

LIQUID CRYSTAL DISPLAY PANELS FOR COMMERCIAL AIRPLANES

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We have been developing and manufacturing liquid crystal display (LCD) panels of aircraft intended for Defense Agency of Japan. Recently, these LCD panels have been employed not only in military aircraft but also in commercial airplanes, thereby increasing demand for the LCD panels.

This time, we have developed LCD panels for commercial airplanes, based on the experience accumulated in LCD technology for the defense business. We have optimally designed the LCD panels to meet the optical characteristics and environmental conditions required in the cockpits of commercial airplanes, so that the panels have achieved good viewability performance at wide viewing angles both day and night.

INTRODUCTION

For the recent cockpits of aircraft, the conventional CRT displays have been being replaced by liquid crystal display (LCD) panels. The LCD panels are superior to CRT display units with regard to space, viewability both in sunlight and at night, weight, reliability, power consumption, and others. Thus, they have been employed in the military aircraft field and are also beginning to be adopted in the commercial airplane field. In the current new passenger airplanes, LCD panels are about to become mainstream. The construction of LCD panels used for aircraft is basically the same as those for LCDs used in personal computers and others, but the LCDs for aircraft are subjected to severer environments as to temperature, barometric pressure, vibration, impact, etc. Moreover, they are also required to demonstrate display performance specific to the cockpits of aircraft. This time, we have taken measures to meet the requirements of these characteristics and have developed LCD panels suitable for commercial airplanes. This paper outlines the cockpit environments of commercial airplanes, the characteristics required of display devices, and the performance of the LCD panels.

Figure 1 shows one of our recently developed LCD panels for commercial airplanes (Screen shows a display example).

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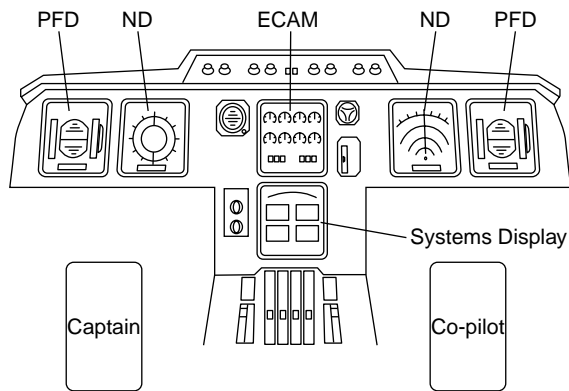
CHARACTERISTICS REQUIRED OF COCKPIT LCD PANELS

Optical Characteristic Requirements

Figure 2 shows an example of the configuration of cockpit displays for commercial airplanes. Generally, the cockpit has six



Figure 1 Liquid Crystal Display Panel
(Screen shows a display example)



ECAM: Electronic Centralized Aircraft Monitor
 PFD: Primary Flight Display
 ND: Navigation Display

Figure 2 Configuration of Cockpit Display for Commercial Airplanes

displays and the captain and co-pilot are seated right and left to manipulate devices and equipment. The following describes what LCD panels must take into account in order to accurately convey information to the pilots in this configuration.

(1) Wide Viewing Angle

The captain and co-pilot mutually check (crosscheck) information indicated on the displays as shown in Figure 3. In this case, the captain and co-pilot are required to accurately recognize indications on displays on both sides, half of which are on the opposing side of each pilot. Therefore, the displays are required to provide high contrast (brightness of the white display against the black display) at a wide viewing angle. It is especially important to reduce the brightness of the black display to achieve high contrast.

(2) Chromaticity

Accurate color identification and recognition are important aspects of flight information, and the displays for aircraft are required to ensure highly accurate chromaticity. Each display must consistently show the same colors in full color, especially for halftone colors. Thus, it is necessary to control variations in the chromaticity on a display basis.

