47 causes the coolant fluid to move through the system 22. As may be appreciated by those skilled in the art, pump 47 may be located at a number of locations along the coolant fluid pathway with suitable

results. However, in order to minimize curvature of plates 44 and 128, it is preferable to position pump 47 after the cooling chamber 4 so that the pump actually pulls liquid coolant from the bottom to the top of cooling chamber 4. If the pump is so positioned, engaging the pump creates an area of low pressure at the top of the cooling chamber 4. In this way fluid flows through the cooling chamber 4 according to the arrows. Due to the "slipperiness" of some coolant fluids, pump 47 is preferably a positive displacement pump.

[0072] In order to regulate the flow of coolant fluid through the cooling chamber, a bypass line with a valve 634 may be provided. The bypass line provides a bypass route for coolant fluid to bypass the cooling chamber 4. The valve 634 is adapted to facilitate control over the amount of coolant fluid diverted through the bypass line. The bypass line and valve 634 allow a predetermined portion of coolant fluid to be diverted away from the flow directed to the cooling chamber 4 and thereby facilitate control over the flow rate through the cooling chamber itself. In this way, the flow rate through the cooling chamber may be regulated.

[0073] As one skilled in the art will appreciate, other methods and devices may also be used to regulate the flow through the cooling chamber. For example, the size and pump speed of pump 47 may be optimized for a given application. Alternatively, a variable speed pump may also be used. Preferably, the variable speed pump may be in electrical communication with at least one pressure transducer (not shown). Preferably, a pressure transducer may be placed upstream of the cooling chamber 4 and another pressure transducer may be placed downstream of the cooling chamber 4. The pressure information provided by the at least one pressure transducer may be utilized to set the operating speed of the variable speed pump. In that way, the flow rate through the cooling chamber 4 may be adjusted to maintain appropriate pressures in the device. Maintaining appropriate pressures in the cooling chamber 4 is important for preventing deformation or breakage of the display glass.

[0074] An optional filter 83 may be added to remove contamination in the fluid. Preferably, a radiator 72 and fan unit 94 may also be included to provide even greater thermal stability. Optionally, a spigot (not shown) may be provided to facilitate the process of filling and emptying the coolant fluid from the system.

[0075] In operation, fluid exits the reservoir tank 37 from an output port 13 which may be located beneath the tank 37. On its way to the cooling chamber 4, the fluid passes through optional filter 83. From the filter 83, the fluid next enters the cooling chamber 4 through inlet 98 of manifold 59. The fluid coolant travels up through the fluid compartment of the cooling chamber 4 in the direction indicated (dash arrows). The coolant fluid exits cooling chamber 4 through outlet 99 of the upper manifold 60. Preferably, the fluid is then received by an optional radiator 72. While traveling through the optional radiator 72, an optional fan unit 94 may force air past the radiator 72 to assist in transferring heat away from the coolant fluid. Pump 47, which may be positioned after the radiator 72, can pull the fluid toward the reservoir tank. The fluid is received into the reservoir tank 37 through return port 14. Preferably, return port 14 may be disposed at a location that is relatively distant from exit port 13 so as to allow the returning fluid the maximum opportunity to cool before it exits the reservoir tank 37 through port 13.

[0076] If desired, fan units may be located at the base of the housing 75 just behind the cooling chamber 4 of display 15. Fan units may provide a laminar flow of air through the interior of the housing 75. Preferably, the airflow will be directed across at least one external surface of reservoir tank 37. As described above, the air exhaust flow may ultimately be redirected onto the cooling chamber surface 44 by way of an optional air curtain system 114.

[0077] If desired, a temperature sensor (not shown) and a switch (not shown) may be incorporated within the electronic display. The temperature sensor may be used to detect when temperatures have reached a predetermined threshold value. In such a case, the pump can be selectively engaged when the temperature in the display meets a predetermined value. Predetermined thresholds may be selected and the system may be configured with a thermostat (not shown) to advantageously keep the display at a relatively constant temperature, or at least within a range of acceptable temperatures. Alternatively, to avoid the need for a thermostat, the pump 47 may run continuously when the electronic display is operational.