(3) Chromaticity Change

Color information is also recognized as an important parameter during crosscheck. If the chromaticity of a display viewed from the front is different from that of the display on the co-pilot side when viewed by the captain, flight information can be mistakenly identified, presenting a significant problem in terms of flight safety. Thus, it is important that the chromaticity does not vary at wide viewing angles. Therefore, changes in the chromaticity have been specified in detail in the SAE Standards ARP4256, an international LCD display standard for aircraft. In general, the LCD panels for aircraft are developed in compliance with this standard.

(4) Low Reflection Coefficient

In the cockpit, the displays are required to deliver good

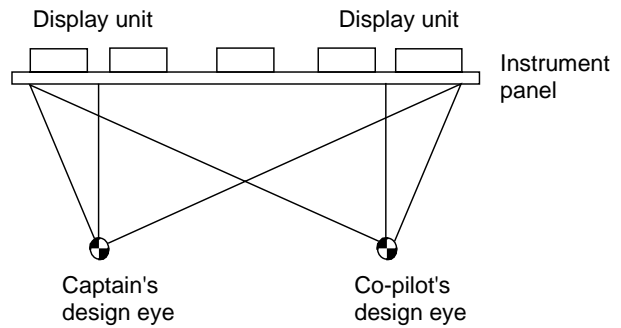


Figure 3 Required Horizontal Viewing Angle

viewability in environments ranging from low-light conditions at night to bright conditions where sunlight streams through the windows in the daytime. At night, an LCD panel can achieve optimum brightness in relation to the surrounding environment by reducing the luminance of the backlight at the rear of the LCD panel. During the daytime, the luminance of the backlight can be raised to increase the display brightness. However, if sunlight streams directly onto the display, its viewability becomes poor due to reflections on the display surface. Therefore, it is essential to secure a display surface with a low reflection coefficient so that the displayed items can be recognized accurately.

Environment Requirements

The displays for aircraft are subjected to operation in environments more severe than those of general-purpose LCDs for office automation equipment, etc.

(1) Temperatures

Because commercial airplanes are used worldwide, the required temperature range must include all temperature environments encountered, ranging widely from low to high temperatures. The cockpits are air-conditioned during flights. However, the displays for aircraft must provide accurate indications in low-temperature environments experienced if air-conditioning fails due to an accident, etc. or if start-up occurs in cold climates, or in high and low temperature environments.

(2) Barometric Pressure

The cockpit is pressurized, but may be subject to abrupt decompression or pressure rises should pressurization be interrupted due to an accident, etc. Thus, the display panels must provide accurate display even under decompressed or pressurized conditions. The requirements in a combined environment, including the altitude (barometric pressure) as well as the temperature as mentioned in item (1) are also important to consider.

(3) Vibration and Impact

In addition to the vibration and impact during landing which are encountered during the normal operations of an aircraft, the display panels are also required to withstand the stresses of conditions occurring during accidents, such as the bursting

Table 1 Specifications for Environmental Testing

Operating Temperature	-15°C to +55°C
Storage Temperature	-55°C to +85°C
Altitude (barometric pressure)	15,000 ft
Pressurization	170 kPa
Humidity	38°C/85% ↔ 50°C/95%
Vibration	Random: 1.48 Grms Frequency range: 10 to 2000 Hz
Impact	6 G., 11 msec.

of a wheel or the breakage of engine blades. Under these circumstances, it is essential for the LCD panels of aircraft to meet the requirements of testing specified in RTCA DO160 (in Table 1).

CONFIGURATION OF LIQUID CRYSTAL DISPLAY PANEL MODULES

An example of the configuration of an LCD panel module is shown in Figure 4. The LCD panel module consists of an LCD panel, the front glass, and the driving circuit, and it is illuminated by a backlight module from the back of the panel.

LCD Panel

The advantages of the currently developed LCD panels are as follows.

(1) High Aperture Ratio

In order to alleviate loads on the backlight, LCD panels are required to have a high aperture ratio. For this, thin-film transistors (TFT) were employed and wiring patterns were optimally designed to reduce the electrode areas thus achieving a high aperture ratio.

(2) Wide Viewing Angle

The LCD panels use an optical compensation film to address the challenge of wide viewing angles. We have analyzed the characteristics of optical compensation films and also the optimum design conditions achievable by a combination of the films with the LCD panels. This allows the LCDs to achieve high contrast at the required wide viewing angle, with ±60 degrees or more horizontal angle.

(3) Chromaticity Change

We have conducted spectral analyses on the materials that

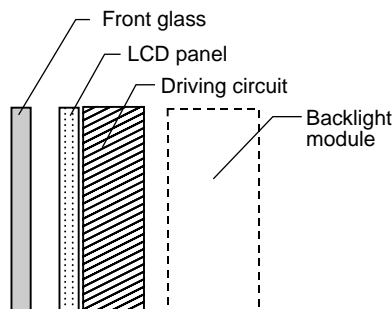


Figure 4 Configuration of an LCD Panel Module

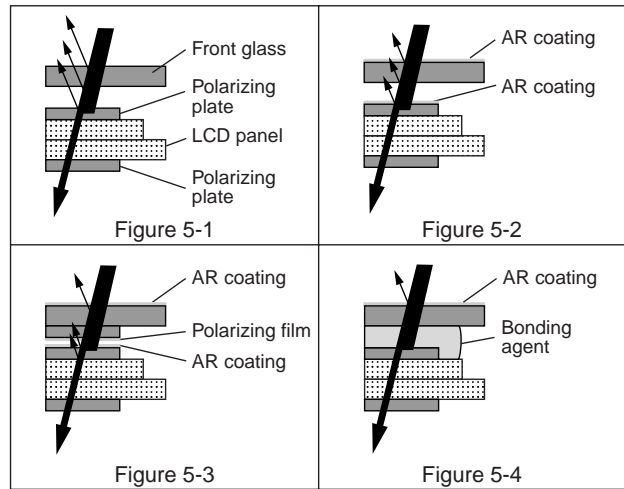


Figure 5 Reflection Coefficient

make up liquid crystal cells, including chromaticity errors in color filters, and have analyzed the effects of cell-gap variations on the chromaticity, etc. These studies have allowed us to develop LCD panels with small changes in the chromaticity at wide viewing angles.

(4) Low Reflectivity

In order to reduce the reflection coefficient within the liquid crystal cells, we have made improvements in terms of materials such as using black matrix masks with a low-reflection multi-layer Cr coating to achieve low reflectivity.

(5) Liquid Crystal Materials

Generally, there are few liquid crystal materials that satisfy operation requirements at both high and low temperatures. In our current development, we have adopted new liquid crystal materials to meet the requirements of the LCD panels for aircraft and have achieved a wide operating temperature range.

Front Glass

Unlike general LCD panels, LCD panels for cockpits have a layer of front glass on the front face of an LCD panel to protect the LCD. This prevents the LCD panels from being damaged by direct contact or from spillage of liquids such as coffee, etc. However, when the reduction of the reflection coefficient is considered, the LCD panels must be optimally designed to minimize the reflection from the front glass in addition to that of the LCD panel.

Figure 5-1 shows the factors responsible for reflection. Reflection occurs at an interface between media of different density. For LCD panels with front glass, both faces of the front glass and the surface of the polarizing plate on an LCD panel will be the major factors responsible for the reflection coefficient. We have newly developed LCD panels based on the following measures to achieve the characteristics necessary to meet the non-reflective requirements.

(1) Surface Treatment for Low Reflection (see Figure 5-2)

Generally, anti-glare (AG) and anti-reflection (AR) coatings

Table 2 Specifications of the LCD Panels

Display Range	Approx. 160 mm × 160 mm
Pixel Configuration	RGB stripes
Pixel Pitch	70 μm (× RGB) × 210 μm
Gray Scale	RGB full color
Liquid Crystal Mode	Normally white

are used as surface treatments for limiting surface reflection to a low level. AG coating is capable of minimizing specular reflection, but diffuses deflection increases, causing the entire screen to appear whitish under sunlight. This results in significantly diminished viewability. On the other hand, AR coating is a treatment that vapor-deposits a reflection-preventive thin film on the surface. For the LCD panels of aircraft, this AR coating is generally employed. Application of an AR coating to the front glass and to the polarizing plate allows a significant lower reflection coefficient to be achieved.