CLAIMS

1. A thermal control system for an electronic display having a display surface and a backlight assembly, the system comprising:

a first gas chamber positioned anterior to the electronic display surface, said first gas chamber having an entrance, exit, and exterior surface;

a second gas chamber in gaseous communication with the entrance and exit of said first gas chamber and positioned posterior to the electronic display surface, said second gas chamber having interior and exterior surfaces;

one or more chamber fans within said second gas chamber to propel gas around the first and second gas chambers; and

means for cooling the isolated gas which is contained within the second gas chamber.

2. The system of claim 1, wherein the means for cooling the isolated gas comprises:

one or more exterior fans adapted to force air over the exterior surfaces of the second gas chamber.

3. The system of claim 1, further comprising:

one or more of the electronic components for operating the electronic display, contained within said second gas chamber.

4. The system of claim 2, further comprising:

one or more surface features on the exterior surfaces of the second gas chamber.

5. The system of claim 1, further comprising:
a means for heating the gas which is contained within the second gas chamber.
6. The system of claim 5, wherein:
the means for heating the gas which is contained within the second gas chamber
comprises one or more heating elements within the second gas chamber.
7. The system of claim 1, wherein:
an exterior surface of the second gas chamber is placed in close proximity to the
backlight assembly, the space between the backlight assembly and the
exterior chamber surface defining a gap, the system further comprising:
one or more constricted convection fans adapted to draw air through said gap.
8. The system of one of claims 1-4, and 7, further comprising:
an air curtain device adapted to force air across the exterior surface of said first
gas chamber.
9. The system of one of claims 1-4 and 7-8 further comprising:
a linear polarizer placed anterior to said first gas chamber.
10. The system of one of claims 2-9, further comprising:
a temperature sensing device adapted to measure the temperature of the display
surface;

a switch in communication with said temperature sensing device and said chamber and exterior fans; and

wherein the fans are switched on when the temperature of the display surface reaches a threshold value.

11. The system of one of claims 1-10 further comprising:

a filter within the second gas chamber.

12. The system of one of claims 2-4 and 7-11 wherein:

said one or more exterior fans are forcing air over the exterior surfaces of the second gas chamber which has been air conditioned.

13. A thermally controlled electronic display comprising:

a display stack;

a backlight assembly positioned posterior to said display stack and having a posterior surface;

a constricted convection plate in close proximity to the posterior surface of said backlight assembly, the space between the convection plate and the posterior surface of the backlight assembly defining a gap;

one or more constricted convection fans adapted to draw air through said gap;

a first plate of anti-reflective glass positioned anterior to said display stack, the space between said anti-reflective glass and said display stack defining an insulating gap;

a linear polarizer positioned anterior to said first plate; and

a second plate of anti-reflective glass positioned anterior to said linear polarizer.

14. The display of claim 13 further comprising:

an air curtain device adapted to force air upon the second plate of anti-reflective glass.

15. The display of one of claims 13 and 14 wherein said backlight assembly comprises:

a printed circuit board (PCB) with an anterior and posterior surface;

a plurality of LEDs attached to the anterior surface of said PCB; and

a metallic coating applied to the posterior surface of said PCB.

16. The display of one of claims 13-15 the display further comprising:

a first gas chamber comprising said insulating gap and having an entrance and exit,

a second gas chamber in gaseous communication with the entrance and exit of said first gas chamber and positioned posterior to the electronic display surface, said second gas chamber having interior and exterior surfaces;

one or more chamber fans within said second gas chamber to propel gas around the first and second gas chambers; and

means for cooling the gas contained within the second gas chamber.

17. A method for thermally controlling an electronic display having a display surface and a backlight assembly, comprising the steps of:

providing an isolated gas system comprising a first gas chamber which is in contact with the electronic display surface and a second gas chamber in gaseous communication with said first gas chamber;

forcing isolated gas into the first gas chamber;

transferring heat from the electronic display surface to the isolated gas;

directing the isolated gas into the second gas chamber;

cooling the isolated gas in the second gas chamber if cooling is desired; and

reintroducing the isolated gas into the first gas chamber.

18. The method of claim 17, wherein the cooling step comprises the steps of:

transferring heat from the isolated gas to the walls of the second chamber;

forcing air over the walls of the second chamber; and

transferring heat from the walls of the second chamber to the air.

19. The method of claim 17, further comprising the step of:

heating the isolated gas within the second chamber if heating is desired.

20. The method of claims 17-19, further comprising the steps of:

providing a constrictive convection plate posterior to the backlight assembly, the area between the constrictive convection plate and the backlight assembly defining a gap;

forcing air through said gap in order to cool the backlight assembly.