- (2) AR Coating plus Polarizing Film (see Figure 5-3)
Adhesion of a polarizing film to the rear of the front glass causes the quantity of light to be reduced by half. The reflection from the polarizing film surface itself is thereby also reduced to half, allowing the reflection coefficient to be further minimized.
- (3) AR Coating plus Front Glass Bonding (see Figure 5-4)
Bonding of the front glass to a polarizing plate using an optical bonding agent in which the refractive index has been considered, allows a configuration with the lowest reflection coefficient to be achieved. However, production costs and reliability must be thoroughly evaluated.

Apart from these measures against surface reflection, we have achieved a design that realizes a low reflection coefficient by taking the internal construction and LCD panel materials into consideration, thereby achieving good viewability even under sunlight.

Driving Circuit

(1) High-voltage Driving

To achieve high contrast, the brightness of the black display needs to be minimized. Increasing the voltage applied to an LCD panel causes the liquid crystals to cut off light, thereby limiting the brightness of the black display to a low level. Thus, we have adopted a high-voltage driver IC for driving the LCD in order to achieve high contrast. This driver IC is connected to the LCD panel using the tape automatic bonding (TAB) method.

(2) Gamma Control

In order for each LCD panel to display the same chromaticity in halftone display (amber, magenta, etc.), each gamma value must be the same. However, it is difficult for LCD panels to achieve the uniform gamma values due to variations in cell gaps and the Δn value (optical anisotropy) of liquid crystal materials. Therefore, as a means of smoothing out individual

differences caused during production, we have employed a method of correcting the gamma values of individual panels using a driving circuit to solve chromaticity errors between each LCD panel.

SPECIFICATIONS OF LCD PANELS FOR COMMERCIAL AIRPLANES

The specifications of the currently developed LCD panels are summarized in Table 2. The pixel dimensions are 70 μm (× RGB) × 210 μm of fine pixels to support the high grade, high precision display required of the displays for aircraft. By optimization of cell gaps and adoption of high-voltage driving, we have achieved the necessary high contrast within the required viewing angle range of commercial airplanes. As to the environment-resistance characteristics, we have conducted the noted RTCA DO160 testing with satisfactory results.

PROCESS OF CONVERSION INTO LCD PANEL MODULES

The currently developed LCD panels have display dots as small as 70 μm × 210 μm to deliver high precision. The reliability of fine pitch connections between an LCD panel and TAB also becomes important from the viewpoint of environmental-resistance performance on temperatures, vibration, etc. TAB and LCD panels are thermo-compression bonded using an anisotropic conductive film (ACF).

In the current project, we have proceeded with the development of a high-precision TAB bonder in parallel with the development of the LCD panels to achieve high precision, reliable TAB.

CONCLUSION

This paper has introduced the characteristics required of LCD panels for aircraft and outlined how to achieve these characteristics and the special requirements of the LCD panels developed for commercial airplanes. Currently, the development of new display devices to replace LCD panels is being conducted increasingly. However, the thus far achieved new devices have both merits and demerits and it is still too early to adopt them as display devices for aircraft. Therefore, we believe that LCD panels will remain in the mainstream for aircraft displays for the time being.

These currently developed LCD panels are scheduled to be used aboard the new Airbus A340-600 and others. In future, we hope to further enter the commercial aircraft market and to expand our product share therein, starting with this product. ◆

REFERENCES

- (1) Radio Technical Commission for Aeronautics RTCA DO160
- (2) SAE Standards AEROSPACE RECOMMENDED PRACTICE ARP 4256 Design Objectives for Liquid Crystal Displays for Part 25 (Transport) Aircraft